Proposed Radioactive Liquid Effluent Mointoring Requirements at the Savannah River Site (U)

Conf-9410138--1

by
G. T. Jannik
Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808
W. H. Carlton
Westinghouse Savannah River Company
SC USA
B. C. Blunt

A document prepared for ENVIRONMENTAL RADIATION "HOW CLEAN IS CLEAN?" at Springfield from 10/11/94 - 10/14/94.

DOE Contract No. **DE-AC09-89SR18035**

PROPOSED RADIOACTIVE LIQUID EFFLUENT MONITORING REQUIREMENTS AT THE SAVANNAH RIVER SITE (U)

G.T. Jannik, W.H. Carlton, and B.C. Blunt
Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808 USA
(803)–725–7311

This paper was prepared in connection with work conducted under Contract No. DE–AC09–89SR18035 with the U.S. Department of Energy.

DISCLAIMER

ABSTRACT

Clear regulatory guidance exists for structuring a radiological air monitoring program, however, there is no parallel guidance for radiological liquid monitoring. For Department of Energy (DOE) facilities, there are no existing applicable federal regulations, DOE orders, or DOE guidance documents that specify at what levels continuous monitoring, continuous sampling, or periodic confirmatory measurements of radioactive liquid effluents must be made. In order to bridge this gap and to technically justify and document liquid effluent monitoring decisions at DOE's Savannah River Site, Westinghouse Savannah River Company has proposed that a graded, dose-based approach be established, in conjunction with limits on facility radionuclide inventories, to determine the monitoring and sampling criteria to be applied at each potential liquid radioactive effluent point. The graded approach would be similar to—and a conservative extension of—the existing, agreed-upon SRS/EPA-IV airborne effluent monitoring approach documented in WSRC's NESHAP Quality Assurance Project Plan. The limits on facility radionuclide inventories are based on—and are a conservative extension of—the 10 CFR 834, 10 CFR 20, and SCR 61–63 annual limits on discharges to sanitary sewers. Used in conjunction with each other, the recommended source category criteria levels and facility radionuclide inventories would allow for the best utilization of resources and provide consistent, technically justifiable determinations of radioactive liquid effluent monitoring requirements.

INTRODUCTION

Although clear regulatory guidance exists for structuring a radiological air effluent monitoring program at Department of Energy (DOE) sites, there is no parallel regulatory guidance for radiological liquid effluent monitoring activities.

Effluent monitoring requirements for radioactive airborne releases from DOE facilities are specified in the National Emission Standard for Hazardous Air Pollutants (NESHAP) regulation of the U.S. Environmental Protection Agency (EPA) (EPA 1989). These requirements are incorporated in DOE Guide DOE/EH–0173T (DOE 1991) and adopted by reference in DOE Orders 5400.1 (DOE 1988a) and 5400.5 (DOE 1990) and in Proposed Rule 10 CFR 834 (DOE 1993).

However, for DOE facilities, there are no applicable federal regulations, DOE Orders, or DOE guidance documents that specify at which levels continuous monitoring, continuous sampling, or periodic confirmatory measurements of radioactive liquid effluents must be made.

To bridge this gap and to technically justify and document liquid effluent monitoring decisions at SRS, Westinghouse Savannah River Company (WSRC) has proposed that a graded, risk-based approach be established—in conjunction with limits on facility radionuclide inventories—to determine the effluent monitoring criteria to be applied at each potentially radioactive liquid effluent discharge point. The graded approach would be similar to—and a conservative extension of—the existing, agreed-upon SRS/EPA-IV airborne effluent monitoring approach documented in WSRC's NESHAP Quality Assurance Project Plan (WSRC 1992). The limits on facility radionuclide inventories are based on—and are a conservative extension of—the 10 CFR 834, 10 CFR 20 (NRC 1977), and SCR 61–63 (SCDHEC 1976) annual limits on discharges to sanitary sewers.

DISCUSSION:

The proposed graded, risk-based program would require that each SRS liquid effluent discharge point be categorized every year according to the maximum, annual, potential, ingestion-pathway dose—determined at the point of discharge—by using the following parameters in the calculation:

- the highest, annual, average radionuclide concentrations—as determined over the previous five years of operations—measured in the actual liquid effluents released
- an ingestion rate of 2 liters per day (730 liters per year) of the untreated effluent
- the internal dose conversion factors from DOE/EH–0071 (DOE 1988b)

For previously unmonitored outfalls that *potentially* contain radioactive liquid effluents, this determination would be made by annualizing the data after at least 3 months of sampling and radioanalysis. This 3-month sampling period would ensure that any residual radioactivity is accounted for. Weekly grab samples can be collected in lieu of continuous sampling if steady-state process conditions can be verified.

The generic term "effluent monitoring" is defined in DOE Order 5400.5 as "... the collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying contaminants, assessing radiation exposures to members of the public, and demonstrating compliance with applicable standards." Therefore, when used in this report, "effluent monitoring" can refer to

- continuous direct measurement of radionuclides in the effluent stream
- sampling and analysis of the liquid waste prior to discharge as a batch release
- continuous sampling, followed by laboratory analyses, to determine the quantity of radionuclides present in the effluent stream
- periodic sampling, followed by laboratory analyses, to determine the quantity of radionuclides present in the effluent stream

Radiological Liquid Effluent Source Categories:

Category I Sources: Category I sources have annual potential emissions that at the point of discharge and prