Source Term Determination for P-Area Reactor Groundwater Operable Unit

March 25, 2003

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

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Margaret R. Millings

Karen M. Vangelas

Mary K. Harris

U.S. Department of Energy
Westinghouse Savannah River Company

Savannah River Site
Aiken, SC 29808

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Executive Summary

A review of historical documents has been conducted to identify potential sources of contamination to the P Area Reactor Groundwater Operable Unit. Both classified and unclassified documents repositories at the Savannah River Site were searched. The results of the historical document review indicated the principal sources of groundwater contamination are associated with routine operating practices over the operating life of the P Reactor facilities. The document search did not find any major abnormal release events/accidents that would have caused a substantial release to the ground surface or surface water bodies. Steel Creek and the Reactor Seepage Basins were the primary discharge points of radioactive contamination. Based on normal operations of land disposal, organic solvent sources would include the ground surface adjacent to maintenance shops in the reactor facility. More specifically, the ground outside of the 704-P maintenance shop, which was a large user of organic solvents, would likely serve as a potential organic solvent source. Review of geologic investigations prior to construction of the reactor, indicate zones of potential preferential flow in the Lower Aquifer Zone of the Upper Three Runs Aquifer. Contaminated water intersecting these zones would potentially be transported at a faster rate than the surrounding formation.

Tritium, cesium-137 (^{137}Cs) and strontium-90 (^{90}Sr) were identified as the most probable radionuclides to contaminate the groundwater. The sources of these contaminants are no longer receiving additional loadings. Thus, the sources are depleting. Of these three radionuclides, tritium is the most mobile in the groundwater. Review of existing data, indicate that ^{137}Cs and ^{90}Sr are bound in the shallow sediments of both the P-Reactor Seepage Basins and Steel Creek.

The review indicates the major sources of groundwater contamination are the results of routine operations during reactor operations and that there may be geologic features of importance in transport of groundwater contaminants.

Introduction

The Soils and Groundwater Closure Projects Reactor Team requested support from the Environmental Sciences and Technology Department of the Savannah River Technology Center to conduct a source term determination for the P Area Reactor Groundwater Operable Unit. This source term evaluation involved searching the document database to identify and review documents that might provide information on routine discharges, leaks, spills, emergency discharges and any other releases to the environment associated with the reactor facility. Atmospheric releases were not part of this evaluation. The identified documents reviewed and pertinent findings are recorded in this report.

More specifically, this source term evaluation consisted of identifying documents through unclassified and classified searches in addition to reviewing known historical documents. Searches were conducted by using the keyword "P Area" together with other keywords such as "Radionuclide", "Reactor", "Spill", "Leak", "Releases", "Incidents", "Seepage Basins", "Disassembly Basin", "Moderator", "TCE", "PCE", "Strontium", "Heat Exchanger", "Distillation Column", "Process Sewers", "Unusual Incident", "Reactor Construction", "Reactor Foundation", "Soft Zone or Soft Spot", "Calcareous Material", "Subsidence", "Sinks or Depressions or Excavations", or "Reactor Grouting or Surface Grouting". Appendix A provides the documents found and reviewed resulting from the unclassified and classified searches. Types of data reviewed also included weekly and monthly control and environmental monitoring reports, reactor memorandums and reports, material balance reports and existing technical reports and books. A phone interview was also conducted with Greg Burbage who has worked in environmental compliance at SRS and is familiar with the history, operations, and environmental issues associated with the reactors. Results from the document search and phone interview include findings concerning foundation grouting, power capacity, liquid discharge sources, and points of discharge. However, there were no findings of major spills, leaks, or other unusual or previously unreported releases. Moreover, specific information on the disposal of organic solvents was not found for P-Area operations.

Early Foundation Grouting Reports

In July 1950 surveying began for the operating facilities at SRS. The Atomic Energy Commission authorized the Corps of Engineers to conduct preliminary soils investigations in connection with the foundation design of SRS structures (i.e., reactors, separations facilities, etc.) in January 1951. The purpose was: (a) to establish the general geology of the area to permit correlation and interpretation of the boring data, geo-physical investigations, and laboratory test results; (b) to ascertain the engineering significance of hundreds of undrained surface depressions or "sinks" found in the area; and (c) to furnish background information for investigation of the ground water and associated surface and subsurface drainage problems (1).

The results of the foundation grouting operations, conducted by the Corps of Engineers as part of the preliminary soils investigations, indicated that there were significant amounts of grout lost to the subsurface near the reactor facilities. The "soft" zones were determined to have developed from the "solution of calcareous and possibly other material at depth". Evaluation of the boreholes at P Area reveals that the average top depth of the calcareous zone was approximately 175 ft below land surface and the average thickness varied from approximately 10 to 40 ft. The actual thickness of this zone may be greater, due to pronounced variability and the replacement of the dissolved calcareous sediments by other minerals (2). The depths reported for P Area indicate that this "soft" zone or calcareous zone is predominantly present in the Lower Aquifer Zone (LAZ) of the Upper Three Runs Aquifer.

Because the emphasis of the work was structural stability of the constructed facilities, the subsurface investigations were conducted in the immediate vicinity of the planned locations of the reactor buildings. The drilling pattern was a grid system of holes at the corners of a 50 ft by 50 ft square with an extra hole in the center. The drilling pattern extended 30 ft or more beyond the perimeter of the reactor buildings.

Borings were grouted if abnormalities were encountered when drilling the borehole. Abnormalities included the sudden dropping of the drill rods and sudden or excessive loss of water and drilling mud. During the grouting process, grout was seen venting from previously drilled borings in the general vicinity. The horizontal distance between the hole in which grout was injected and from which it vented varied from 40 to 235 ft. Some of the venting boreholes had not shown any abnormal behavior during drilling operations and thus were not originally grouted. This venting of nearby holes indicated the presence of preferential channels in the subsurface. Flow of a viscous material such as grout would indicate water should readily flow through these zones. The failure to find thick layers of grout at any one location, even where large quantities were pumped into the foundation, suggested to the investigators that large cavities did not exist. Instead, the investigators concluded that a porous or "spongy" condition existed with the soil containing numerous solution channels that were sufficiently large to receive the sand-cement grout (2). Figure 1 shows the locations of the grouted holes in relation to P Reactor and provides the approximate volume (cubic feet) of grout used in the each hole. Table 1 provides information regarding the total number of holes drilled, the number of holes grouted and the quantity of grout used in P Area and for comparison, a nearby reactor area, L Area.

Reactor Power Capacity

P Reactor, the second reactor completed at the SRS, went critical February 20, 1954 and operated with relatively few interruptions until 1988. Similar to the other SRS reactors, P Reactor produced primarily tritium and plutonium and was initially designed to operate at low temperatures (less than 100^{o}C) and pressure (slightly above atmospheric pressure) using heavy water (deuterium or D_2O) to moderate and cool the reactor (3).

In the mid-1950's increased defense needs required greater production from the reactors. With improvements in fuel and target elements, heat exchangers systems, and flow distribution systems, reactor power gradually increased from 378 megawatts to 2,250 megawatts by the end of 1957. The completion of Par Pond in 1958 and the addition of pumps at Par Pond in 1960 allowed further increases in reactor power by providing more cooling water for the reactors (3,4). Figure 2 shows the thermal or power output for P Reactor, with the nearby R and L Reactors for comparison (5). P Reactor reached its maximum monthly power output of 73,600 megawatt days in December 1963 (daily average of 2,374 megawatts) (5). It operated fairly continuously for nearly 35 years and maintained relatively high power levels for much of that time. Although R and L Reactors reached similar peaks in power, they had much shorter operational histories.

Thermal output from the reactors can be used as a measure of reactor production (generation of fission products) and therefore can provide insight regarding effluents released into the environment. More specifically, P Reactor's long operational history corresponds with a long history of discharges, which included disassembly basin purges, reactor cooling water, and miscellaneous spills and leaks related to normal operations. The duration of P Reactor's operation may have a particularly large impact on the nature and distribution of contaminants found.

Potential Sources of Organics

Solvents and diesel fuel used in P Reactor operations were disposed of onsite. In particular, the 704 maintenance shop and maintenance shops within the 105 reactor building used solvents for cooling and cleaning equipment. The 704 shop performed maintenance on the heavy industrial equipment used in the power house and was probably the largest user of solvents (6). No written records were found on solvent usage. However, verbal history indicates that the standard practice during early operations of reactor facilities was land disposal of small quantities of solvent within the reactor facility perimeter fence. More specifically, a drum was used to collect the solvent waste and when full the solvent was discarded onto the ground 50 to 100 yards from the building (6). Figure 3 shows the location of the 704 maintenance shop in relation to other P Reactor facilities.

Potential Sources of Radioactive Liquid Discharges

Through parts of its operational history, P Reactor released liquid effluent to Steel Creek, Par Pond, and the Reactor Seepage Basins (i.e. three inter-connected seepage basins). Liquid effluents included disassembly basin purges, cooling water from the reactor heat exchangers, and other miscellaneous sources. Table 2 provides a timeline showing the history and predominant destination of disassembly basin purges and releases of cooling water and process sewer water.

Disassembly Basin Purges

The P Reactor disassembly basin consists of a 4.6 million gallon basin constructed of epoxy-lined or painted, reinforced concrete. According to a 1995 DOE technical report, the reactor disassembly basins were all designed to withstand a 1000 psf (pounds per square foot) blast load and a minor 0.1 earthquake, however leakage through basin walls and water stops could occur even under normal conditions. The report cites as an example the L Reactor disassembly basin where the concrete wall next to the reactor building reportedly had cracks that leaked. In addition, the report noted that the disassembly basins did not have systems designed to detect small leaks in the basin walls or water stops (7). No evidence was found in this document search that the P Reactor disassembly basin had known or documented leaks in the basin concrete walls or water stops.

P Reactor's disassembly basin includes four sections (vertical tube storage section or VTS, the machine area, the horizontal bundle and bucket storage area or HBBS, and the transfer area) used for disassembling and storing irradiated fuel and target elements (7). The basins were initially designed so that the water was free circulating among the four sections (i.e. water used in one section mixed with water used in other sections) (6,8). When irradiated elements were first discharged from the reactor they were suspended underwater from stainless steel hangers on a monorail system in the vertical tube storage (VTS) section. This cooling period in the VTS allowed short-lived radionuclides to decay so that the elements could be disassembled and eventually transferred to the separations area for reprocessing. Initially, VTS water was purged continuously (several thousands gallons per minute) to site streams. A continuous feed of "fresh" water was used to cool the stored fuel and targets and to maintain the clarity of the water (8,9).

As production increased in the late 1950's, controls began to be emplaced to reduce the amount of radioactivity released to streams. The volume of continuous flow through the VTS was reduced and some of the disassembly basin overflow weirs were closed. In 1963 the VTS section was isolated from the rest of the disassembly basin in all of the reactor areas. The isolated VTS water was recirculated to allow for radionuclide decay before it was released and mixed with other disassembly basin water. Portable filter/deionizer systems and heat exchanger systems were also installed. These provisions helped to decrease the volume and radioactivity of purge water released from the basin (8,9). In the late 1960's and early 1970's, all of the disassembly basin overflow weirs were closed and permanent sand filters were installed to help maintain clarity of the water. It is estimated that less than 1% of the total aqueous releases of ^{32}P, ^{51}Cr, ^{60}Co, ^{65}Zn, and ^{90}Sr for P Reactor occurred after 1970; the greatest amounts of these constituents were released in the 1960's (8,9, 10).

Even with instituted controls, periodic purging of the disassembly basin occurred primarily to reduce the tritium and other radioactive exposure to personnel. The frequency of disassembly basin purging is not clear. The P-Reactor 1993 Annual Groundwater Monitoring Report states that the disassembly basin was purged biannually although elsewhere in the document it specifies that the basin was purged when tritium concentrations reached 400,000 pCi/mL (11). Disassembly basin purge water was released predominately to Steel Creek from 1954 to 1956, 1969, and from 1971 to 1977; it was released mainly to the seepage basins from 1957 to 1968, 1970, and from 1978 to 1991 (8,9) (table 2). Standard practice for releasing disassembly basin purges to streams involved mixing the purge water with large volumes of cooling water from the heat exchangers to help dilute and reduce the concentration of the releases (8). However, in the 1970's, most of the cooling water was no longer discharged to Steel Creek. This resulted in minimal dilution of the disassembly basin water prior to discharge into Steel Creek (12).

During normal reactor operations, contaminants entered the disassembly basin water through moderator adsorbed to the surfaces of irradiated fuel and target elements discharged to the basin and through small cracks or defects in the cladding of discharged irradiated elements. These contaminants included tritium (which ranged from 0 to 17 Ci/L in the reactor moderator), activation products (e.g. ^{32}P, ^{51}Cr, ^{60}Co, and ^{65}Zn), and fission products (e.g. ^{90}Sr, ^{137}Cs, and ^{129}I) (8,9,13). Weekly and monthly environmental and health monitoring reports of reactor operations began in the early 1960's to document specific contaminant activities in the disassembly basin water and weir releases. Based on the reports, tritium would have contributed the most activity from the disassembly basins. Table 3 lists common radiological contaminants with a description of how they were generated and their associated half-life. Based on the extremely short half-life of ^{32}P and ^{51}Cr, these activation products would have been completely decayed prior to discharge or shortly thereafter. The other activation products with half-lives in the hundreds of days to a few years would have been found in trace amounts compared to the fission products. The history of releases and impact of the activation products are documented in other reports (9,14).

Appendix B presents a descriptive history of the disassembly basin and discharged elements (normal and failed). A "failed" element is described as a rod in which small defects in element cladding developed into holes or splits. A failed element had the potential to release considerable concentrations of radionuclides to the moderator and disassembly basin water (9,13). To minimize the release of radionuclides, the reactor was typically shut down and the failed element was transferred to a "harp", a container stored underwater in the disassembly basin and vented to the reactor stack, to cool. Prior to identification of the failure, the failed rod would release higher levels of radionuclides to the disassembly basin than a normal rod. As the P-Reactor 1993 Annual Groundwater Monitoring Report indicated the disassembly basin was purged either biannually or when concentrations reached 400,000 pCi/mL (11), it can be assumed that increased numbers of discharged rods (particularly failed rods) would correlate to increased purges of the disassembly basin to the discharge point.

Cooling Water

In addition to disassembly basin purge water, large quantities of reactor cooling water were released from P Reactor. Cooling water consisted of river or pond water which circulated around the outside (or shell side) of the reactor heat exchanger tubes to remove heat from the moderator which circulated inside the tubes. Although cooling water consisted predominantly of river or pond water, it also contained moderator that had escaped through leaks and cracks in the heat exchanger system. This moderator had the potential to contain tritium (from 0 to 17 Ci/L) and minor amounts of activation products and fission products that had collected during normal operations. Release of contaminants to the environment through leakage to the cooling water is considered a minor pathway compared to the radionuclides released from the disassembly basin (8,9). P Reactor cooling water was discharged to Steel Creek until the early 1960's when the canal to Par Pond was completed (table 2). Figures 4 through 9 show the outfall to Steel

Creek and the construction and completion of the outfall and canal to Par Pond. Between 1961 and 1963 cooling water from P Area, which was comprised of Par Pond water (containing R Area releases) and make up water from the river, was released to both Par Pond and Steel Creek. After 1963, most of P Reactor's cooling water was discharged to Par Pond (12,15). Later, after the construction of L-Lake in 1985, all of the cooling water was discharged to Par Pond (8,9). This document search produced little analytical data concerning cooling water discharges.

Miscellaneous Releases

Other miscellaneous releases included water in the reactor process sewer system, leaks that developed during P Reactor operations and spills that occurred during maintenance periods. The reactor process sewer system primarily received cooling water from the shell side of the disassembly basin heat exchangers but also included other process water (e.g. from numerous floor, roof, and fan drains). Like the cooling water, the process sewer system water was released to Steel Creek until the early 1960's when most of it was diverted to Par Pond. With the construction of L-Lake, the process sewer system water was all diverted to Par Pond (8,9).

Appendix C shows some examples of documented leaks and spills for P Reactor cited in weekly and monthly environmental and health monitoring reports, material balance reports, and reactor reports. Some of the wastewater from leaks and spills was collected in process sumps and analyzed for radionuclides and moderator content. Disposal of this wastewater included processing through the D-Area Heavy Water Rework Facility or through the waste evaporators at the separations areas, or discharging to seepage basins or streams depending on the analytical results (9). For many of the leaks listed in Appendix C, the method of disposal for the collected wastewater is unclear (or not documented).

Since the moderator in P Area had the potential to contain considerable amounts of tritium during parts of its operational history (up to approximately 15 Ci/L), a loss of moderator due to leaks, spills, or routine maintenance could release significant amounts of tritium to the environment (16). However, since moderator was generally considered a valuable commodity, efforts were made to recover lost moderator. A report from 1984 cited that 800 lbs of lost moderator had an estimated value of $60,000 (or $75 per pound) (Appendix C). Monthly material balance reports tracked the shipments, use, storage, loss and recovery of moderator for all of the reactors. These losses were categorized under headings such as "normal operational losses", "material unaccounted for", "inventory differences", and "accidental losses". Losses from discharges and shutdowns, heat exchanger leaks and maintenance, and maintenance/replacement work on the evaporators and deionizers were often included under "normal operational losses". Stack losses appear to have been considered "material unaccounted for" in the early material balance reports whereas later it was included under "normal operational losses".

A review of the K Area Reactor Facility conducted in 1999 identified the distillation columns and heat exchanger laydown area as possible sources of contamination (16). The distillation columns, which were located outside of the 105-P reactor building, processed tritiated moderator (heavy water) for purification purposes. Moderator may have been released from the distillation columns due to small leaks or during routine maintenance. For example, a 1971 report documented a loss of approximately 150 lbs of moderator during a general overhaul maintenance of the distillation facility at P Area. Another incident in 1983 involved a broken line at the distillation pad due to freezing, which released moderator containing an estimated 85 Ci of tritium to Steel Creek via the storm sewer (Appendix C). The heat exchanger laydown area consisted of old heat exchangers that had been replaced and temporarily stored in a laydown area within the reactor facilities. These parts may have contained residual moderator with tritium on their surfaces and served as potential sources of tritium to the environment. No specific documentation concerning the P Area heat exchanger laydown area was found in this search.

In 1963 a 50 million gallon earthen retention basin was constructed as part of the Emergency Cooling System (ECS) (figure 3). This basin was designed to hold contaminated water that would be released if a loss of cooling or loss of circulation accident occurred within the reactor (11). No record of such a release was found. The retention basin was also used as in the case of K Reactor if the seepage basins were ineffective at percolating. Verbal communications with a worker knowledgeable about P Reactor indicates that the P Area retention basin was never used for this purpose (6). In 1979, a 500,000 gallon storage tank was added to the basin to store contaminated water as a backup for the process water storage tank. According to the P-Reactor 1993 Annual Groundwater Monitoring Report, the system was set up for moderator or water leaks that would collect in the -40 ft sumps. The first 60,000 gallons of moderator or water would be pumped to Building 106, the process water storage tank, and then the next 500,000 gallons would be pumped to the new storage tank in the retention basin (figure 3). Any additional moderator or water would be routed to the retention basin. Any moderator or water leakage originating in the reactor room 0 ft level or from pump operation was supposed to go to the retention basin as well (11). Based on this document search, it is unclear if or to what extent this system was used. According to the “RI Work Plan for the Steel Creek Integrator Operable Unit (U)”, the ECS (emergency cooling system) was never activated and the P Area retention basin never received any discharges (17).

Discharge Points of Radioactive Releases

Steel Creek

Figure 10 shows the annual curies of tritium originally released to Steel Creek from L and P Reactors. The data comes from the report "Radioactive Releases at the Savannah River Site 1954-1989 (U)", which provides a summary and history of effluent releases for various facilities at the SRS (14). The report includes liquid and air monitoring results from routine and special sampling events but does not contain data related to spills or leaks. As shown by figure 10, P Reactor's annual contribution to the curies of tritium in Steel Creek was not exceedingly different than L Reactor's. However, the duration that P Reactor discharged is much longer, resulting in a larger loading to Steel Creek.

Flow rates in Steel Creek have varied widely according to the operational history of the reactors and have affected the concentrations of radionuclides discharged to Steel Creek. In the early 1960's when P and L Reactors were both discharging to Steel Creek, flow in Steel Creek was approximately 600-800 ft^3/sec. After P Reactor's cooling water was diverted to Par Pond, flow rates decreased to 400 ft^3/sec in the late 1960's. With the shutdown of L Reactor in 1968, flow rates decreased further to around 20-30 ft^3/sec and remained at this rate until all of P Reactor's process effluents were diverted to Par Pond in the mid-1980's. This decrease in flow rate in Steel Creek in the late 1960's and 1970's resulted in less water available for dilution contributing to the rise in tritium and other radionuclide concentrations in the creek (8, 12, 17).

Figure 11 shows the curies of tritium originally released to Steel Creek from P Reactor with calculated decay corrected annual and cumulative activities. The increase in the annual tritium activity released to Steel Creek appears to correspond with the rise in reactor power from 1955 through the mid 1960's. In the early and mid 1970's while the seepage basins were deactivated, Steel Creek received disassembly basin purge water. Instituted controls (e.g. sand filters/deionizers) on the disassembly basin water would have had little affect on tritium concentrations. Consequently disassembly basin purges would have added to the tritium released to Steel Creek during this time. With the reactivation of the seepage basins in 1978 the tritium released to the creek dropped considerably. After all miscellaneous effluents and cooling water discharges were diverted from Steel Creek in 1985 and P Reactor was shutdown in 1991, no major sources existed.

Since ^{137}Cs is one of the longer-lived radionuclides (with a half life of 30.1 years) discharged during reactor operations and its movement through surface water and groundwater can be retarded by sorption, its release history to Steel Creek is presented here. Out of the estimated 600 Ci of ^{137}Cs released from the reactors to site streams, only about one-third is thought to have reached the Savannah River; the other two-thirds is thought to remain in streams beds, ponds, and wetlands onsite (13). In general Cs tends to be bound strongly to clays exchanging for cations between the structural layers of clay minerals. For Cs, this process occurs relatively quickly whereas its release is very slow (the process is sometimes thought of as irreversible). Adsorption to iron oxides and humic material can also affect the migration of Cs but typically to a lesser extent. The high retardation potential of Cs coupled with the variability of discharges and erosional/depositional episodes associated with the Steel Creek would likely have made its distribution partly scattered in surficial sediments along Steel Creek. It also had the potential to travel farther downstream, for example bound to clay particulates that were carried with the flow of discharge water. Figures 12 and 13 present gamma overflight data from 1985 and 1991 for P Reactor and Steel Creek. These figures show that part of ^{137}Cs released from P Reactor has remained bound probably to surficial sediments along Steel Creek. In addition, the similarity of the data from the two overflights demonstrate that the distribution of ^{137}Cs that was deposited along Steel Creek has changed little from 1985 to 1991 also suggesting that the ^{137}Cs is bound strongly to sediment along the creek.

As figure 14 shows, most of the ^{137}Cs released to Steel Creek occurred during the 1960's. Again, this increase took place during the rise in reactor power. More specifically, during this time monitoring of reactor discharges revealed that fuel element failures were a large contributor to the radioactive releases (more than the number and type of fuel discharges) and the "severity of certain failures" made the prediction of radioactive releases uncertain (18). In a 1963 monthly operating report, a P Area failed element discharge was documented as an example of the large impact that one failed element can have on annual releases: a failed Mark VB element discharged in 1962 accounted for 60% of the long-lived radionuclides (64 Ci) and 50% of the short-lived radionuclides (178 Ci) for the year (18). During the 1960's, disassembly basin purges were discharged primarily to the seepage basins, however failed elements also had the potential to release radionuclides into the moderator (D_2O), which could be discharged with cooling water or miscellaneous effluents to Steel Creek.

In addition, another source of ^{137}Cs was noted in a March 1970 monitoring report as contributing to the Cs released to the Savannah River. In 1964 partially declad irradiated fuel elements were transferred from R Reactor disassembly basin to P Reactor disassembly basin. The fuel was stored in 15 ft cans that allowed for direct venting to the process room exhaust filters. Transfer of these elements from the P Area disassembly basin to the Receiving Basin for off-site fuel (RBOF) did not start until September 1968 at which point the ^{134,137}Cs activity released to the river decreased from 42 Ci to 13 Ci in 1969. The final transfer of elements to the RBOF took place in January 1970 (19).

Like ^{137}Cs, ^{90}Sr is another one of the longer lived radionuclides (with a half life of 28.8 years) released during reactor operations. ^{90}Sr was also a fission product produced from the neutron induced fission reactions in the reactors and would have been released in similar pathways as the ^{137}Cs (e.g. moderator contamination from irradiated elements and failed elements). Figure 15 provides the release history of ^{90}Sr to Steel Creek and like ^{137}Cs it was predominantly released during the 1960's. It is estimated that 90% of the ^{90}Sr which entered site streams was carried rapidly to the Savannah River; the other 10% is thought to have been deposited in stream beds, floodplains, or ponds (10). The migration of the deposited Sr would have been affected by adsorption to clay minerals, metal oxides and organic matter. However, relative to Cs, Sr tends to sorb and desorb easily and competes with calcium for exchange sites. Therefore, it generally tends to migrate faster than the Cs.

Although much of the radionuclides released from the P Reactor appears to be attributed to irradiated elements and fuel element failures, other smaller releases of radionuclides to Steel Creek occurred during regular operations. For example, a small contributor to the release of ^{90}Sr and ^{137}Cs to Steel Creek early in P Reactor operations was through cooling water from Par Pond. Beginning in 1958, P Reactor received some of its cooling water from Par Pond, which contained radionuclides from R Area releases. Analyses of cooling water received from Par Pond indicated that approximately 6.6 Ci of $^{89,90}Sr$ (and 19.8 Ci of $^{134,137}Cs$) released to Steel Creek between 1960 and 1963 were from cooling water originating from Par Pond. This cooling water was discharged solely to Steel Creek until May 1961 when the P Area canal to Par Pond was completed and some of the cooling water was diverted to Par Pond. By 1963 most of the P Reactor's cooling water was discharged to Par Pond (15). Another small source of ^{137}Cs to Steel Creek was cited in a monthly monitoring report in October 1972. During the drainage of the 186-3P cooling water settling basin approximately 0.05 Curies of ^{137}Cs were released in sludge and effluent to Steel Creek (20). Since other documents concerning the drainage of cooling water settling basins were not found in this search, it is unclear how frequently the cooling water settling basins were drained.

The annual activity associated with tritium, ^{137}Cs and ^{90}Sr as reported in "Radioactive Releases at the Savannah River Site 1954-1989 (U)" were decay corrected and a decay corrected cumulative activity was calculated. These are shown on Figures, 11, 14, and 15, respectively. As there are no new discharges to Steel Creek from P-Reactor, these figures show a depleting source of all three radionuclides. Based on the highest cumulative activity level, the activities have decreased by approximately 70%, 50% and 50% for tritium, ^{137}Cs and ^{90}Sr, respectively. Because tritium is highly mobile and would not have settled out of the creek water, the cumulative activity shown in figure 11 is only indicative that 70% of the tritium has decayed; it implies nothing regarding the distribution of tritium in the environment. In contrast the movement of ^{90}Sr and particularly ^{137}Cs can be retarded by sorption. The ^{137}Cs overflight data and sediment analyses from the IOU database indicate the presence of ^{137}Cs in the Steel Creek bed (figure 12). Although only a few locations in the IOU database had analytical data for ^{90}Sr, available sediment data for Steel Creek did not indicate the presence of ^{90}Sr near the discharge pipes into the creek. The cumulative activities, as shown in figures 14 and 15, show that the activities of ^{137}Cs and ^{90}Sr have decreased by 50% and indicate that where these contaminants are found in the creek bed, they are depleting sources. The geochemical behavior and sorption characteristics of these radionuclides, particularly ^{137}Cs, would be an important consideration in the design of any treatment system in this area.

Seepage Basins

Figure 16 shows the annual curies of tritium originally discharged from P Reactor to the seepage basins with Steel Creek for comparison. As indicated in the figure, Steel Creek received the majority of the tritium activity discharged from P Reactor. However, these releases occurred primarily in the early and middle part of the reactor's history (1954 through 1978) and had a primary pathway downstream toward the Savannah River. In addition, these releases were usually accompanied by large volumes of water. As indicated by release volume histories, Steel Creek typically received two orders of magnitude more liquid effluent annually than the seepage basins (figure 17) (14). In contrast, the seepage basins received most of the tritium activity toward the latter part of the reactor's history (1978 through 1987) accompanied with less volume of effluent water. The lower discharge volumes coupled with the closed system of the basins (i.e. not intermixing with fresh water) would have led to high concentrations of tritium (among other radionuclides) in the seepage basins with a greater potential to locally affect P Area groundwater than the discharges to Steel Creek.

Monitoring wells around the seepage basins were installed in 1978 (and later replaced in 1984). Tritium data collected from these wells during the early and mid-1980's appear to be similar to the calculated concentrations of tritium released to the seepage basins from 1978 through 1989 (figure 18). Tritium concentrations were calculated using historical activity release data and discharge volume data (14). In figure 18, the bottom error bars for the seepage basin discharges represent the decayed tritium concentration. Historically, PSB1 (PSB1A), which is on the downgradient side of seepage basin #1, has had the most elevated tritium concentrations followed by PSB2 (PSB2A), PSB3 (PSB3A) and PSB7 (PSB7A). Analyses of sediments below the seepage basins also indicate that seepage basin #1 received the greatest amount of discharged radionuclides, followed by seepage basin #2, and then seepage basin #3 (21).

Figure 19 provides a more detailed view of monitoring well data and seepage basin releases beginning in 1978 through 1999. A decayed concentration of the last recorded release has been calculated and is shown in figure 19 as a dashed line. This concentration of the last release can be used as a worst case concentration emanating from the seepage basins into the groundwater assuming no mixing or dispersion. Beginning in the early 1990's, tritium concentrations in the monitoring wells started decreasing and by 1999 reached concentrations significantly less than the decayed concentration of the last release. This difference indicates that the seepage basins are a depleting source of tritium.

Releases of two of the longer-lived radionuclides, ^{137}Cs and ^{90}Sr, to the seepage basins were also considered and are presented in figures 20 and 21 (14). Compared to Steel Creek, the seepage basins received fewer curies ^{137}Cs and ^{90}Sr. As documented in the November 2002 Technical Evaluation Report for the P Area Seepage Basins, much of the ^{137}Cs and some of the ^{90}Sr discharged to the seepage basins remain distributed in sediments below the basins. More specifically, analyses of soil sample borings revealed that ^{137}Cs contributes approximately 90% to the total radioactivity found in basins #1 and

#2, and ^{90}Sr contributes approximately 4% to the total radioactivity in these basins. According to this technical evaluation, most of the radioactivity in basin #3 is attributable to naturally occurring radionuclides (21). Mass balance analyses of the ^{137}Cs show reasonable closure with the decay corrected amount of ^{137}Cs released to the basins closely matching the amount of ^{137}Cs remaining in the sediments of basins #1 and #2 (Appendix D). This is an indication that the ^{137}Cs released to the basins have been held in the soils. Thus, closure of the basins per the Plug-In ROD will eliminate a potential source of groundwater contamination.

The majority of ^{137}Cs and ^{90}Sr released to the seepage basins occurred in 1959 early in P Reactor's history. Weekly monitoring reports for this year suggest that an atypical discharge of a failed element and the handling of developmental reactor fuels may have contributed to the increased releases of radionuclides to P Reactor's seepage basins. In particular, in March 1959, a failed element was transferred to the emergency section of the disassembly basin but not contained in the "harp" (the container used to store failed elements underwater). According to weekly reports, the water from the emergency section was pumped into the seepage basins where subsequent large concentrations of radioactivity were found (22,23).

In addition to discharge incidents, P Reactor disassembly basin handled Spent Canadian Reactor Uranium Products (SCRUP) casks in 1959 and 1960 as part of an Atomic Energy Commission program designed to make uranium available as fuel in experimental power reactors and university research reactors. The program mandated that once the fuel was no longer needed or was spent, it was to be returned to the Savannah River Site for reprocessing. The experimental fuel elements were diverse in dimensions, types of cladding, and nature of the fuel cores. Before the Receiving Basin for Off-site Fuels (RBOF) was built in 1964, P Area received some of the early fuel elements from the Canadian heavy water reactors (4, 24). According to weekly monitoring reports, ^{137}Cs and ^{90}Sr were found to contribute to the high gamma and nonvolatile beta activities in the transfer area of the disassembly basin where these casks were handled. Effluents from the transfer area and from the casks were typically pumped to the seepage basins (24, 25).

An overflow of the seepage basins which occurred in October 1959 would also suggest that the basins were receiving extensive use during this period. As documented in a weekly monitoring report, water levels in seepage basin #2 were found over the berm producing an "outcrop" of water extending approximately 45 feet from the basin. Tritium analyses of water collected from the outcrop were 0.440 uC/L (440 pC/mL) confirming that the water originated from the basin (26).

Summary of Findings

The major findings and implications from this source term determination are presented below.

- A calcareous zone exists with numerous and erratic solution channels under P Area. The average top of this zone is approximately 175 ft below land surface in P Area and was found to vary between 10 and 40 ft thick. The data indicate that this zone is in the Lower Aquifer Zone (LAZ) of the Upper Three Runs Aquifer. The dissolution channels of this calcareous zone can act as preferential pathways of contaminant transport should a contaminant reach this zone. Additionally, the amount and distribution of grout from the Corps of Engineers foundation grouting has the potential to affect chemistry and transport behavior below P Reactor.
- This document search did not find any major abnormal release events/accidents that would have caused a substantial release to the ground surface or surface water bodies.
- The releases that accompanied normal operations during P Reactor's long operational history may have the most impact on the distribution and types of contaminants found.
- The 704-P maintenance shop is a potential source of organic solvents due to the heavy use of solvents in this building. Standard practice for disposal of organic solvents in the maintenance shops consisted of discarding drummed waste onto the ground 50 to 100 yards from the building.
- Before 1978, P Area discharged the majority of the tritium activity to Steel Creek whereas from 1977 through 1987, the seepage basins received most of the tritium activity. A greater volume of water was discharged to Steel Creek than the seepage basins which would have decreased the concentration of tritium (and other contaminants) discharged. With tritium's low sorption potential and non-reactive nature, the large volumes of water would also have carried the tritium downstream toward the Savannah River reducing the likelihood that it would affect groundwater near P Area. In contrast, the closed system of the seepage basins provided a longer term source of tritium to the groundwater. With no current source from the basins, local hydrogeologic properties and decay would determine tritium migration.
- P Area discharged most of the ^{137}Cs activity to Steel Creek rather than the seepage basins and most of the ^{137}Cs was released during the 1960's. The high retardation potential of Cs coupled with the variability of discharges and erosional/depositional episodes associated with the creek would likely make its distribution partly scattered in surficial sediments along Steel Creek. Gamma overflight data and sediment data indicate that some of the ^{137}Cs remains along Steel Creek. ^{137}Cs discharged to the seepage basins would tend to remain bound to sediments near the bottoms of the seepage basins as evidenced by analyses of sediments below the basins.
- Like ^{137}Cs, most of the ^{90}Sr discharged from P Area was released to Steel Creek during the 1960's. Most of the ^{90}Sr traveled relatively quickly to the Savannah River after being discharged. The migration of any ^{90}Sr deposited would have likely been affected by adsorption to clay minerals, metal oxides and organic

matter. Relative to Cs, Sr tends to sorb and desorb easily and would have had a greater potential to migrate.

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3. Savannah River Site at Fifty, by M. B. Reed, M. Swanson, S. Gaither, J.W. Joseph, and W. Henry, published by U.S. Government Printing Office, Washington, D. C., 2002.
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10. "Assessment of Strontium in the Savannah River Site Environment (U)", by W.H. Carlton, A. G. Evans, L. A. Geary, C. E. Murphy, Jr., and R. N. Strom, WSRC-RP-92-984.
11. "P-Area Reactor 1993 Annual Groundwater Monitoring Report", WSRC-TR-94-0355.
12. "Radioactivity in the Environs of Steel Creek", Radiological Sciences Division, Radiological Chemistry Group, Savannah River Laboratory Monthly Report, August 1972.
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19. "^{134,137}Cs in the Savannah River", Radiological Sciences Division, Savannah River Laboratory, Earth Sciences Monthly Report, March 1970.
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21. "Unit-Specific Plug-In Technical Evaluation Report for the P-Area Reactor Seepage Basins (904-61G, 904-62G, and 904-63G) Operable Unite (U)", WSRC-RP-2002-4082.
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25. "Special Analysis", Weekly Report – Control, September 21-25, 1959.
26. "P Area Seepage Basin", Weekly Report – Control, October 26-30, 1959.

Figure 1 Location of Grouted Boreholes in P Area
from Corps of Engineers Foundation Grouting Operations

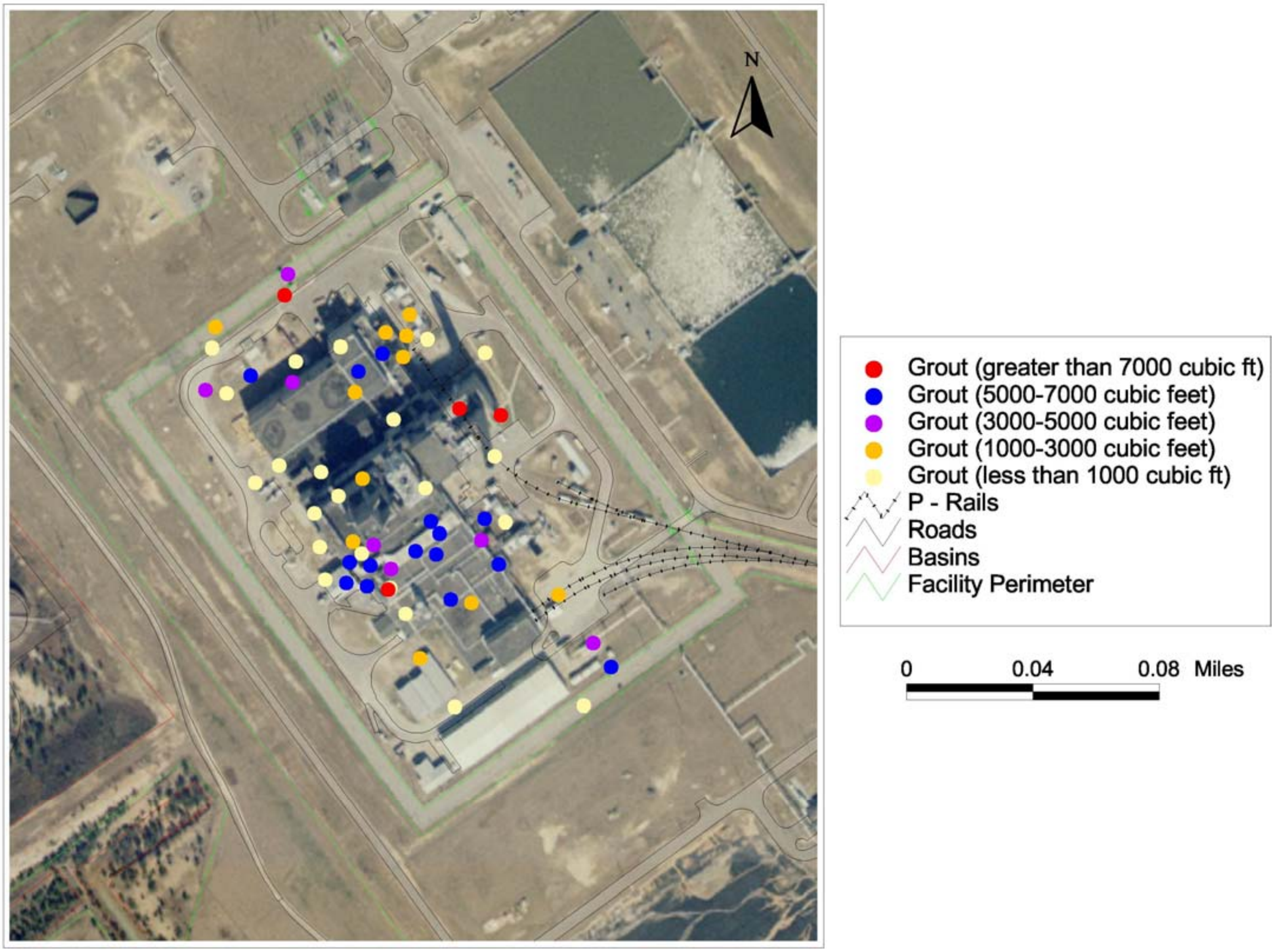
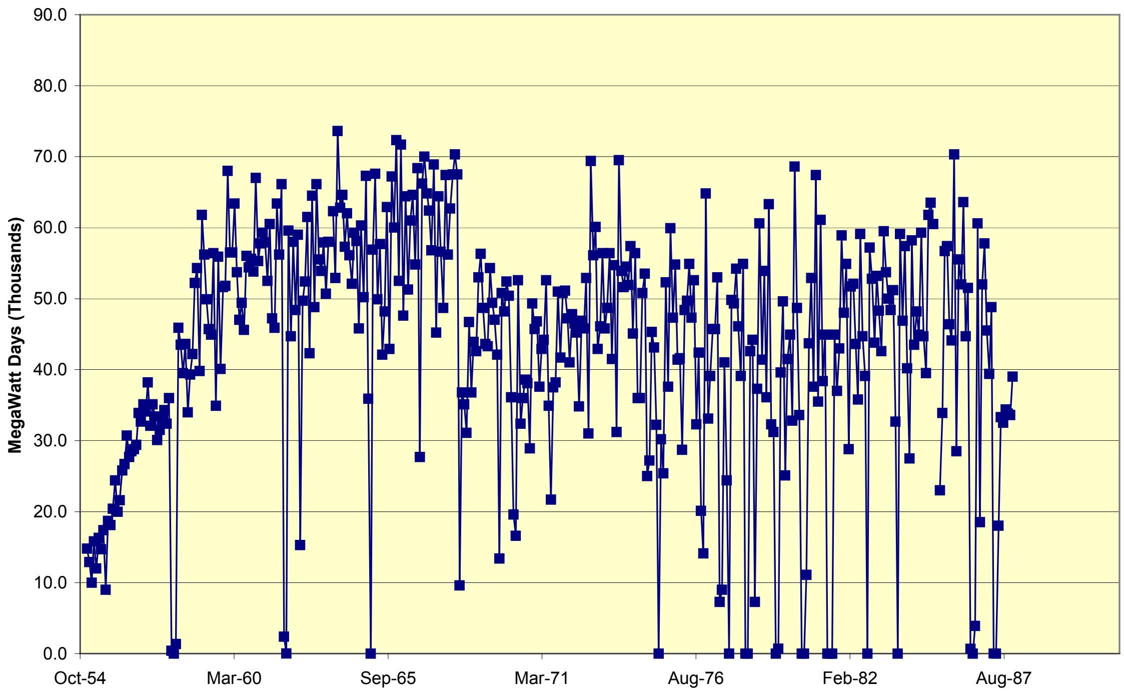


Table 1 Subsurface Characterization and Foundation Grouting Information

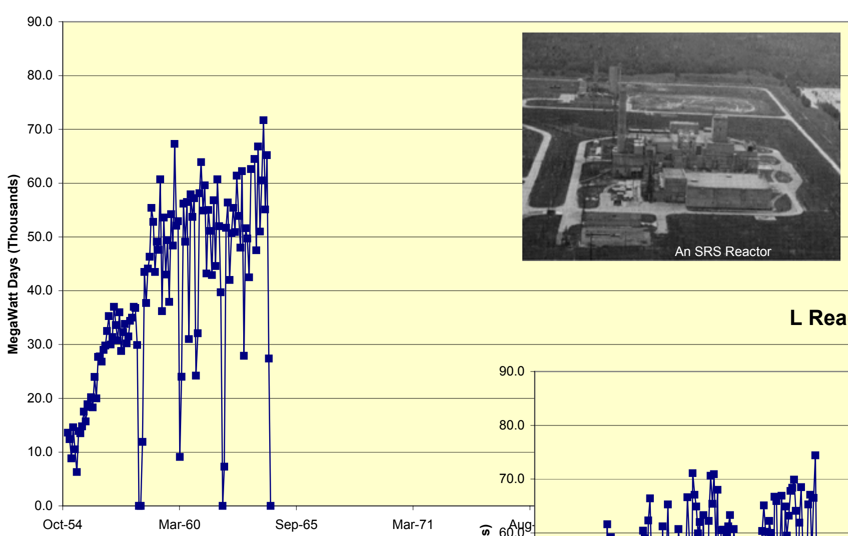
	# of borings	# of split-spoon & undisturbed holes	Total # of holes	Total # of holes grouted	% of holes grouted	# of holes venting	Qty of grout pumped (ft3)	# of borings indicating $CaCO_3$
P Area	344	4	348	77	22	24	212,783	276
L Area	296	8	304	94	31	21	223,268	224

Figure 2 Power (Thermal) Output for P, R, and L Reactors

P Reactor Power Levels

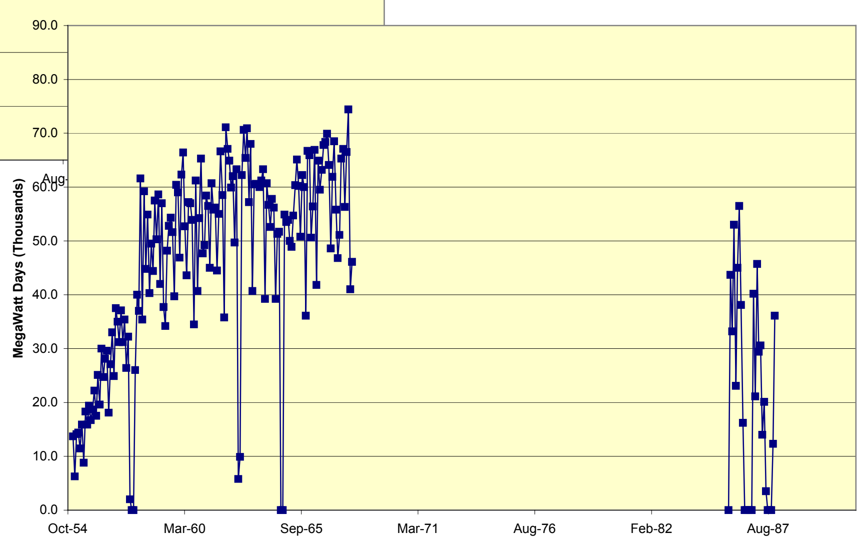


R Reactor Power Levels



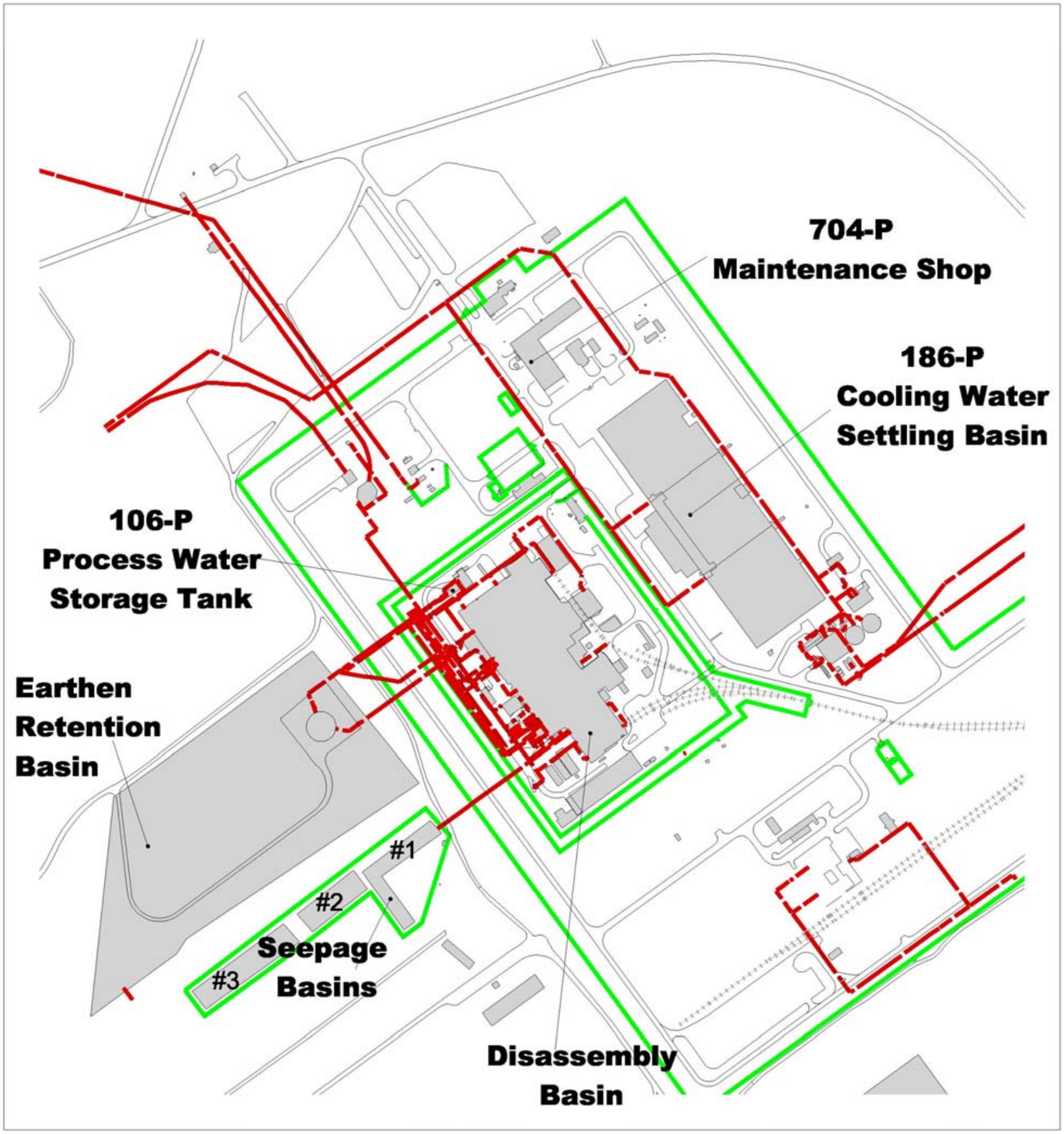
An SRS Reactor

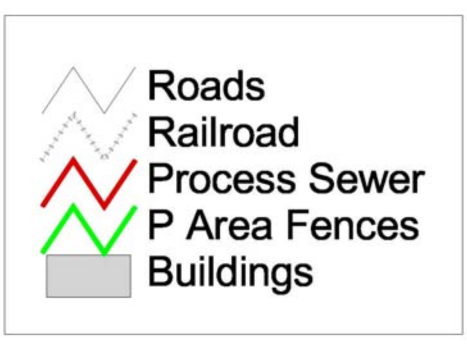
L Reactor Power Levels



(figures from reference #5, Dose Reconstruction Report)

Figure 3 Map of P Reactor Facilities





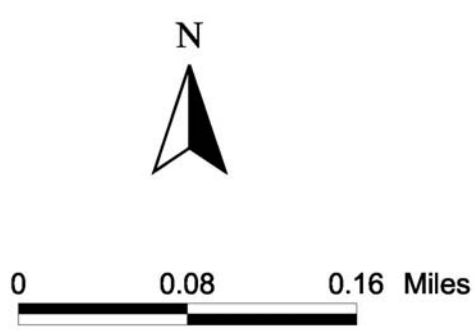
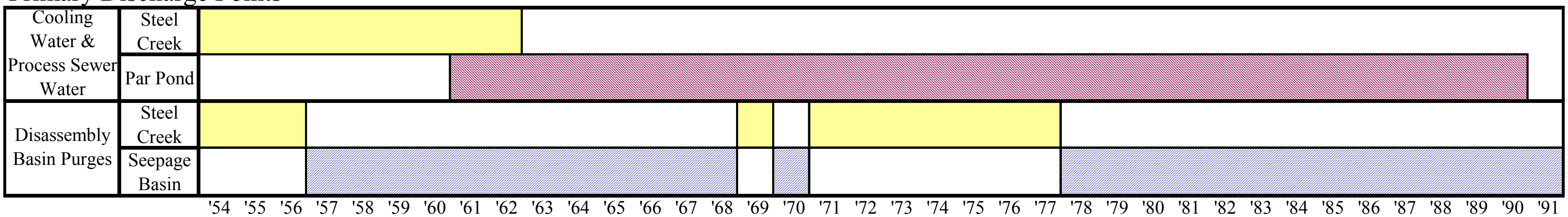


Table 2 Timeline and History for P Reactor

Primary Discharge Points



P Area Event History

1951	P Area ash basin activated; P Area burning rubble pit constructed and activated; Corps of Engineers began soil investigations and subsurface foundation grouting operations
1954	P Reactor started
1955	Acid/Caustic basin activated
1957	Seepage Basins activated
1958	Par Pond completed
1959	P Reactor participated in program for reprocessing spent fuel from other sites (primarily SCRUP, Spent Canadian Reactor Products, casks)
1960	Construction of discharge canal from P Area to Par Pond
1963	Installation of disassembly basin heat exchangers and deionizers; most of cooling and process sewer water diverted to Par Pond; 50 million gallon earthen retention basin constructed for ECS (Emergency Cooling System); in December, P Reactor reached its maximum monthly power output of 73,600 MW days
1969	Seepage basins deactivated; bypassed disassembly basin water filtered and discharged directly to Steel Creek
1978	Seepage basins reactivated; P Area burning rubble pit reaches capacity and closed
1979	500,000 gallon storage tank and related piping added to earthen (ECS) rentention basin
1981	P Area coal pile retention basin activated
1982	Acid/Caustic basin deactivated
1985	Construction of L Lake completed; all remaining cooling and process sewer water effluents diverted from Steel Creek
1991	P Reactor placed in shutdown status

Table 3 Common Radiological Contaminants

Source of contaminants	half-life
^{32}P came from the activation of sulfur leached from moderator deionizers during normal operations and from the use of phosphoric acid to clean the heat exchangers in the mid-1960's	14.3 days
^{51}Cr & ^{60}Co came from the activation of stable ^{50}Cr & ^{59}Co in the stainless steel parts of the reactor tank and the stainless steel used in the reactor cooling system piping	27.7 days & 5.27 years
^{65}Zn came from the activation of ^{64}Zn a trace element found in the aluminum reactor fuel and target components	243.9 days
^{137}Cs formed as a fission product from neutron-induced fission reactions involving the ^{235}U fuel elements; additional ^{137}Cs was formed from the activation of stable Cs produced by neutron fission	30.1 years
^{129}I & ^{131}I formed as fission byproducts in the fuel and target elements	1.57E+07 years & 8.04 days
^{90}Sr formed as a fission byproduct in the fuel and target elements	28.8 years
^{3}H produced from neutron irradiation of Li-Al targets, interaction between neutrons and moderator (considered principal source of liquid release), and by ternary fission (the occasional splitting of U atom into three, one of which was ^{3}H)	12.35 years

Figure 4 Discharge to Steel Creek
(DPSPF-6580-8) 3/4/1960

Figure 5 Effluent Stream, P Area
Construction of Discharge Point to Par Pond
(DPSPF-6872-47) 8/17/1960

Figure 6 Effluent Stream, P-Area
Construction of P Area Canal to Par Pond
(further downstream from P Area, heading toward Par Pond)
(DPSPF-6872-36) 8/17/1960

Figure 7 Effluent Canal, P-Area
Discharge Point to Par Pond Completed
(DPSPF-7459-1) 5/5/1961

Figure 8 Effluent Canal, P Area
Completion of P Area Canal to Par Pond
(further downstream from P Area, heading toward Par Pond)
(DPSPF-7459-5) 5/5/1961

Figure 9 Effluent Canal, P-Area
Looking downstream toward Par Pond
(DPSPF-7459-2) 5/5/1961

Figure 10 P and L Reactor Releases to Stream (Steel Creek)
Tritium Activity Originally Released

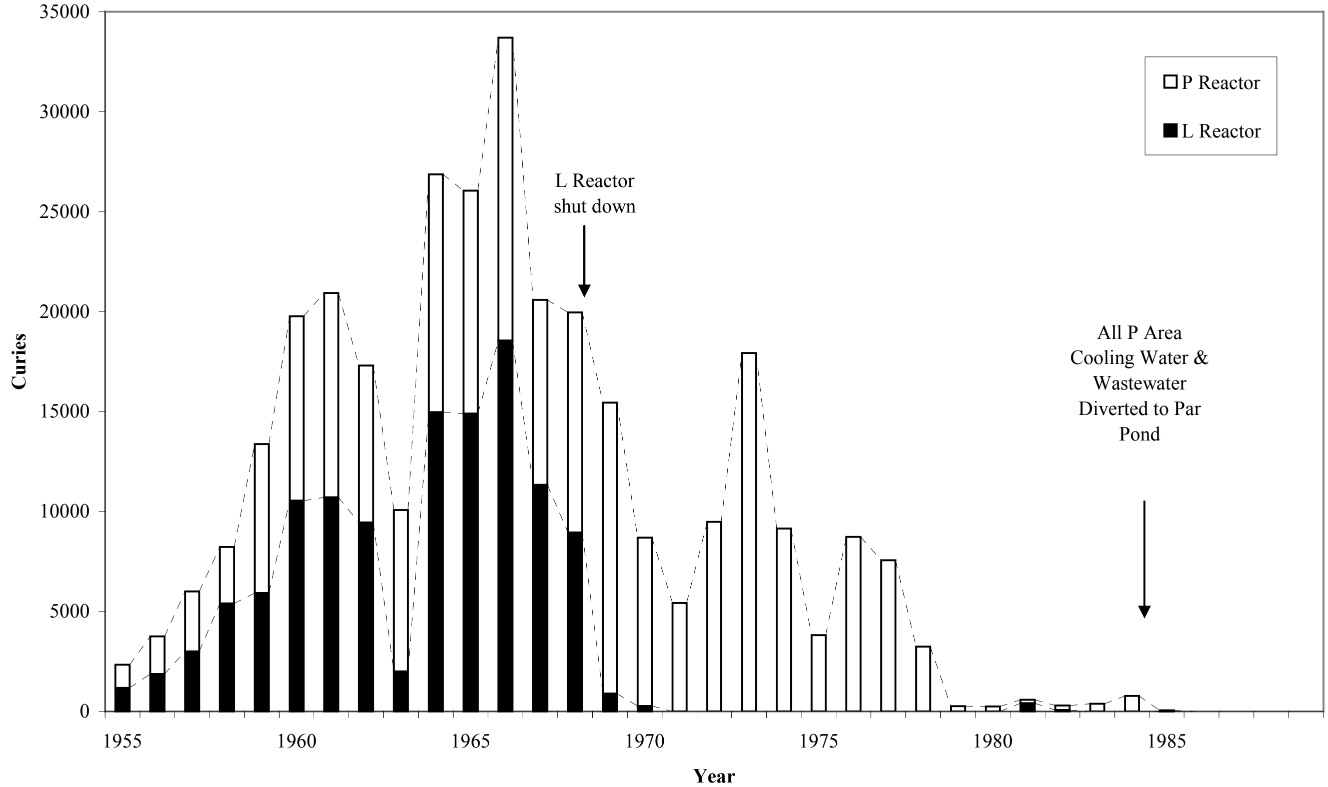


Figure 11 Tritium Released to Stream (Steel Creek)

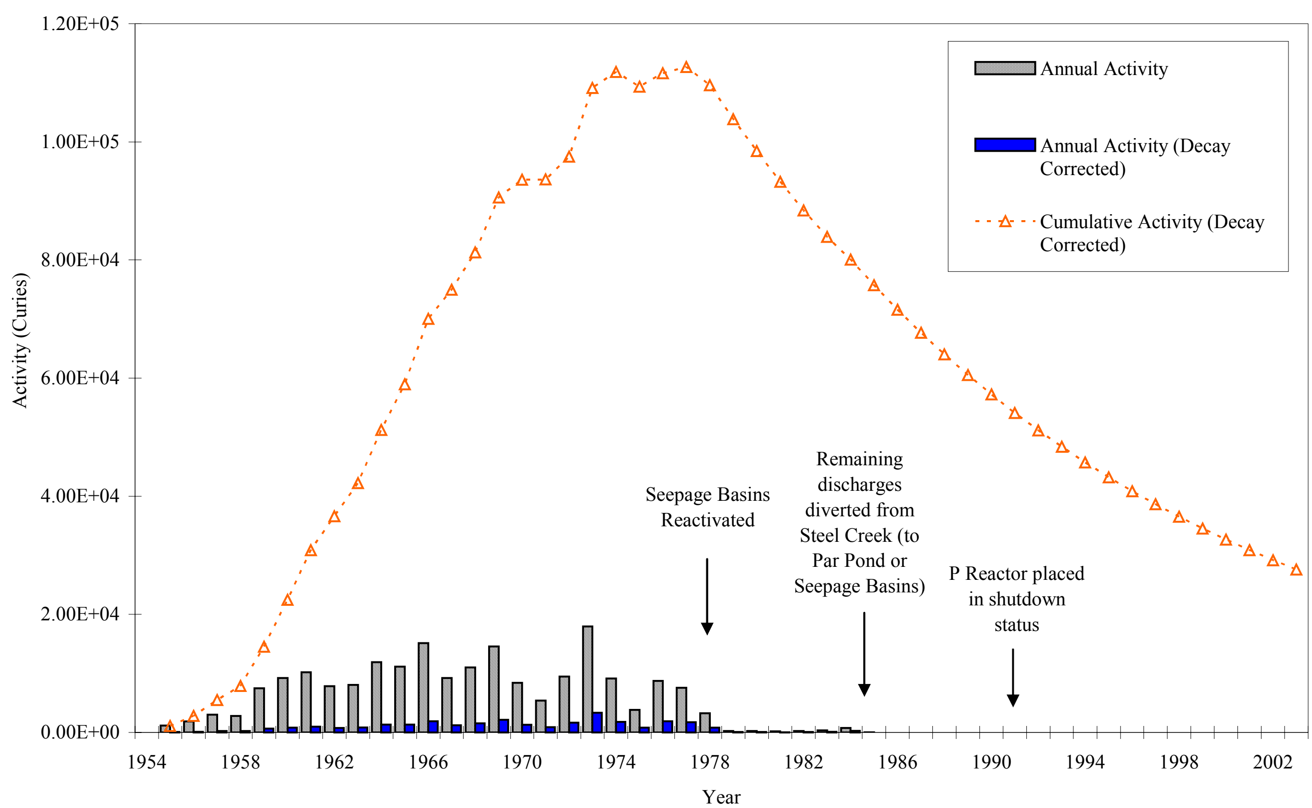


Figure 12
1985 Gamma Overflight Data
(obtained from GIS database)

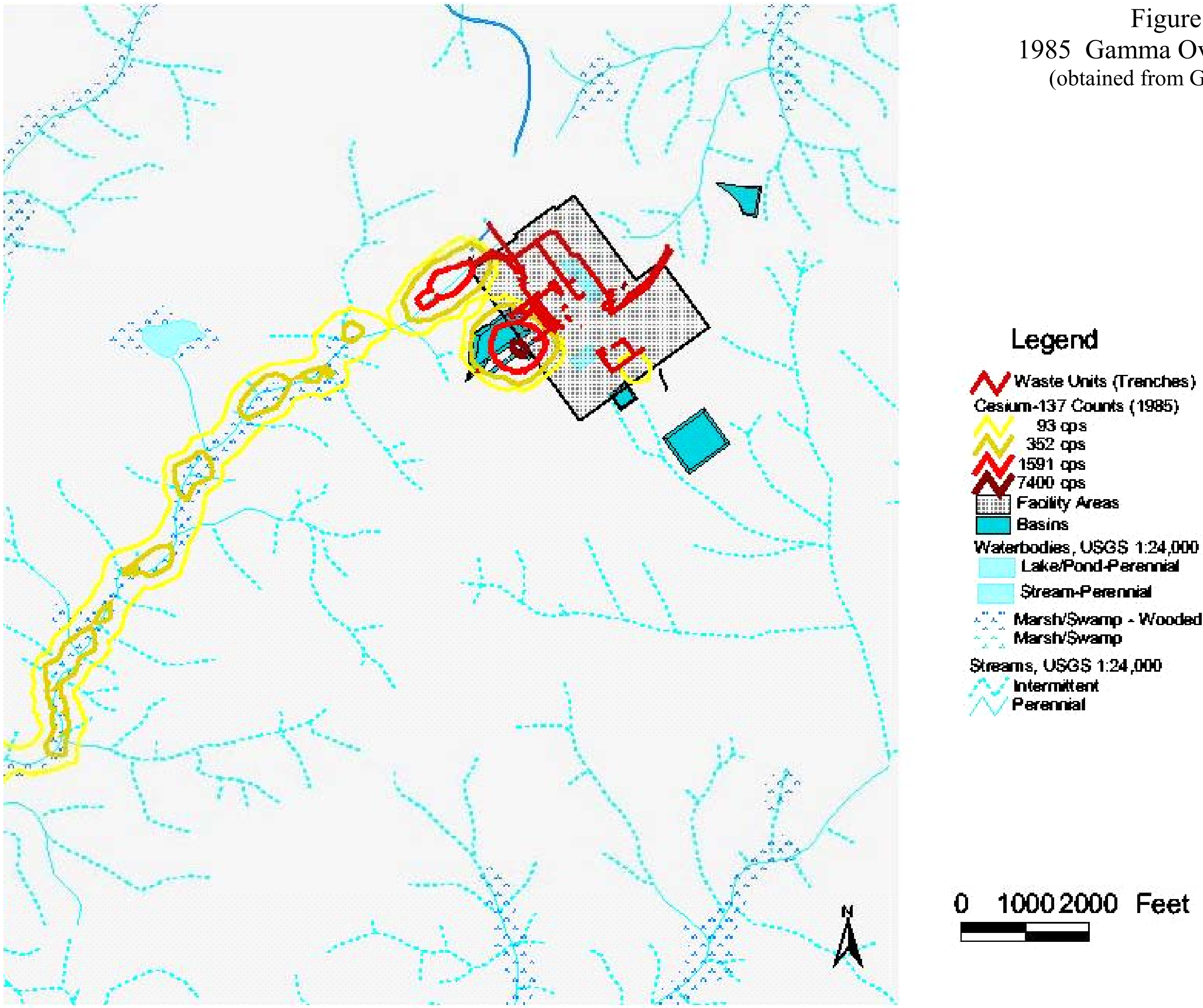


Figure 13
1991 Gamma Overflight Data
(obtained from GIS database)

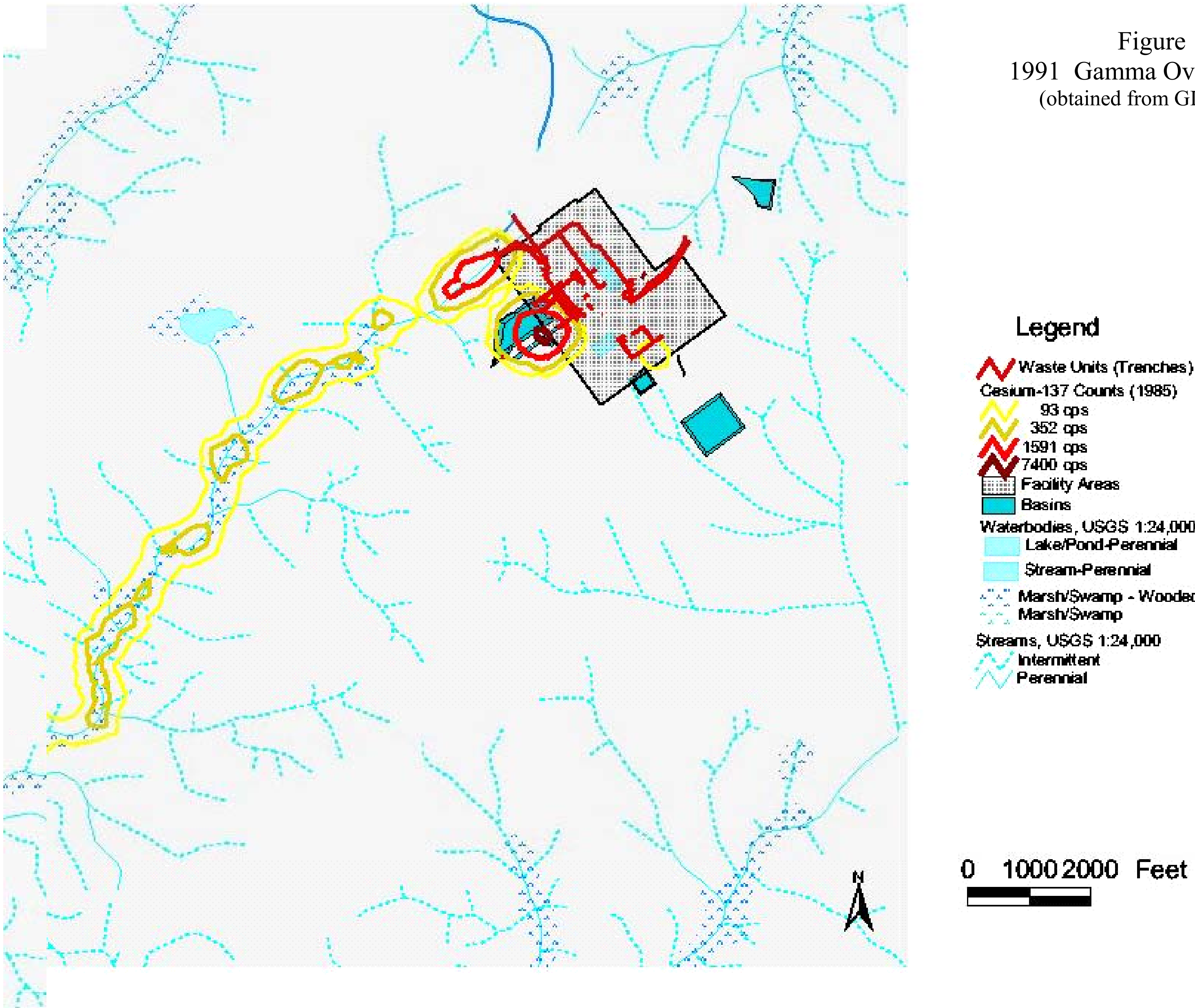


Figure 14 ^{137}Cs Released to Stream (Steel Creek)

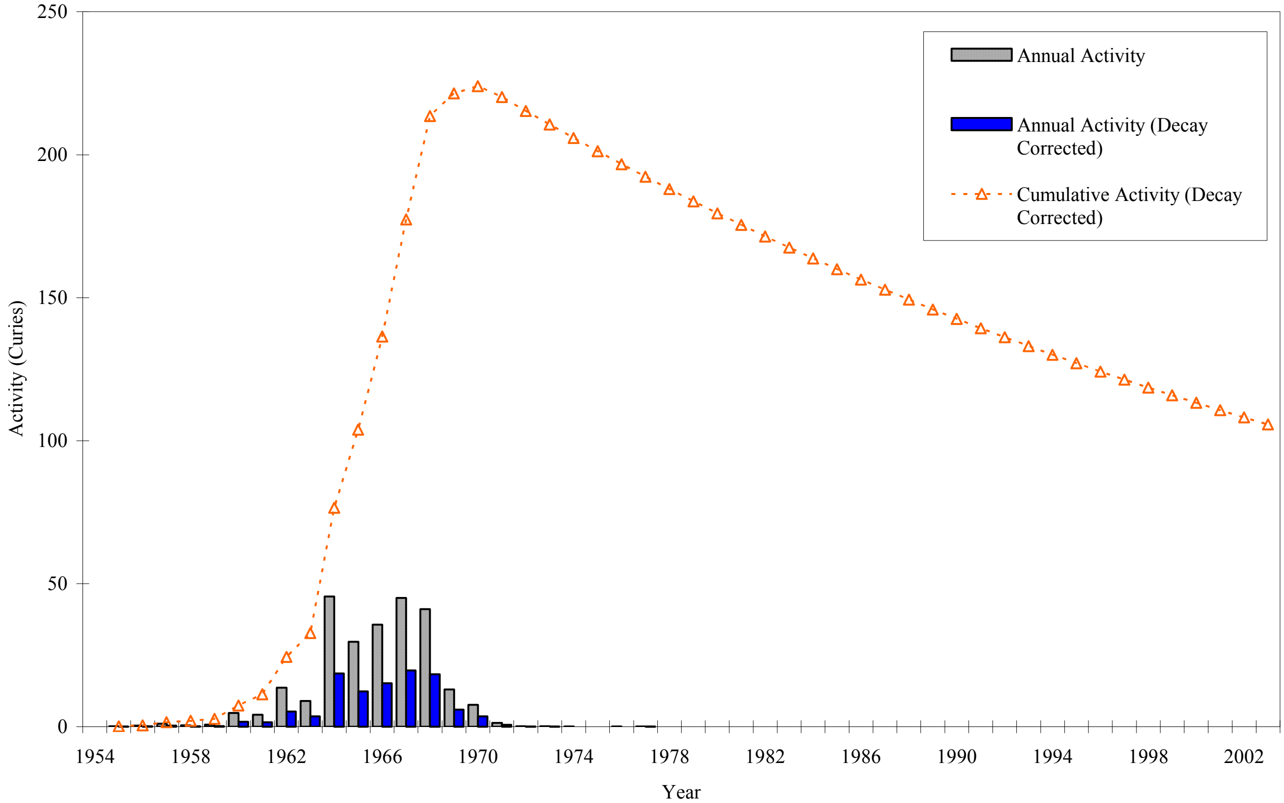


Figure 15 ^{90}Sr Released to Stream (Steel Creek)

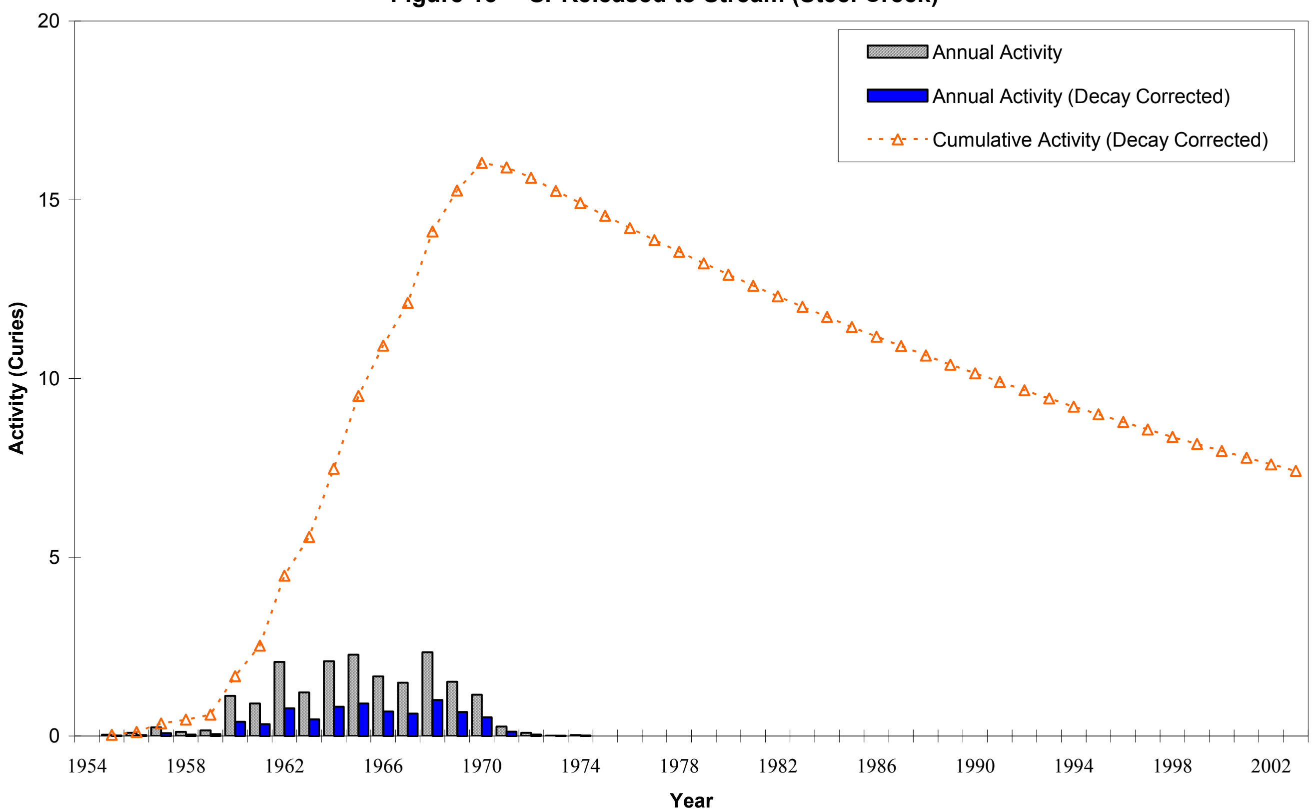


Figure 16 Annual Tritum Activity Released to Steel Creek and to Seepage Basins

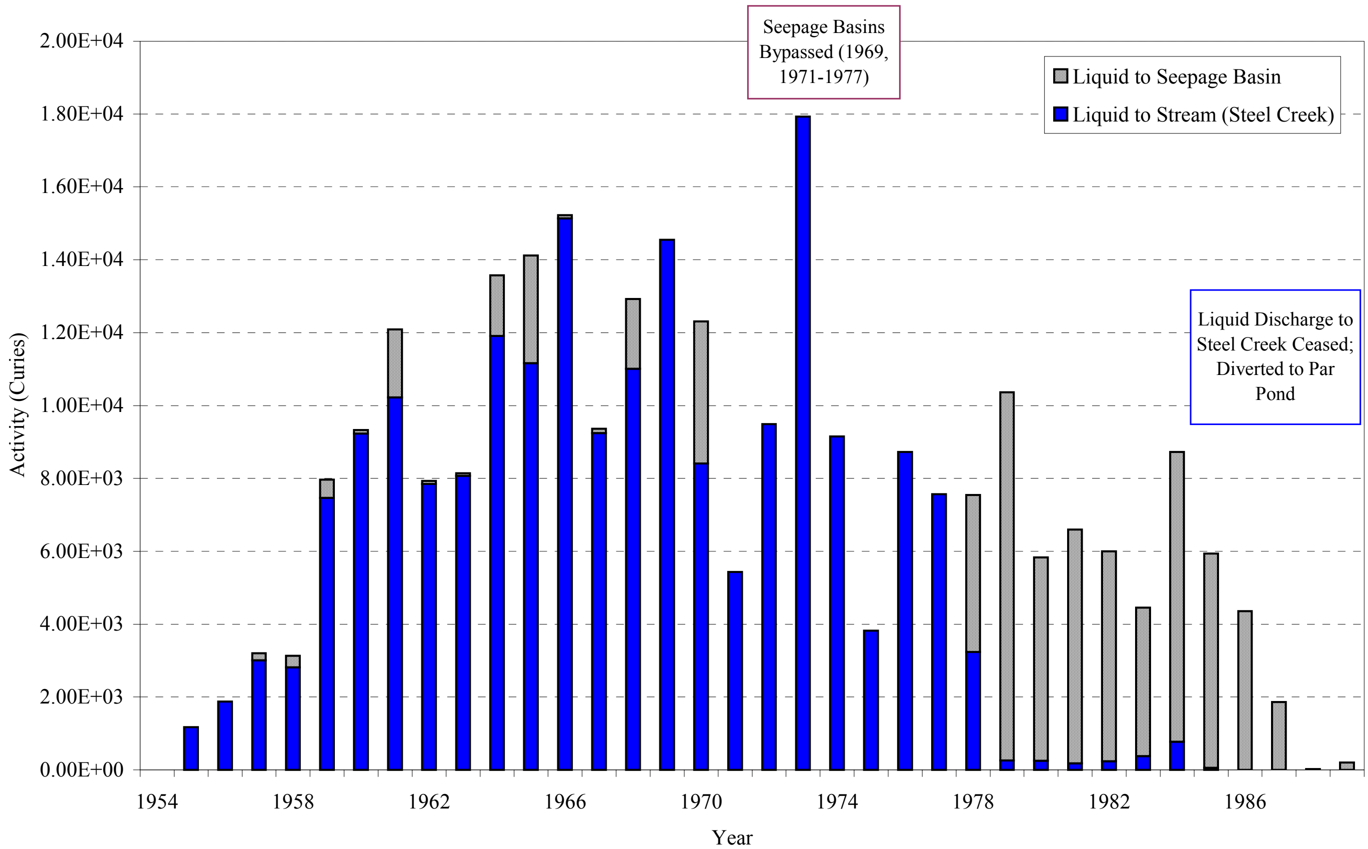


Figure 17 Annual Effluent Volumes Released to Steel Creek and to Seepage Basins

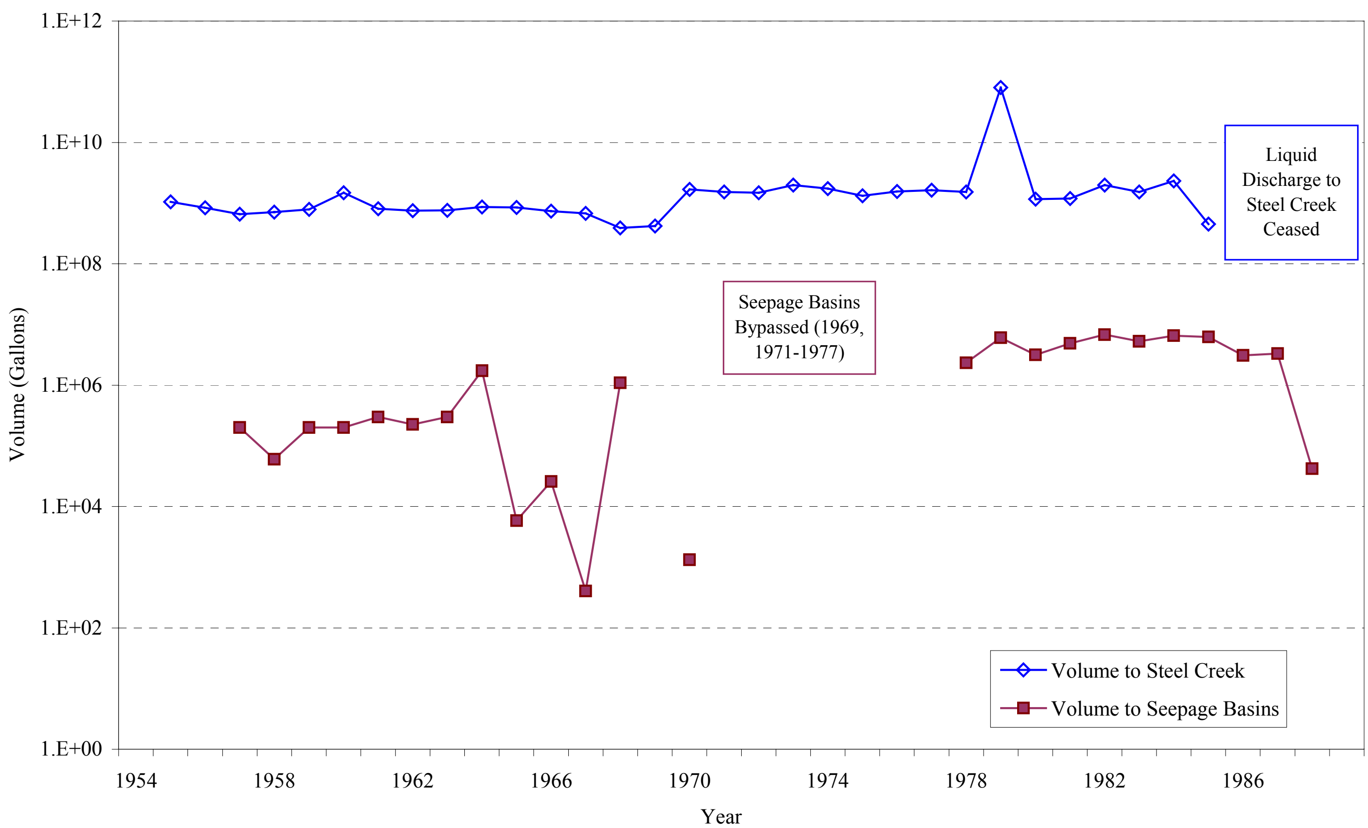


Figure 18 Tritium in Seepage Basins and PSB Wells

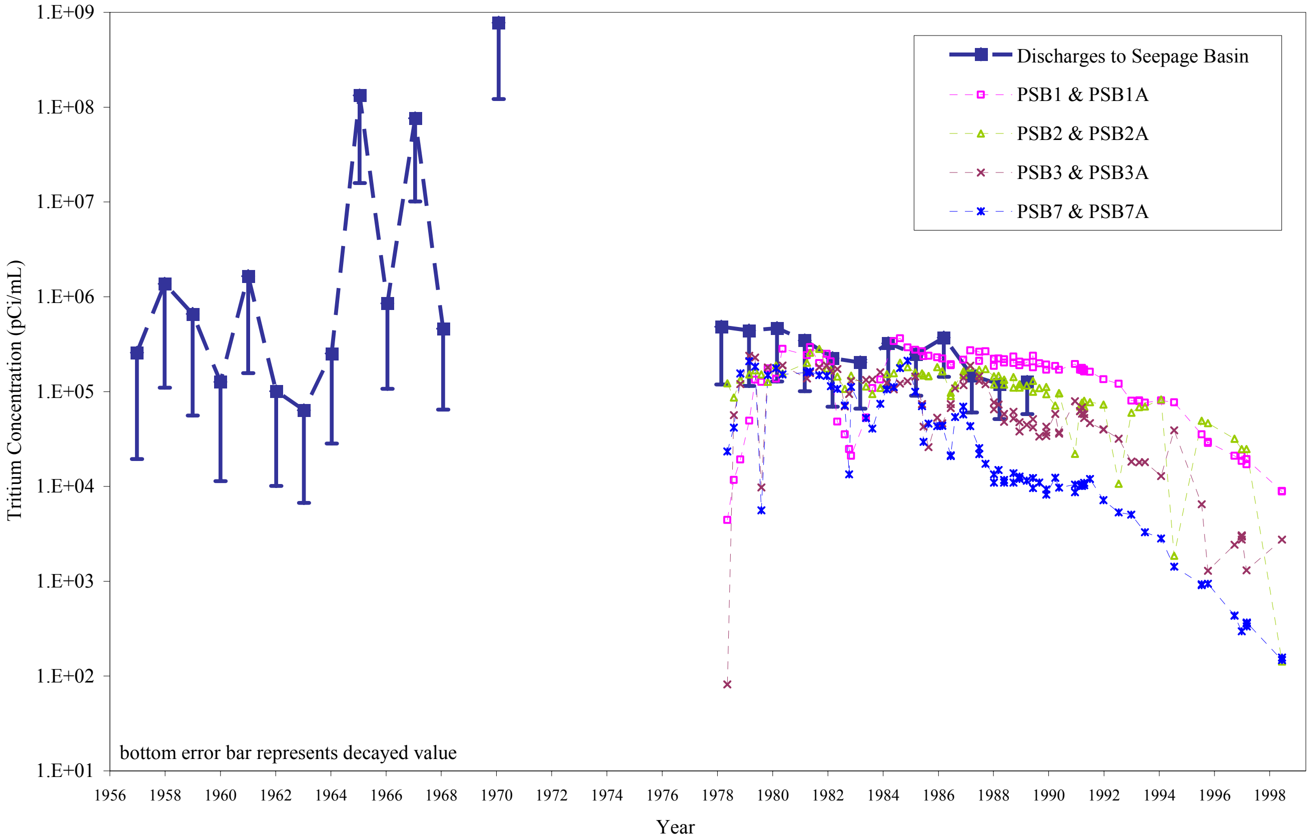


Figure 19 Tritium in Seepage Basins and PSB Wells 1978-1999

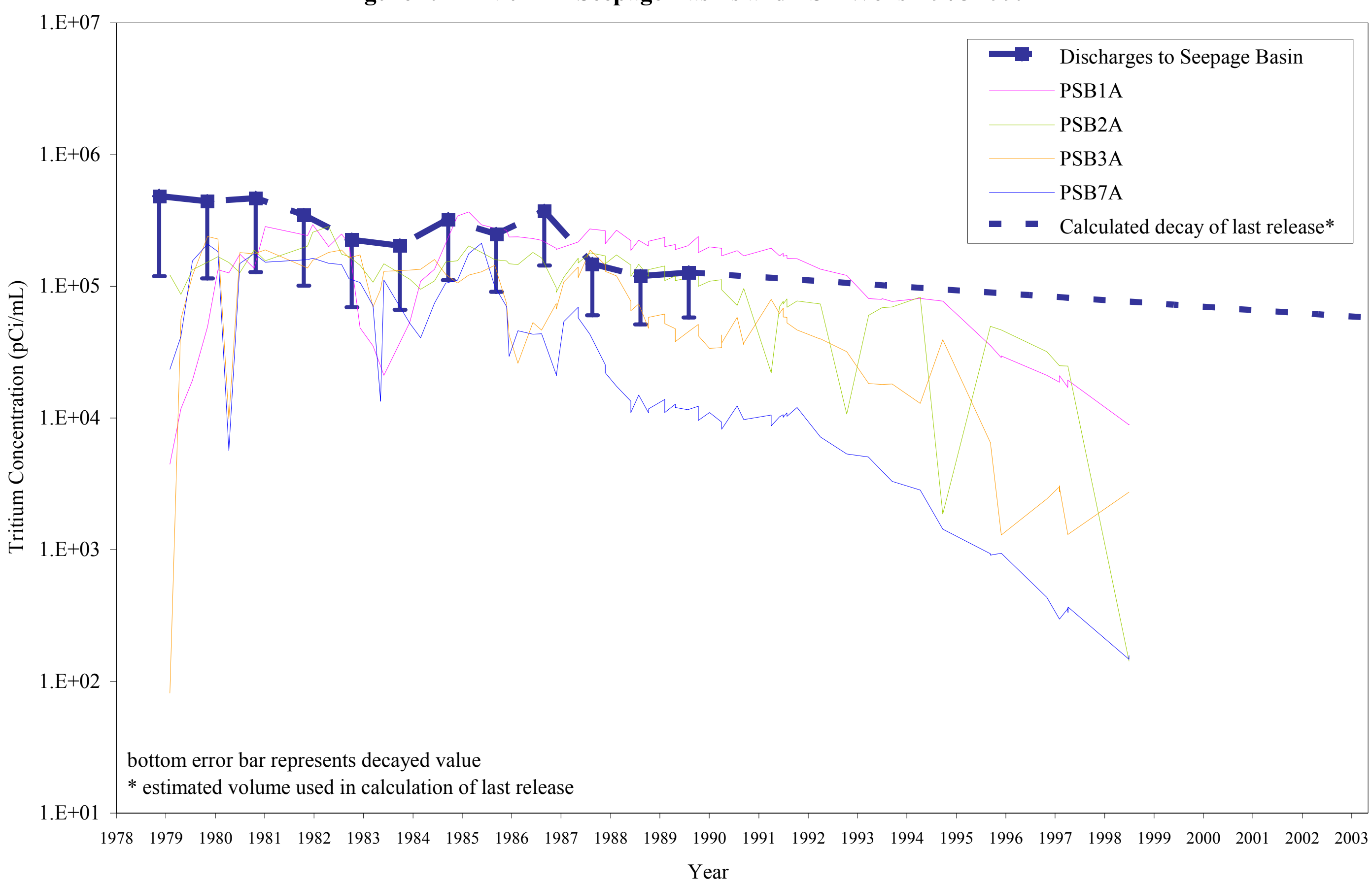


Figure 20 ^{137}Cs Released to Seepage Basins

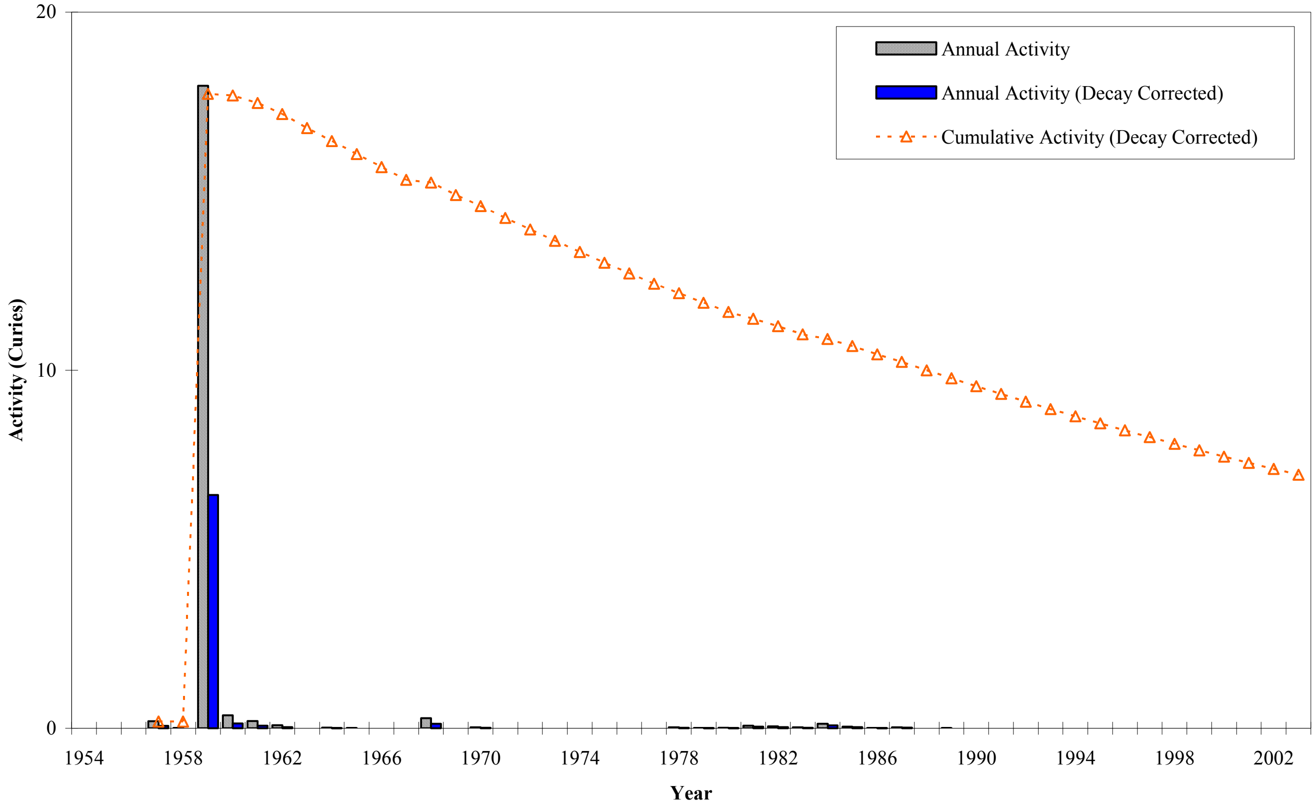
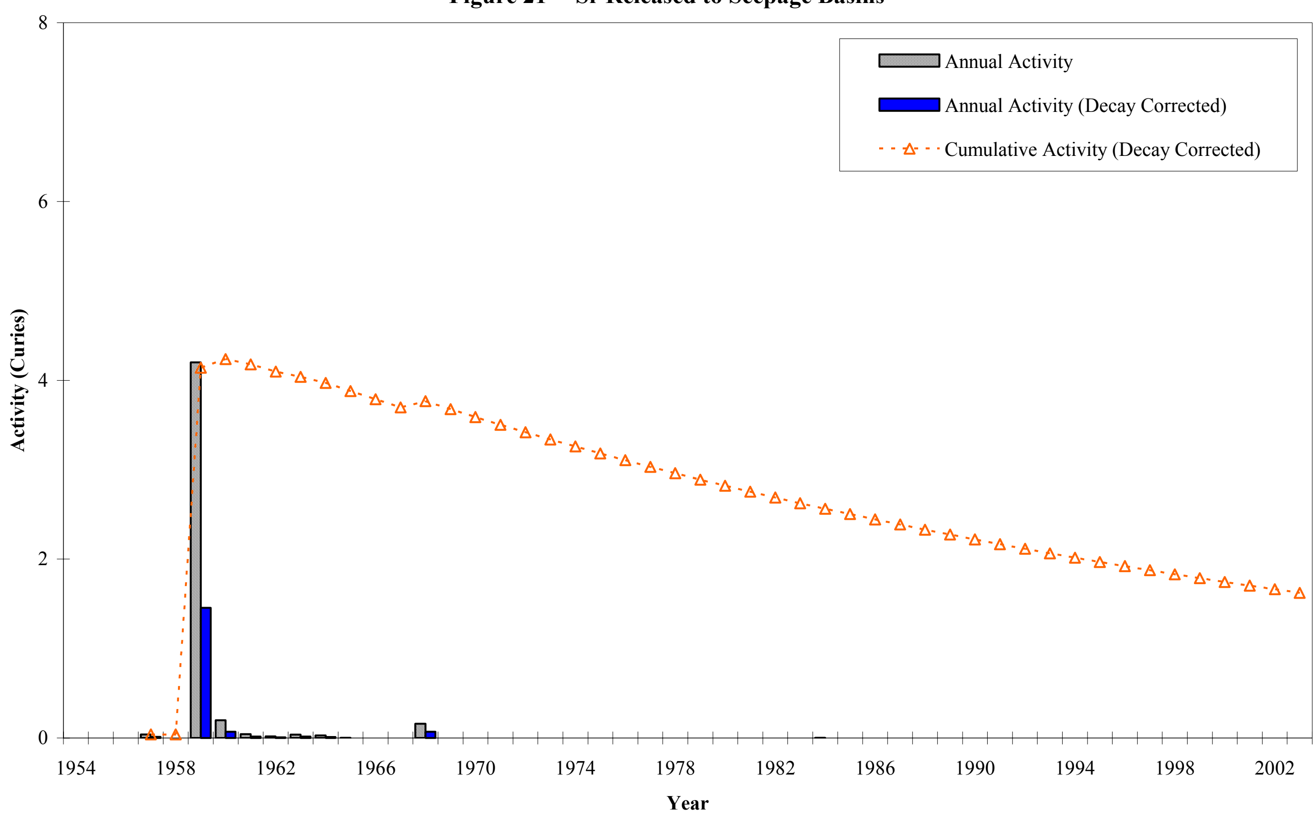


Figure 21 ^{90}Sr Released to Seepage Basins



Appendix A Documents Reviewed (from Unclassified and Classified Searches)

Object Name	Title	Bin Num/Date	Box Num or Author	Subject
38343	IMPROVED FLUSHING FACILITIES - C,K, AND P AREAS - PROCESS SCOPE OF WORK	*VARC/12/18/1984 12:00:00 AM	RTGEWR149	
100182	SITE CLEARANCE FOR 300M GALLON TANK WITH DRAIN LINE AND ELECTRIC FACILITIES - IMPROVED REACTOR CONFINEMENT FACILITY - P AREA	*VARC	RTGEWR97	
105167	REACTOR ROOM FLOOR DRAIN CALCULATION - P AREA	*VARC	RTGSG12	
401738	DISASSEMBLE WATER RECIRCULATION; P AREA; AUXILIARIES BLDGS.; OME PLAN; FILTER CUBICLES; TRENCH; BACKWASH PIT; HEAT EXCHANGE SUPPORT	*VARC	RTGCALC60	
401764	OUTSIDE ISOLATION TANK; P AREA; O.M.E.; DISASSEMBLY AREA	7/14/1959 0:00	CORNWELL,JA, THURMAN,HR	BAYS, DOORS, CRANES, PRESSURE, BASINS, CASKS, SLABS, BASES, HYDROSTATICS, WALLS, TANKS, CALCULATIONS
401766	HEAT EXCHANGER STUDY; R AREA; P AREA	*VARC	RTGCALC60	
401782	FAILED REACTOR; P AREA; CROSS SECTION OF LIFT	*VARC	RTGCALC60	
401799	RAILROAD CAR CASK SHIELD TANK; P AREA	1/27/1960 0:00	SIMPSON,CW	PLATES, SHIELDS, TANKS, CASKS, CALCULATIONS
401918	SEISMIC BRACING; HEAT EXCHANGER; P AREA	*VARC/4/3/1969 12:00:00 AM	RTGCALC66	
401990	COLLAPSING PRESSURES OF MAIN TANK; R AREA; P AREA; L AREA; K AREA; C AREA; REACTOR; OPERATION FATSO; ED-2341; DPE-772	*VARC	RTGCALC70	
401992	100-P AREA MODIFICATIONS TO COOLING WATER SUPPLY; POWER; PAR POND	9/6/1961 0:00	DEFRATE,LA, SCHWALM,JM, HUNT,FL	PAR POND, FLUID FLOW, COOLING WATER, POWER, CALCULATIONS
402124	SEISMIC PROTECTION; REACTOR BUILDING; P AREA; K AREA; C AREA; FINAL REPORT; JOHN A. BLUME AND ASSOCIATES	*VARC/7/22/1977 12:00:00 AM	RTGCALC79	
540000012	SPECIAL HAZARDS INCIDENT INVESTIGATION CLASS I REACTOR DEPARTMENT EMPLOYEES 100-P AREA (U)			
540000013	SPECIAL HAZARDS INCIDENT INVESTIGATION CLASS I MAINTENANCE DEPARTMENT EMPLOYEES 100 P-AREA (U)	3/18/1954 0:00	SRP	EXPOSURES, P-AREA, SPECIAL HAZARDS INVESTIGATION
540000027	UNUSUAL INCIDENT MODERATOR SPILL IN D CELL SUMP 100-P DECEMBER 14 1954 (U)	12/14/1954 0:00	EGGERT,J, GALLOWAY,L	PURIFICATION, P-AREA, MODERATORS, INCIDENTS, UNUSUAL INCIDENTS
540000523	PRODUCTION AND JOINT PROBLEMS R AND P AREAS (U)	5/1/1954 0:00	KUGLER,FS	CORRESPONDENCE
540001892	ADAPTER REMOVAL-DISASSEMBLY AREA P AREA (U)	3/26/1954 0:00	BOSWELL,JM	AREAS, CORRESPONDENCE
550000002	100 AREA METALLURGICAL REPORTS COMPLIATION (U)	1/18/1955 0:00	SMITH,WE	K-AREA, R-AREA, L-AREA, P-AREA, REACTORS, EQUIPMENT, METALLURGICAL REPORTS, 100-AREA
550000027	SEPTIFOIL FLOW RATES WITH HOT COOLANT SUPPLY R AND P AREAS (U)	5/13/1955 0:00	LEYSE,RH	P-AREA, R-AREA, COOLANTS, FLOW RATE, SEPTIFOILS
560001671	MODERATOR PROCESSING FACILITY-P AREA (U)			
560001705	100-P AREA PROCESS WATER LEAK (U)			
560002744	FUEL SLUG 100-P AREA (U)	3/15/1956 0:00	MOUSEL,RM	CORRESPONDENCE
560002782	FUEL INSPECTION IN P AREA SLUGS (U)	3/15/1956 0:00	MOUSEL,RM	CORRESPONDENCE

Appendix A Documents Reviewed (from Unclassified and Classified Searches) (continued)

Object Name	Title	Bin Num/Date	Box Num or Author	Subject
570000107	100-P AREA REPAIR ORDER LIST INCOMPLETE AFTER THREE MONTHS OR MORE	8/10/1957 0:00	SELKIRK,RH RHODES,SC	REPAIR, MAINTENANCE, INSTRUMENTS, ELECTRICITY, P-AREA
570001829	P AREA DISASSEMBLY BASIN WATER AND STEEL CREEK EFFLUENT (U)	*VARC	M419-11584-4	
580000951	HIGH LEVEL WASTE STORAGE SHED	10/7/1958 0:00	MCCLEAREN,HA	P-AREA, R-AREA, WASTES, STORAGE
600001778	P AREA HEAT EXCHANGER			
610001351	PRELIMINARY REPORT P AREA PROCESS INCIDENT P-79 PROCESS WATER SPILL IN - 20 HEAT EXCHANGER BAY			
610001357	SRP REACTOR DEPARTMENT PROCESS INCIDENT C-63 TILTED HORIZONTAL STORAGE RACK CONTAINING BUNDLES OF MARK-6J FUEL ELEMENTSBLD-105C			
750000324	FUEL PREP AREA RADIOACTIVE RELEASES-ATMOSPHRC& LIQUID"MO TO ERDA BY C M PATTERSON"			
800000192	RESPONSE TO PROJECT REVIEW-P AREA-IMPROVED CONFINEMENT OF RADIOACTIVERELEASES(S1745)-IMPROVED SUPPLY OF EMERGENCY COOLANT(S1830)			
850000586	REACTOR INCIDENT STATUS - P AREA JANUARY-FEBRURARY, 1985			
850002611	REACTOR INCIDENT STATUS - P AREA JULY 1985 - AUGUST 1985			
138956-11	DCF 11 - SPILL CONTAINMENT - 100P AREA POWER AND ENVIRONMENTAL PROTECTION	*FILMDES	FE5200-1836-95-290	
138956-16	DCF 16 - SPILL CONTAINMENT - 100P AREA POWER AND ENVIRONMENTAL PROTECTION	*FILMDES	FE5200-1836-95-290	
138956-19	DCF 19 - SPILL CONTAINMENT - 100P AREA POWER AND ENVIRONMENTAL PROTECTION	*FILMDES	FE5200-1836-95-290	
CORR-870085	REACTOR MATERIALS PROGRAM SRP REACTORS PROCESS WATER PIPINGWATER HAMMER			
DDR-12415	100 AREA - POWER HOUSE - BUILDINGS 184-K, L, P, & R - 100 AREA - COOLING TOWER - BUILDINGS 185-K, L, P & R - 100 AREA - ASH DISPOSAL BASIN - BUILDINGS 188-K, L, P & R (U)	5/14/1952 0:00	MEASLEY,HF, DAUDT,LR	DESIGN DATA REPORTS, R-AREA, L-AREA, P-AREA, K-AREA
DPE-0971-VOL2	SAVANNAH RIVER PLANT ENGINEERING DESIGN HISTORY - VOLUME 2 - PROJECT 8980 - 100 RPLKC AREAS	1/1/1957 0:00		C-AREA, P-AREA, L-AREA, K-AREA, R-AREA, SAVANNAH RIVER PLANT, ENGINEERING, DESIGN HISTORY
DPSOP-22-HIST-VOL1	OPERATING PROCEDURE FOR 100-R & P AREA ENGINE HOUSES (3/53 - 6/58)	6/30/1958 0:00		PROCEDURES, P-AREA, R-AREA, 100-AREA
DPSOX-00582	ELIMINATION OF FLOW ZONE III P AREA	8/20/1954 0:00	WINGERD,DH	MONITORS, ZONES, TEST CONCLUSION
DPSOX-01125	PROCESS WATER GAMMA AND TEMPERATURE MONITORS P AREA			
DPSP-54-0025-023	MODERATOR CHARGING - P AREA	7/21/1954 0:00	REYNOLDS,HE	AREA, MODERATORS
DPSP-54-0046-001	INVENTORY AND CONSUMPTION REPORT 100-P PRODUCER ALLOY-3.5% LITHIUM FEBRUARY, 1954	2/1/1954 0:00		LITHIUM, ALLOYS, P-AREA, REPORTS
DPSP-54-0046-002	INVENTORY AND CONSUMPTION REPORT 100-P FUEL SLUGS-NORMAL URANIUM MARCH , 1954	3/1/1954 0:00		URANIUM, P-AREA, REPORTS
DPSP-54-0046-004	INVENTORY AND CONSUMPTION REPORT 100-P PRODUCER ALLOY-3.5% LITHIUM, MAY1954	5/1/1954 0:00		LITHIUM, ALLOYS, P-AREA, REPORTS
DPSP-54-0046-006	INVENTORY AND CONSUMPTION REPORT 100-P FUEL SLUGS-NORMAL URANIUM, JULY , 1954	7/1/1954 0:00		URANIUM, P-AREA, REPORTS
DPSP-54-0541	ASSEMBLY SLUG HANDLING STUDY 100-P AREA	9/19/1954 0:00	CROLEY,JJJR	SLUGS

Appendix A Documents Reviewed (from Unclassified and Classified Searches) (continued)

Object Name	Title	Bin Num/Date	Box Num or Author	Subject
DPSP-56-0601	MODERATOR DILUTION AND DISTILLATION EFFICIENCY - P AREA			
DPSP-56-1199	REACTOR CHARGES P AREA			
DPSP-57-0943	PROCESS INCIDENT NO P3 105 P AREA FUEL ELEMENT FAILURE IN MARK 1 SLUG ON JUNE 20 1957			
DPSP-57-1005	PROCESS INCIDENT NO 105 P AREA FUEL ELEMENT FAILURE IN MARK1 SLUG ON JULY 15 1957			
DPSP-58-0196-P-14-15	DAILY SHIFT REPORT	1/1/1958 0:00		P-AREA, SHUTDOWNS
DPSP-58-1678	ACTIVITY OF PAR POND WATER BEING PUMPED TO R AND P AREAS	10/27/1958 0:00	MCCLEAREN,HA	PAR POND
DPSP-59-0972	TEMPORARY PROCEDURE UNDER TA 1-747 100-R AND P AREAS - ASSEMBLY AND DISASSEMBLY AREAS	5/11/1959 0:00	GRIER,BH	REACTORS
DPSP-59-1452	FUEL ELEMENT FAILURE P AREA	8/7/1959 0:00	BRYAN,SE	REACTORS
DPSP-59-1803	PRELIMINARY INSPECTION REPORT VISUAL INSPECTION OF FAILURE NUMBER 73 100 P AREA	11/10/1959 0:00	MOUSEL,RM	REACTORS
DPSP-61-1005	MARK VI-JL REACTOR CHARGE SPECIFICATIONS - L AND P AREAS			
DPSP-61-1816	INVENTORY AND CONSUMPTON REPORT COBALT 60 100-P AREA	6/1/1961 0:00	SMOLAND,HT BLITHE,WL	P-AREA
DPSPF-02436	PROCESS PIPING, P AREA (photography)			
DPSPF-35060	10C P AREA PROCESS WATER PIPING (photography)			
DPSPU-56-011-029	HEAT EXCHANGER FAILURE P AREA (U)	*COMBINED	M419-8322-1	
DPST-55-00322	SEPARATION OF ACTIVITY FROM BLD-105P MODERATOR WATER BY CENTRUFUGATION - TEST RESULTS.	7/12/1955 0:00	VAUX,JE	TABLES, CENTRIFUGES, P-AREA, DECONTAMINATION, RADIOACTIVITY, PURIFICATION, CHEMISTRY, MODERATORS, OPERATION, REACTORS
DPST-57-00193	ANALYSIS OF SPENT ION EXCHANGE DEIONIZER RESIN FROM BLD-105P.	3/28/1957 0:00	BAUMANN,EW	TABLES, CATIONS, ANIONS, SLUDGES, CONTAMINATION, SERVICE, EQUIPMENT, P-AREA, RESINS, IONS, ANALYSIS, OPERATION, REACTORS
DPST-80-00323	RESPONSE OF ABS/SC TO ROD WITHDRAWAL ACCIDENTS IN SRP REACTORS.	N61-05-04	L1000-0307-92-402	
DPST-80-00618	CONTAINMENT & RECIRCULATION OF SPILLED WATER IN SRP REACTORBUILDINGS.			
DPST-81-00626	GENERIC STUDY OF ABS/SC RESPONSES FOR MARK-22 CHARGES IN SRP REACTORS.			
DPST-82-00284	SRP REACTOR RISKS.			
DPST-85-00717	TWO-PHASE NATURAL CIRCULATION IN SRP REACTORS - (AFTER PUMPSTOPPAGE).			
DPTT-70-7-17	DAILY REPORT - PART ONE REACTORS			
DPTT-70-7-17A	DAILY REPORT - PART ONE A REACTORS			
DPTT-70-7-22	DAILY REPORT - PART ONE REACTORS			
DPTT-70-7-23	DAILY REPORT - PART ONE REACTORS			
DPTT-70-7-27-A	DAILY REPORT - PART ONE A REACTORS			
DPTT-70-8-18	DAILY REPORT - PART ONE REACTORS			
DPTT-70-8-20	DAILY REPORT - PART ONE REACTORS			
DPTT-70-8-24	DAILY REPORT - PART ONE REACTORS			
DPTT-70-8-25	DAILY REPORT - PART ONE REACTORS			
DPTT-70-8-4	DAILY REPORT - PART ONE REACTORS			
DPTT-70-8-5	DAILY REPORT - PART ONE REACTORS			
DPTT-70-9-10	DAILY REPORT - PART ONE REACTORS			
DPTT-71-12-20	DAILY REPORT - PART ONE REACTORS			
DPTT-71-12-20A	DAILY REPORT - PART ONE A REACTORS			
DPTT-71-12-21	DAILY REPORT - PART ONE REACTORS			

Appendix A Documents Reviewed (from Unclassified and Classified Searches) (continued)

Object Name	Title	Bin Num/Date	Box Num or Author	Subject
DPTT-71-12-21A	DAILY REPORT - PART ONE A REACTORS			
DPTT-71-12-22	DAILY REPORT - PART ONE REACTORS			
DPTT-71-12-22-B	WEEKLY PRODUCTION SUMMARY REACTORS			
DPTT-71-5-13A	DAILY REPORT - PART ONE A REACTORS			
DPTT-71-6-14A	DAILY REPORT - PART ONE A REACTORS			
DPTT-74-12-16A	DAILY REPORT - PART ONE A REACTORS			
DPTT-74-12-17	DAILY REPORT - PART ONE REACTORS			
DPTT-74-12-17A	DAILY REPORT - PART ONE A REACTORS			
DPTT-74-8-16	DAILY REPORT - PART ONE REACTORS			
DPTT-74-8-19	DAILY REPORT - PART ONE REACTORS			
DPTT-74-9-10	DAILY REPORT - PART ONE REACTORS			
DPTT-74-9-23	DAILY REPORT - PART ONE REACTORS			
DPTT-75-1-31	DAILY REPORT - PART ONE REACTORS			
DPTT-75-2-20	DAILY REPORT - PART ONE REACTORS			
DPTT-75-2-25	DAILY REPORT - PART ONE REACTORS			
DPTT-75-2-4	DAILY REPORT - PART ONE REACTORS			
DPTT-75-2-7C	WEEKLY PRODUCTION SUMMARY REACTORS			
DPTT-75-3-14A	DAILY REPORT - PART ONE A REACTORS			
DPTT-75-4-23	DAILY REPORT - PART ONE REACTORS			
DPTT-75-4-30	DAILY REPORT - PART ONE REACTORS			
DPTT-75-5-27	DAILY REPORT - PART ONE REACTORS			
DPTT-75-8-13A	DAILY REPORT - PART ONE A REACTORS			
DPTT-75-8-13A	DAILY REPORT - PART ONE REACTORS			
DPTT-75-8-19	DAILY REPORT - PART ONE REACTORS			
DPTT-75-9-11	DAILY REPORT - PART ONE REACTORS			
DPTT-8807	DAILY REPORT - PART ONE REACTORS			
DPTT-8835	DAILY REPORT - PART ONE REACTORS			
DPTT-8845	DAILY REPORT - PART ONE REACTORS			
DPTT-8846	DAILY REPORT - PART ONE A REACTORS			
DPTT-8853	DAILY REPORT - PART ONE REACTORS			
DPTT-8854	DAILY REPORT - PART ONE A REACTORS			
DPTT-8879	DAILY REPORT - PART ONE REACTORS			
DPTT-8941	DAILY REPORT - PART ONE REACTORS			
DPTT-8942	DAILY REPORT - PART ONE A REACTORS			
DPTT-9021	DAILY REPORT - PART ONE A REACTORS			
DPTT-9124	DAILY REPORT - PART ONE REACTORS			
DPTT-9156	DAILY REPORT - PART ONE REACTORS			
DPTT-9191	DAILY REPORT - PART ONE REACTORS			
DPTTWD-75-9-12-B	WEEKLY PRODUCTION SUMMARY REACTORS			
PI-P-60-53	PROCESS INCIDENT NO P-53 NO 6 BINGHAM PUMP SEAL FAILURE (U)	11/28/1959 0:00	LIST,JA	REACTORS, TANKS, PUMPS, LEAKS, P-AREA, PROCESS INCIDENTS
PI-P-60-54	PROCESS INCIDENT NO P-54 PW SPILL PARTIALLY FILLED DEIONIZER (U)	2/6/1960 0:00	LIST,JA	LEAKS, P-AREA, PROCESS INCIDENTS
PI-P-60-55	PROCESS INCIDENT NO P-55 SPARJET INSERT FAILURE (U)	2/16/1960 0:00	LIST,JA	RINGS, FAILURES, P-AREA, PROCESS INCIDENTS
PI-P-60-57	PROCESS INCIDENT NO P-57-105P SEAL FILTER HOUSING LEAKS (U)	5/28/1960 0:00	LIST,JA	PUMPS, FILTERS, REACTORS, SHUTDOWNS, LEAKS, P-AREA, PROCESS INCIDENTS
PI-P-60-58	PROCESS INCIDENT NO P-58 105-P INCOMPLETE DRAINING OF HEAT EXCHANGERS (U)	7/18/1960 0:00	LIST,JA	HEAT EXCHANGERS, P-AREA, PROCESS INCIDENTS
PI-P-60-59	PROCESS INCIDENT NO P-59 105-P MARK VII-AL LOW P (U)	7/19/1960 0:00	LIST,JA	SHUTDOWNS, REACTORS, P-AREA, PROCESS INCIDENTS
RI-P-0024	EXCESSIVE SHUTDOWN FLOW	10/21/1957 0:00	MCMANAWAY, GW	P-AREA, REACTOR INCIDENTS
RI-P-0119	TURBID MODERATOR PUMPED TO SURGE TANK	6/27/1959 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA, MODERATORS
RI-P-0120	LOSS OF REACTOR OVERFLO	7/14/1959 0:00	HINTON,JH	P-AREA, REACTOR INCIDENTS
RI-P-0127	SEAL COOLER PW LEAK	8/14/1959 0:00	BOSWELL,JM	P-AREA, REACTOR INCIDENTS
RI-P-0135	PW LEAKS	10/13/1959 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA, LEAKS
RI-P-0138	PW LEAK VALVE 8J	10/19/1959 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA, VALVES

Appendix A Documents Reviewed (from Unclassified and Classified Searches) (continued)

Object Name	Title	Bin Num/Date	Box Num or Author	Subject
RI-P-0152	NO 6 SYSTM SEAL LEAK	11/30/1959 0:00	HINTON,JH	P-AREA, REACTOR INCIDENTS, SEALS
RI-P-0179	CIC - EFFLUENT HEADER LEAK.	5/18/1960 0:00	VANNIEL,CR	INFORMATION, PTERM, P-AREA, INCIDENTS, UNUSUAL INCIDENTS, PIPINGS, LEAKS, REPAIR, OPERATION, REACTORS, WELDING
RI-P-0188	PW LEAK AT VALVE 84	6/22/1960 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA, LEAKS
RI-P-0192	PW LEAK AT VALVE 85	6/23/1960 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA, LEAKS
RI-P-0193	SHUTDOWN FOR 3B HX TUBE SHEET SPACE LEAK	6/29/1960 0:00	VANNIEL,CR	P-AREA, REACTOR INCIDENTS, SHUTDOWNS
RI-P-0195	PROCESS WATER SPILL	6/30/1960 0:00	VANNIEL,CR	P-AREA, REACTOR INCIDENTS, WATER
RI-P-0203	EXCESS REACTOR OVERFLOW	9/6/1960 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA
RI-P-0268	PW SPILL C-MACHINE	11/14/1961 0:00	HINTON,JH	REACTOR INCIDENTS, P-AREA, SPILLS
RI-P-0269	CW HEADER LEAKS	11/16/1961 0:00	VANNIEL,CR	REACTOR INCIDENTS, P-AREA, LEAKS
RI-P-0271	HX 4A STAYBOLT LEAK	12/17/1961 0:00	VANNIEL,CR	P-AREA, REACTOR INCIDENTS
RRD-RED-92-0152	CURRENT HEAT EXCHANGER HEAD STATUS IN P AREA (U)			
RTM-00393	FAILURE OF DRAIN TANK PUMP IN 100-P AREA	3/26/1954 0:00	JOHNSON,AA	RINGS, SEALS, PUMPS, REACTORS
RTM-00604	DISASSEMBLY AREA CORROSION TESTS P AREA	11/8/1954 0:00	GRIER,JD	EQUIPMENT, REACTORS, EQUIPMENT, REACTORS
RTM-01261	REPAIR PROCESS WTR VALV 86 -P AREA			
RTM-01432	REDUCTION OF RADIOACTIVITY IN R AND P AREAS	9/27/1957 0:00	FOX,LW	SCHEDULES, PLANS, PROGRAMS, REACTORS, MONITORING, SURVEYS
RTM-01531	HYDRAULIC TESTS WITH BINGHAM PUMPS P AREA	2/13/1958 0:00	INGHAM,RR, GIMMY,KL	RINGS, SEALS, PUMPS, REACTORS
RTM-01673	PROCESS WTR GAMMA MONITOR LINE BRACE #1 SYSTM -P AREA			
RTM-01731	LIGHT WATER INLEAKAGE - P AREA	2/18/1959 0:00	HINTON,JH JOHNSON,AA	REACTORS, P-AREA, LEAKAGE, WATER
RTM-02059	TOP AND BOTTOM SHIELD LEAK P-AREA (U)	11/10/1960 0:00	HINTON,JH	FLOW RATE, PRESSURE, WATER, MODERATORS, SHIELDS, LEAKS, P-AREA, REACTOR TECHNOLOGY MEMORANDUM
RTM-0321	CHARGE AND DISCHARGE FLOWS - 100 AREAS (U)	1/21/1954 0:00	BUTTON,DL	R-AREA, P-AREA
RTM-0393	FAILURE OF DRAIN TANK PUMP IN 100 P AREA (U)	3/26/1954 0:00	JOHNSON,AA	DRAINS
RTM-0604	DISASSEMBLY AREA CORROSION TESTS (U)	11/8/1954 0:00	JOHNSON,AA	P-AREA, CORROSION
RTM-0850	COOLING WATER GAMMA MONITORS (U)	8/25/1955 0:00	JOHNSON,AA	P-AREA, R-AREA, MONITORS
RTM-0971	COOLING WATER GAMMA MONITOR OPERATION (U)	4/3/1956 0:00	JOHNSON,AA;ERNST,ML	C-AREA, K-AREA, L-AREA, P-AREA, R-AREA, COOLING WATER
SRL-USA-90-0110	POSSIBLE PROCESS WATER PIPING DEGRADATION IN K AND P AREAS (U)			
UI-P-012	SRP POWER DEPARTMENT UNUSUAL INCIDENT REPORT 100-P AREA REPORT NO P-12 (U)			
UI-P-012	SRP POWER DEPARTMENT UNUSUAL INCIDENT REPORT 100-P AREA REPORT NO P-12 (U)	11/29/1955 0:00	SRP	STEAM, POWER, TANKS, BURNS, INCIDENTS, UNUSUAL INCIDENTS
UI-P-105	UNUSUAL INCIDENT 105-P SEAL FAILURE ON #1 B-J PUMP (U)	3/9/1955 0:00	GALLOWAY,L	UNUSUAL INCIDENTS, POWER, PUMPS, MOTORS
WSRC-FM-94-1481	26C DISASSEMBLY BASIN SAMPLING 105-R P AREA INSTRUMENT AIR DRYERS TANK D AND D R AREA (U) (photography)			
WSRC-TR-94-00403	CRITICALITY SAFETY EVALUATION FOR P AREA DISASSEMBLY BASIN CLEANUP (U)			

Appendix B Examples of Events in P Area Disassembly Basin History

Examples of Events in Disassembly Basin History

				reactor weir release (Ci)		
Date	**Subject[1]**	**Source**	**Disassembly Basin values**	^{89,90}Sr	^{137}Cs	^{3}H
Mar-1959	reactor discharge failed fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[2]	NR	NR	NR
Apr-1959	reactor discharge failed fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[3]	NR	NR	NR
July-1959 through Dec-1959	reactor discharges of two failed fuel element; handling of Chalk River fuel elements	Health Physics Regional Monitoring Semiannual Report July through December 1959	see note[4]			
Aug-1961	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
Oct-1961	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
Nov-1961	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
Jan-1962	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
Apr-1962	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
May-1962	reactor discharge failed Mark VB fuel element (& 12 other Mark VB fuel elements?)	Health Physics Regional Monitoring, Weekly Report -- Control	see note[6]	NR	NR	NR
Jun-1962	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
Aug-1962	reactor discharge Mark VIIA fuel element	Health Physics Regional Monitoring, Weekly Report -- Control	see note[5]	NR	NR	NR
Mar-1963	reactor discharge Mark VB fuel element	Health Physics Regional Monitoring, Monthly Summary Report		NR	NR	NR
Jun-1963	reactor discharge Mark VB fuel element	Health Physics Regional Monitoring, Monthly Summary Report		NR	NR	NR
Sep-1963	reactor discharge Mark VB fuel element	Health Physics Regional Monitoring, Monthly Summary Report	see note[7]	NR	NR	NR
Oct-1963	reactor discharge Mark VB fuel element	Health Physics Regional Monitoring, Monthly Summary Report		NR	NR	NR
Nov-1963	reactor discharge Mark VB fuel element	Health Physics Regional Monitoring, Monthly Summary Report	see note[8]	NR	NR	NR
Jan-1965	reactor discharge of failed Mark VB fuel element	Radiological & Environmental Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	from disassembly basin a large I-131 release (73 Ci) along with 39 Ci of primarily Sr-89,90; Ce-141,144; and ZrNb-95	0.28 (Sr-90)	NR	26
Aug-1965	reactor discharge (in late July) of Mark VB fuel element	Radiological & Environmental Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	not reported	0.1	1.2	120
Oct-1965	reactor discharge of Mark VE fuel element	Radiological & Environmental Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	not reported	0.12	2.51	1781
Dec-1965	reactor discharge of Mark VE fuel element	Radiological & Environmental Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	not reported	0.06	1.92	826
Jan-1970	reactor discharge of Mark 30 depeleted uranium target	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS (vertical tube storage in the disassembly basin), peak value 10.3 Ci of Cr-51 & 1480 Ci tritium	0.39	0.79	428

Appendix B Examples of Events in P Area Disassembly Basin History (continued)

Examples of Events in Disassembly Basin History						
				reactor weir release (Ci)		
Date	**Subject[1]**	**Source**	**Disassembly Basin values**	^{89,90}**Sr**	^{137}**Cs**	^{3}**H**
Feb-1970	reactor discharge (in Dec) of Mark 30 depeleted uranium target	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 12.5 Ci of Cr-51 & 1750 Ci tritium	0.41	0.56	407
Mar-1970	reactor discharge of Mark 30 depeleted uranium target & Mark 14 fuel element	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 74 Ci of Cr-51 & 5300 Ci tritium[9]	0.97	0.61	226
Jun-1970	reactor discharge of Mark 30 depeleted uranium target	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 17.1 Ci of Cr-51 & 4011 Ci tritium	0.64	0.68	665
Jul-1970	reactor discharge of Mark 30 depeleted uranium target	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 17 Ci of Cr-51 & 1840 Ci tritium	1.17	0.67	164
Aug-1970	reactor discharge of Mark 30 depeleted uranium target	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 24 Ci of Cr-51 & 2398 Ci tritium[10]	0.8	2.54	510
Oct-1970	reactor discharge of Mark 30 depeleted uranium target & Mark 14 fuel element	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 39 Ci of Cr-51 & 5500 Ci tritium	0.22	0.15	256
Dec-1970	reactor discharge of Mark 30 depeleted uranium target	Radiological Sciences Division, SRL, Envrionmental Monitoring Group, Monthly Report	in VTS, peak value 12 Ci of Cr-51 & 3831 Ci tritium	0.47	0.22	3115
Apr-1972	reactor discharge of Mark 30 depeleted uranium target, Mark 14 fuel element & Mark 40 Pu target	Health Physics Section, Envrionmental Monitoring Group, Monthly Report	not reported	0.01	0.01	3294
May-1972	reactor discharge of Mark 30 depeleted uranium target	Health Physics Section, Envrionmental Monitoring Group, Monthly Report	not reported (VTS purge on 5/13 included in release numbers)	0.01	0.01	218
Jun-1972	reactor discharge of Mark 30 depeleted uranium target	Health Physics Section, Envrionmental Monitoring Group, Monthly Report	not reported	0.01	0.02	165
Jul-1972	reactor discharge of Mark 30 depeleted uranium target & Mark 14 fuel element	Health Physics Section, Envrionmental Monitoring Group, Monthly Report	not reported	0.04	--	128
Dec-1972	reactor discharge of Mark 30 depeleted uranium target	Health Physics Section, Envrionmental Monitoring Group, Monthly Report	not reported[11]	0.03	0.05	152
Oct-1976	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
1977	Disassembly Basin Purge	January 1978 Health Physics Department Environmental Monitoring Monthly Report	see footnote[12]	NR	NR	NR
Nov-1978	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Jun-1979	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Dec-1979	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Feb-1982	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Jun-1982	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Jan-1983	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Mar-1983	reactor discharge of Mark 31 slug failure	DuPont SRP Monthly Technical Report DPSP-83-1-4	not reported	NR	NR	NR
Jul-1984	~ 100 gallons of moderator was inadvertently put in the D&E Canal during discharge of elements (reactor incident P-1620)	DuPont SRP Monthly Technical Report DPSP-84-1-7	VTS tritium levels increased from 0.2uCi/mL to 1.02 uCi/mL; VTS water was purged through deionizers to the seepage basin to reduce tritium levels to normal	NR	NR	NR

Appendix B Examples of Events in P Area Disassembly Basin History (continued)

NR = not reported and/or not measure

[1] not clear in reports (particularly early reports) if discharges of elements are typical discharges or from failed elements

[2] failed element (3/6/59) was discharged to the emergency section of the disassembly basin but not contained in the "harps"; weekly report 3/16/59-3/22/59 noted contamination incident near fence of P-Area seepage basin; attributed to pumping of water from the emergency section of the P-Area disassembly basin to the seepage basin

[3] Weekly Report 4/6/59-4/10/59 noted that a radioactive gasket was found in the 105-P "clean" burning pit; item was found 15mrad/hr at 2" and radioactivity attributed to Co-60

[4] 2 Ci estimated to have been released to seepage basins from Chalk River fuel elements; according to DPSP-59-1452 regarding the fuel element failure on 8/2/59, a total of 24 failures had occurred in P-Area

[5] Weekly Report for 10/15/1962 records an investigation into the increase in Cr-51 released to Steel Creek from P-Area; find that in all of the cases, the type of fuel element discharged was the same (Mark VIIA); also note they are looking at the moderator and corrosion of stainless steel attachments; report also records an investigation related to radioisoptopes that adhere to the aluminum oxide film formed on the fuel elements during irradiation and are discharged with the elements into the disassembly basin water.

[6] Environmental Monitoring and Allied Studies report attributes increased radioactivity in Steel Creek to the "discharge of a failed Mark VB fuel element (a total of 13 elements including the failed element were discharged) in P-Area on 5/7"; radioiodine was found at the Steel Creek sampling location (Steel Creek Road A) in addition to at the sampling location at the 301 Crossing

[7] report noted that although the number of discharges and type of fuel discharged influence the quantities of radioactive materials released from the disassembly basins, fuel element failures contributed greatly to the increased releases during 1962 and 1963; in 1962 there were two failed Mark VB fuel elements discharged in P-Area and in 1963 a total of six failed Mark VB fuel elements discharged among P, C, and K-Areas; noted the impact that one failed element can have on yearly releases by highlighting a failed Mark VB element discharge in P-Area in 1962 which accounted for 60% of the long-lived radionuclides (64 Ci), 50% of the short-lived radionuclides (178 Ci), and all of the I-131 (77 Ci) released from P-Area disassembly basin for the year

[8] report noted that invesigations in R-Area have revealed that increased releases of Cs-134,137 are related to failed fuel elements in vented cans that are stored in open buckets in the disassembly basin; by removing several buckets of cans from the bucket storage section of the basin to the isolation tank, they were able to reduce the amount of Cs released

[9] noted in report about storage of partially declad irradiated fuel elements in the P-reactor Disassembly Basin (transferred from R-reactor disassembly basin in 1964); is the principal source of release of Cs-134 and Cs-137 to river; transfer of the 15ft cans to the Receiving Basin for offsite fuel (RBOF) began 11/1968 and the final transfer took place 1/1970

[10] noted in report about the increase in Cs-134-Cs-137 ratio in the releases from the disassembly basin to Steel Creek from stored material (Mark VR fuel, Zr clad fuel, uranium oxide filters and tubes; removal & transfer of material in process)

Cs release from P-disassembly basin (Ci)

week ending	Cs-134	Cs-137
7/5/1970	--	0.11
7/12/1970	--	0.16
7/19/1970	--	0.32
7/26/1970	--	0.56
8/2/1970	0.14	0.24
8/9/1970	0.21	0.47
8/16/1970	0.38	0.1
8/23/1970	0.1	0.34

[11] 186-3P cooling water settling basin drained to Steel Creek on 9/5 and estimated 0.05 Ci Cs-137 contained in sludge and released to effluent

[12] Purged at high rate to reduce tritium levels in disassembly basin following a reactor discharge; released 90 mCi of ^{137}Cs to stream (Steel Creek); although the concentration of ^{137}Cs was small, the large volume of water discharged caused the ^{137}Cs release to be larger than expected and larger than the annual guide of 85 mCi

Appendix C Examples of Documented Leaks and Spills for P Reactor

Date	Subject/Source	Description
12/14/1954	Unusual Incident - moderator spill in D Cell Sump 100-P	estimated 80 gallons moderator overflowed to the Purification D cell sump; expected that processing of spilled moderator through purification equipment will result in > 90% recovery
8/14/1959	Reactor Incident RI-P-127 -- seal cooler process water leak	a weld failed on the process water outlet line of the no. 4 pump shaft seal cooler; 3015 lbs of 94.4% moderator recovered from the 208.1 sump and attributed primarily to the leak
10/13/1959	Reactor Incident RI-P-135 -- process water leaks	abnormal number of leaks occurred during the hydraulic startup 10/12; biggest was from no. 5 pump shaft seal (50 gal/hr); 100 lbs of moderator were recovered from the -40 and the 208.1 sump drum
10/19/1959	Reactor Incident RI-P-138 -- process water leak at Valve 84	a diaphragm failure caused process water leak on the -40' level floor in front of the system no. 5 Bingham pump; leakage rate ~ 50 lbs/hr; estimated 500 lbs moderator lost
week of 10/26 - 10/30 1959	Weekly Report -- Control, P-Area Seepage Basin	water level in the 100-P Seepage Basin #2 was higher than the berm causing the water to "outcrop" approximately 45 feet from the basin; tritium sample from collected 11/3 from the outcropped water measured 440 X 10-3 uCi/L
week of 11/9 - 11/13 1959	Weekly Report -- Control, P-Area Seepage Basins	Pulse height analysis showed > 95% of the alpha activity in the P-Area seepage basins is from Pu-239; although overall concentration is low (< 0.3 d/m/mL), report acknowledges that it is the first positive indication of Pu-239 in the 100 Areas seepage basin complex
11/28/1959	Process Incident no. P-53 -- no. 6 Bingham pump seal failure	leakage from a shaft seal of the no. 6 Bingham pump; water was later observed in the Far Pump Room Sump; estimated unrecovered process water loss was 630 lbs D2O; 2450 lbs (100% basis) D2O was recovered from the Pump Room Sump
11/30/1959	Reactor Incident RI-P-152 -- Number 6 System Seal Leak	on 11/28 shaft seal on system number 6 Bingham pump began leaking requiring reactor shutdown on 11/30; maximum leakage (on 11/30) to the 208.1 tank was ~ 48 gal/hr; 2498 lbs degraded moderator recovered in far sump; following hydraulic startup 12/2 systems 1, 2, 4, & 6(again) were leaking
2/6/1960	Process Incident no. P-54 -- process water spill -- partially filled deionizer	a mixed bed deionizer from K-area was installed in A-cell in P-area; it was partially filled with D2O when placed online (recirculation with the Purification Surge Tank); postulated that the trapped air in the deionizer was forced out into the process water system causing process water to spill on the plenum top and collect in the plenum leak collection drum
5/18/1960	Reactor Incident RI-P-179 -- CIC Effluent Header Leak	light water leak found in the eflluent drain system for the nuclear instruments
5/20/1960	Reactor Incident RI-P-177	process water leak discovered betweent the tube sheets of the 3B heat exchanger (at the hot process water end)
6/22/1960	Reactor Incident RI-P-188 -- process water leak at Valve 84	discovered a D2O leak between a pipe flange and a valve flange during a shutdown; upon further inspection found that it was missing a gasket and speculated that it had been missing since installation (1957); the amount of D2O lost could not be determined
6/23/1960	Reactor Incident RI-P-189	external leak at the hot process water end of the 3B heat exchanger discovered from about 10 points with total leakage about 200 drops/min; installed a polythene covering to enclose that end of the heat exchanger and connected a hose from the covering to a drum in the 208-1 sump to collect the process water; estimated that from 6/8 - 6/29 the rate increased from 220 drops/min to 430 drops/min; estimated from 6/8-6/27 ~ 58 lbs/day leaked, 6/28 30 lbs/day, and 6/29 40 lbs/day
6/23/1960	Reactor Incident RI-P-192 -- process water leak at Valve 85	Valve 85 leaked when flow to the purification system started during shutdown; the diaphragm for the valve was replaced the day before when the process water line was drained; the valve bonnet was not adequately tightened to prevent process water leakage with the valve open when flow was initiated; the amount of D2O lost had not been determined
6/29/1960	Reactor Incident RI-P-193 -- shutdown for 3B HX Tube Sheet Space Leak	reactor was shutdown because the external tube sheet leak of the 3B heat exchanger could not be contained within the polythene covering; leakage rate ~ 200 drops/min to the floor and ~ 100 lbs moderator were lost
6/30/1960	Reactor Incident RI-P-195 -- process water spill	process water spilled when the flanges on the inlet end of 3A and 3B heat exchangers were loosened; estimated ~ 80 gallons of process water spilled on the floor (100 lbs of moderator lost)
11/10/1960	Top and bottom shield leak in P-Area	determined that there is inleakage of light water into moderator most likely from leak in in top shield; calculations show that it is possible to have both inleakage and outleakage from the same hole depending on the level in the surge tank; proposed to increase the pressure of the moderator system so that it is greater than the light water (deionized) pressure and leakage will be outward in the future (purity of moderator will be retained)

Appendix C Examples of Documented Leaks and Spills for P Reactor (continued)

Date	Subject/Source	Description
11/14/1961	Reactor Incident RI-P-268 -- process water spill -- charge machine	during the start of a shutdown, a process water supply valve was open to the charge machine and pressure was allowed to build up which spilled process water into the Charge and Discharge machine process water supply system (and onto the process room floor); the quantity of spilled process water could not be determined
11/16/1961	Reactor Incident RI-P-269 -- Cooling Water Header Leaks	during a shutdown, leaks were discovered from the abandoned thermovells in the effluent cooling water headers
12/17/1961	Reactor Incident RI-P-271 -- Heat Exchanger 4A Staybolt Leak	reactor was shutdown because of excessive leakage from staybolts on the hot end of the heat exchanger; a pencil size stream of moderator was flowing out of the plastic cover that is over the head of the heat exchanger; ~1900 lbs moderator were lost; intially the leak (discovered 12/4) was collected in a drum (and changed when necessary) but by 12/17 the drum was bypassed so that the water went to the 208-1 tank
11/15/1962	Weekly Report -- Control, Reactor Moderator Analysis	two samples from L-Area and one sample from P-Area moderator were analyzed for Cs-137 and Sr-90 as part of an investigation to determine the elevated radiostrontium concentrations experienced in L-Area effluent streams after the recent discharge of Mark VI reactor load; sample from P-Area (P-9/21) had 98.1 uCi/mL total Sr, 1.5 uCi/mL Sr-90, 96.6 uCi/mL Sr-89, and 8.7 uCi/mL Cs-137 (as compared to 190 uCi/mL Sr-90 and 575 uCi/mL Cs-137 in one of the L-Area samples)
Aug-1965	Reactor Daily Report DPTT-8835 and DPTT-8845	shutdown of P reactor on 8/1/65 to correct moderator leakage from heat exchanger 1A
Aug-1965	Reactor Daily Report DPTT-8854	P Reactor again shutdown on 8/3/65 to correct moderator leakage from hot end side of heat exchanger 1A; repaired the surface of the boss under the two stop-leak devices
Aug-1965	Material Balance Monthly Report DPSP-65-13-8 Composition of Deuterium Inventory - 86 as of August 31, 1965	100 lbs of moderator lost as a result of a leak on the reactor tank top
Nov-1965	Material Balance Monthly Report DPSP-65-13-11 Schedule Deuterium	300 lbs of moderator lost resulting from blow-back through vacuum pots
Dec-1967	Material Balance Monthly Report DPSP-67-13-12 Deuterium Report of Composition of Ending Inventory as of December 31, 1967	1628 lbs of moderator accidently lost in Building 105-P resulting from the failure of a section of tubing being used in a test system for measurement of differential pressure
Nov-1968	Material Balance Monthly Report DPSP-68-13-11 Deuterium Report of Composition of Ending Inventory as of November 30, 1968	25 lbs of moderator accidently lost in P Area as a result of a hole in a drum of stored moderator
Dec-1968	Material Balance Monthly Report DPSP-68-13-12 Deuterium Report of Composition of Ending Inventory as of December 31, 1968	60 lbs of moderator accidently lost in P Area from an overflowed drum
Feb-1969	Material Balance Monthly Report DPSP-69-13-9 Schedule Deuterium	120 lbs of moderator were accidently lost in Building 105-P from a spill from valve #85 (~100 lbs) and from a tank top leak (~20 lbs)
Feb-1971	Material Balance Monthly Report DPSP-71-13-2 Schedule Deuterium	105 lbs of moderator estimated to have been lost as unrecovered moderator from three separate spill events in P Area during C&D outage; estimated 5 lbs lost from rotovalve packing leak on 1/25; 50 lbs lost due to tank top leak on 1/30; 50 lbs lost due to tank top leak on 2/2
Apr-1971	Material Balance Monthly Report DPSP-71-13-4 Schedule Deuterium	175 lbs of moderator were lost from spills in P Area during general overhaul maintenance of the distillation facility (estimated 150 lbs) and the replacement of a deionizer (25 lbs)
Jun-1971	Material Balance Monthly Report DPSP-71-13-6 Schedule Deuterium	20 lbs moderator lost from tank top leak during scram recovery on 5/31 in P Area; a S-foil guide tube retaining pin was found to have broken
Jul-1971	Material Balance Monthly Report DPSP-71-13-7 Schedule Deuterium	48 lbs of moderator were accidently lost in P Area Reactor Department due to drippage from a piping connection

Appendix C Examples of Documented Leaks and Spills for P Reactor (continued)

Date	Subject/Source	Description
Aug-1971	Material Balance Monthly Report DPSP-71-13-8 Schedule Deuterium	50 lbs of moderator were accidently lost in P Area Reactor Department due to tank top leak caused by delatched APM and DC rods and O-rings which appeared to be of questionable quality
Sep-1971	Material Balance Monthly Report DPSP-71-13-9 Schedule Deuterium	10 lbs of moderator were accidently lost due to a poor connection when a new evaporator dip tube was installed in P Area; 30 lbs of moderator were accidently lost from pressure build up when two deionizers stored in P Area were vented
Nov-1971	Material Balance Monthly Report DPSP-71-13-11 Schedule Deuterium	10 lbs of moderator were accidently lost due to a poor connection when a new evaporator dip tube was installed in P Area; 30 lbs of moderator were accidently lost from pressure build up when two deionizers stored in P Area were vented
Feb-1972	Material Balance Monthly Report DPSP-72-13-2 Schedule Deuterium	10 lbs of moderator were lost in P Reactor from leakage of a poorly seated septifoil O-ring
Apr-1972	Material Balance Monthly Report DPSP-72-13-4 Schedule Deuterium	406 lbs of moderator were lost in the P Reactor Department from the blanket gas system due to a leak through the diaphram and packing of an isolation valve situated between the reater and purification section
Aug-1972	Material Balance Monthly Report DPSP-72-13-8 Schedule Deuterium	65 lbs of moderator were lost in P Area Reactor Deparment during replacement of a defective heat exchanger; 9 lbs of moderator were lost from leakage of damaged and displaced O-rings for two safety rod thimbles
Sep-1972	Material Balancet Monthly Report DPSP-72-13-9 Schedule Deuterium	70 lbs of moderator were accidently lost in Building 105-P from a spill in the P Reactor Room when the blanket gas system was pressurized during startup; the leakage came from an unlatched thermocouple rod; most of the spilled moderator evaporated and was vented out the stack
Apr-1974	Material Balance Monthly Report DPSP-74-13-4 Schedule Deuterium	5 lbs of moderator accidently lost in P Area Reactor Department when the vacuum breaker blew out while pressurizing the blanket gas system
May-1974	Material Balance Monthly Report DPSP-74-13-5 Schedule Deuterium	10 lbs of moderator accidently lost in Reactor Department, Building 105-P from coolant return tank overflow into hot sump; total overflow was 341 lbs; all but 10 lbs were recovered
Jul-1974	Material Balance Monthly Report DPSP-74-13-7 Schedule Deuterium	14.5 kg (~32 lbs) moderator lost in Reactor Department at P Area from a leak though a broken inhibitor system sightglass
Jan-1975	Reactor Daily Report DPTT 75-2-7C and DPTT 75-2-4	P Reactor shut down on 1/30 to correct moderator leak in pin room; estimated D2O loss was 465 lbs; approximately 200 lbs of 92% D2O was recovered in collection systems
Feb-1975	Reactor Daily Report DPTT 75-2-20	emergency D2O cooling water was needed due to problems during the discharge of a Mark 31B assembly; approximately 1100 lbs of D2O were collected from the reactor top and process room floor drain pots; initial estimate of 400 lbs of D2O loss resulting from the incident
May-1975	Material Balance Monthly Report DPSP-75-13-2 Schedule Deuterium	233.6 kg (~514 lbs) of moderator accidently lost at Building 105-P from an instrument tubing leak in the pin room below the reactor; 186 kg (~409 lbs) loss of moderator while providing emergency D2O cooling for an irradiated assembly stuck in the reactor
Aug-1975	Reactor Daily Report DPTT 75-8-13A	shutdown of P reactor because of continuing indications of moderator leakage in the -20 and 40 elevations of building; moderator leak was found at the 4B heat exchanger expansion joint; since shutdown leakage has been contained and the leakage rate is estimated at 1.5 gallons/hour
Aug-1975	Reactor Daily Report DPTT 75-8-19	loss from the distillation overheads spill (reported on 8/15) was approximately 19 lbs D2O

Appendix C Examples of Documented Leaks and Spills for P Reactor (continued)

Date	Subject/Source	Description
Jan-1977	Material Balance Monthly Report DPSP-77-13-1 Schedule Deuterium	200.5 kg (~441 lbs) of moderator accidently lost at Building 105-P resulting from a leak at a deionizer jumper following the replacement of a deionizer
Mar-1978	Jan 1979 Health Physics Dept Environmental Monitoring Monthly Report and Environmental Monitoring at the Savannah River Plant Annual Report for 1978, DPSPU 79-302	higher than normal release of tritium to P Process Sewer (400 Ci in March; 1,116 Ci for year; 300 is the annual guide; attributed to isolated spill of D2O)
May-1978	Reactor Incident RI-P-1131	effluent hose from deionizer failed and released approximately 4000 gallons of deionizer basin water containing approximately 6 Ci of tritium and neglible amounts of other isotopes to the plant effluent stream; inspection of the hose revealed a 6 inch split around the cirmcumference; hose had been in service for 2 years and was periodically inspected and pressure tested
Jun-1978	Reactor Incident RI-P-1144	effluent hose from deionizer failed and released approximately 300 gallons of deionizer basin water containing approximately 0.4 Ci of tritium and neglible amounts of other isotopes to the plant effluent stream; inspection of the hose revealed a 9 inch split around the cirmcumference; hose had been in service for 2 years and was periodically inspected and pressure tested
Mar-1979	Reactor Incident RI-P-1202	3.3 Ci of tritium and 0.8 Ci of miscellaneous isotopes released when 500 gallons contaminated water from top and bottom shield system overflowed in Building 109
Mar-1980	Reactor Incident RI-P-1291	drained basin water to process sewer instead of to drums as required by procedure
Jul-1980	Material Balance Monthly Report DPSP-80-13-7 Schedule Deuterium	24.9 kg (~55 lbs) of moderator were lost in Building 105-P; the material was released to the environment when heavy water leaked through an unseated check valve
Mar-1982	Reactor Incident RI-P-1451	70 Ci of tritium were released to process sewer when an inhibitor system rotometer broke; 60 gallons of deionized water (2% D2O) flowed into the 216B sump which discharges to the process sewer; classified as equipment failure (rotometer broke)
Jan-1983	Reactor Incident RI-P-1501	182 Ci tritium released to process sewer due to procedure deviation (personnel error); personnel pumped the distillation hold tank contents to the process sewer without authorization and sampling
Feb-1983	DuPont SRP Monthly Technical Report DPSP-83-1-2	P Area disassembly basin filter tank developed a leak in the bottom of the tank requiring shut down of the filtering system; overpressurization led the bottom section (1/4" carbon steel plate) to bow out and I-beam supports welds to fail; during time while waiting for replacement tank, main basin water was to be piped through the vertical tube storage filter loop
Nov-1983	Reactor Incident RI-P-1564	approximately 730 gallons of disassembly basin water were inadvertently released to the process sewer during annual testing of the confinement heat removal valves; basin water was drained to the 216B sump instead of the 1206B sump and subsequently pumped to the process sewer; 0.58 Ci of tritium and less than 0.0008 Ci of other radionuclides were released to the process sewer; the release was less than 0.2% fo the annual guide (300 Ci)
Dec-1983	DuPont SRP Monthly Technical Report DPSP-83-1-12	small moderator leak occurred on 105-P distillation pad from a broken line (attributed to freezing); estimated 85 Ci of tritium were released to Steel Creek via storm sewer (caused the annual tritium release guide of 300 Ci to streams via process sewer to be exceeded)
Jul-1984	DuPont SRP Monthly Technical Report DPSP-84-1-7 & RI-P-1620	VTS (vertical tube storage) tritium levels increased from 0.25 uCi/mL to 1.0 uCi/mL when approximately 85 gallons (800 lbs) of moderator was inadvertently put in the D&E Canal due to binding difficulties during the discharge of a Mark 42 assembly; VTS water was purged through deionizers to the seepage basin to reduce tritium levels to normal (estimated value of the lost 800 lbs of D2O = $60,000)

Appendix D Mass Balance Calculations of ^{137}Cs in P Reactor Seepage Basins

Using the data reviewed from this source term search, a simple mass balance analyses was performed for seepage basin #1. This seepage basin, the first in a series of three basins that received effluent from P Reactor, contains the most radioactive contamination of the three basins based on sediment sampling. The mass balance results are summarized below along with the assumptions and methods used.

Approximately 7.94 Ci of ^{137}Cs remains undecayed from the original discharges of ^{137}Cs to the seepage basins. This value was calculated by decay correcting the annual releases of ^{137}Cs provided in "Radioactive Releases at the Savannah River Site 1954-1989 (U)" (14). The mass balance calculations provided below support that this remaining ^{137}Cs is predominantly bound in the sediments beneath the basins, particularly beneath seepage basin #1. More specifically, the calculated median of ^{137}Cs remaining in the sediments of basin #1 (7.73 Ci) appears to be a close estimate of the decayed corrected ^{137}Cs released to the basins (7.94 Ci). When using averages rather than medians, the calculated ^{137}Cs remaining in the sediments of basin #1(13 Ci) is higher than the decayed corrected ^{137}Cs released to the basins (7.94 Ci). However, the decay corrected value falls in the range of the 90% confidence intervals calculated for the average. Because the initial concentration distribution of ^{137}Cs in the sediments is skewed by a few high values, the method based on median values (rather than averages) may provide a more reliable estimate of the remaining inventory.

A similar methodology and mass balance calculation shows that the sediments in seepage basin #2 contain a smaller portion of the original curies of ^{137}Cs released to the seepage basins. Nevertheless, the calculated median value of ^{137}Cs remaining in the sediments of basin #2 (0.26 Ci) brings the mass balance nearer to closure supporting that the ^{137}Cs released to the basins predominantly remains in the sediments below the basins.

Assumptions and methodology used in mass balance calculations:

- Sediment bulk density = 1.89 g/cm^3
- Total basin area for seepage basin #1 = 20,000 ft^2 (based on dimensions given in the report "Unit-Specific Plug-In TER for the P-Reactor", Reference # 21; outside dimensions for N-S portion of the basin = 211' X 50' and for the E-W portion of the basin = 254' X 50'; rounded down in order to roughly estimate inner area of the basin without the sloping sides)
- Depth of contamination = 10' (according to the report "Unit-Specific Plug-In TER for the P-Reactor", Reference # 21, 95% of the total activity in basin #1 is within the top 10' of soil beneath the basin)
- Seepage basin #1 received most of ^{137}Cs released to the seepage basins (basin #1 was the first in the series of three basins to receive discharged effluent from the reactor; sediment sampling from in the report "Unit-Specific Plug-In TER for the P-Reactor", Reference # 21, also confirm that it contains the most radioactivity of the three basins)
- For the ^{137}Cs activity discharged to the seepage basins used the1998 cumulative ^{137}Cs activity (decay corrected) = 7.94 Ci (data for ^{137}Cs activity discharged to the

basins from "Radioactive Releases at the Savannah River Site 1954-1989 (U)", Reference #14)

- For the ^{137}Cs activity in the sediments of the basin used the data provided in the report "Unit-Specific Plug-In TER for the P-Reactor", Reference # 21, down to 10' (see "Depth of contamination" bullet above); only used data from borings that were completed to 10'; much of this data was collected in 1998; for the two borings that had no ^{137}Cs value listed due to saturation, assumed a ^{137}Cs concentration for the initial foot interval similar to the value listed for the next interval (see attached data)
- In an attempt to simply but accurately capture a realistic distribution of contamination in seepage basin #1, the following methodology was used:
    1. Split seepage basin #1 into 4 zones (A through D) based on areas of similar contamination in the sediments (Zone A had the highest radioactivity and deepest contamination); see attached diagram for zones
    2. For each zone, divided the 10 ft (depth) of contamination into four layers; layer 1 = 1st foot beneath basin bottom; layer 2 = next 3 feet beneath bottom; layer 3 = next 3 feet; layer 4 = last 3 feet of contamination (depth of contamination assumed to be 10' – see above bullet)
    3. Calculated average (or mean) and median ^{137}Cs activity (using sediment data) for each layer for each zone; upper and lower 90% confidence intervals were also calculated for the average in order to show the uncertainties associated with the estimates; see attached sheet with calculations
- Compared the results of these calculations (i.e. the ^{137}Cs found in the sediments within seepage basin #1) with the 1998 cumulative ^{137}Cs activity (decay corrected) released to the basins

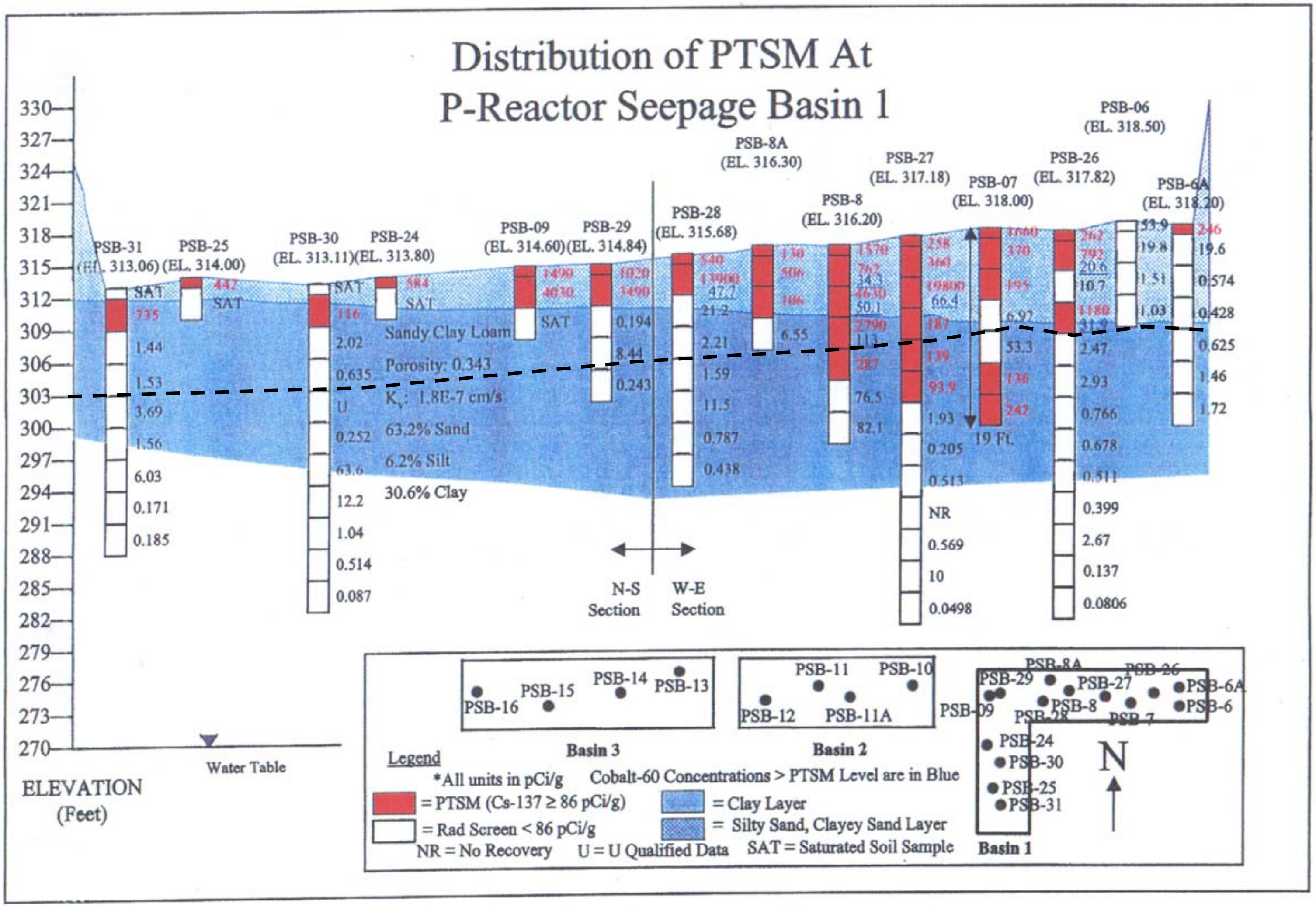
Caveats of mass balance calculations:

- Ambiguity of the contaminant distribution in the seepage basin will account for some error or uncertainty in the calculations (leading to either underestimation or overestimation of ^{137}Cs in the basin). Knowledge of the distribution of contamination is constrained to the analytical data provided by the sediment samples. The methodology developed and used in the above calculations (Zones A-D and Layers 1-4) is based on the sediment sampling and therefore may not fully depict the contaminant distribution.
- Some error or uncertainty will also exist in the total area used for seepage basin #1 and the assumed depth of contamination (10'). Because only a rough estimate of the outside dimensions of seepage basin #1 was known, the area of the center of the basin where most of the contamination was likely deposited (i.e. not on the sloping sides) had to be approximated. For a small area of seepage basin #1 (particularly in Zone A), the assumed depth of contamination (10') did not include all of PTSM (^{137}Cs $\geq$ 86 pCi/g) and may account for an underestimation of the amount of ^{137}Cs remaining in the sediments.
- The average (or mean) and median will be affected by the small sample populations within each zone and layer. The methodology used tries to simply but accurately capture a realistic distribution of contamination within the basin by

making the assumption that the layers within each zone are similar. Assuming that each layer within a given zone might be normally distributed, an average (or mean) was calculated for each layer of each zone in order to try to capture a realistic ^{137}Cs activity present in different sections of the basin. The calculated upper and lower 90% confidence intervals show the uncertainty associated with the averages used in this methodology. However, the distribution within these zones and layers identified may not be normally distributed (as often found in environmental sampling). Factors such as differences in discharges and volumes (which would have affected the spread or dissemination of contaminants in the basin), the slope of the basin and heterogeneities within sediments below the basin could produce non-normal distributions. Therefore, a median was calculated in addition to the mean in an attempt to provide a descriptive statistic that might be more realistic. Overall, the sparse data within each layer and zone presents difficulty in computing good estimates (whether using the mean or median) of the contamination.

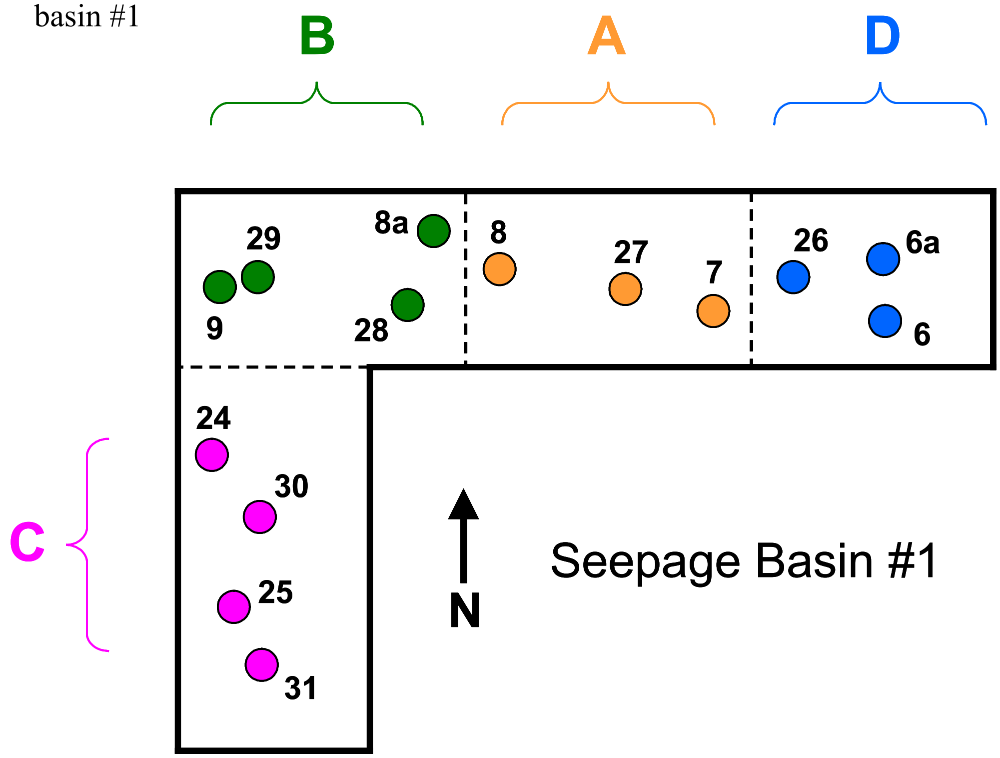
- The original measurements of release of ^{137}Cs are strongly dominated by the release(s) during a single year, 1959. (Weekly environmental and health monitoring reports suggest that an atypical discharge of a failed element and the handling of developmental reactor fuels may have contributed to the increased releases of radionuclides to P Reactor's seepage basins for this year. An overflow of the seepage basins which occurred in October 1959 would also suggest that the basins were receiving extensive use during this period.) Release estimates at that time were based on total counts and expected isotopic ratios that might vary somewhat over time. As a result, the decay corrected source input may be less accurate than one resulting from steady inputs over many years (i.e. based on many measurements).

10 ft depth = 95% of contamination



(Figure modified from the report "Unit-Specific Plug-In TER for the P-Reactor", Reference # 21)

Zones A-D and sample locations used for determining distribution of ^{137}Cs in seepage basin #1



Sediment data (from the report "Unit-Specific Plug-In TER for the P-Reactor", Reference # 21) used in calculations of ^{137}Cs remaining in seepage basin #1

Sample	Depth	^{137}Cs pCi/g
PSB 31*	0 to 1	700
PSB 31	1 to 4	735
PSB 31	4 to 7	1.44
PSB 31	7 to 10	1.53
PSB 30*	0 to 1	100
PSB 30	1 to 4	116
PSB 30	4 to 7	2.02
PSB 30	7 to 10	0.635
PSB 29	0 to 1	1020
PSB 29	1 to 4	3490
PSB 29	4 to 7	0.194
PSB 29	7 to 10	8.44
PSB 28	0 to 1	540
PSB 28	1 to 4	13900
PSB 28	4 to 7	21.2
PSB 28	7 to 10	2.21
PSB 8A	0 to 1	130
PSB 8A	1 to 4	506
PSB 8A	4 to 7	106
PSB 8A	7 to 10	6.55
PSB 8	0 to 1	1570
PSB 8	1 to 4	762
PSB 8	4 to 7	4630
PSB 8	7 to 10	2790

Sample	Depth	^{137}Cs pCi/g
PSB 27	0 to 1	258
PSB 27	1 to 4	360
PSB 27	4 to 7	19800
PSB 27	7 to 10	187
PSB 7	0 to 1	1660
PSB 7	1 to 4	370
PSB 7	4 to 7	195
PSB 7	7 to 10	6.97
PSB 26	0 to 1	262
PSB 26	1 to 4	792
PSB 26	4 to 7	10.7
PSB 26	7 to 10	1180
PSB 6	0 to 1	53.9
PSB 6	1 to 4	19.8
PSB 6	4 to 7	1.51
PSB 6	7 to 10	1.03
PSB 6A	0 to 1	246
PSB 6A	1 to 4	19.6
PSB 6A	4 to 7	0.574
PSB 6A	7 to 10	0.428

* estimated a ^{137}Cs value based on the ^{137}Cs concentration in the 1-4 ft interval

Calculations of ^{137}Cs in seepage basin #1

zone	layer	thickness	concentration (pCi/g)		area of zone (fraction of	soil mass (g)	average basis total activity	median basis total activity	upper 90% confidence interval	lower 90% confidence interval
			average	median						
Area A	1	1	1162.67	1570.00	0.23	2.46E+08	2.86E-01	3.87E-01	4.70E-01	1.03E-01
Area A	2	3	497.33	370.00	0.23	7.39E+08	3.67E-01	2.73E-01	5.28E-01	2.07E-01
Area A	3	3	8208.33	4630.00	0.23	7.39E+08	6.06E+00	3.42E+00	1.33E+01	0.00E+00
Area A	4	3	994.66	187.00	0.23	7.39E+08	7.35E-01	1.38E-01	1.83E+00	0.00E+00
Area B	1	1	563.33	540.00	0.24	2.57E+08	1.45E-01	1.39E-01	2.53E-01	3.60E-02
Area B	2	3	5965.33	3490.00	0.24	7.71E+08	4.60E+00	2.69E+00	9.74E+00	0.00E+00
Area B	3	3	42.46	21.20	0.24	7.71E+08	3.27E-02	1.63E-02	7.37E-02	0.00E+00
Area B	4	3	5.73	6.55	0.24	7.71E+08	4.42E-03	5.05E-03	6.76E-03	2.08E-03
Area C	1	1	400.00	400.00	0.33	3.53E+08	1.41E-01	1.41E-01	3.16E-01	0.00E+00
Area C	2	3	425.50	425.50	0.33	1.06E+09	4.51E-01	4.51E-01	9.90E-01	0.00E+00
Area C	3	3	1.73	1.73	0.33	1.06E+09	1.83E-03	1.83E-03	2.34E-03	1.33E-03
Area C	4	3	1.08	1.08	0.33	1.06E+09	1.15E-03	1.15E-03	1.93E-03	3.67E-04
Area D	1	1	187.30	246.00	0.20	2.14E+08	4.01E-02	5.27E-02	6.36E-02	1.66E-02
Area D	2	3	277.13	19.80	0.20	6.42E+08	1.78E-01	1.27E-02	4.50E-01	0.00E+00
Area D	3	3	4.26	1.51	0.20	6.42E+08	2.74E-03	9.70E-04	6.15E-03	0.00E+00
Area D	4	3	393.82	1.03	0.20	6.42E+08	2.53E-01	6.61E-04	6.68E-01	0.00E+00
						Total for basin =	**1.33E+01**	**7.73E+00**	**2.87E+01**	**3.66E-01**

Calculations of ^{137}Cs in seepage basin #2

layer	thickness	concentration (pCi/g)		area of zone (fraction of	soil mass (g)	average basis total activity	median basis total activity	upper 90% confidence interval	lower 90% confidence interval
		average	median						
1	1	419.25	386	1	6.42E+08	2.69E-01	2.48E-01	4.63E-01	7.55E-02
2	3	117.49	4.555	1	1.93E+09	2.26E-01	8.78E-03	5.87E-01	0.00E+00
					Total for basin =	**4.96E-01**	**2.57E-01**	**1.05E+00**	**7.55E-02**

Total Basin Area =	12000	ft^2
Total Depth* =	4	ft
Bulk Density =	1.89	g / cm^3

*96% of total radioactivity within first 4' below surface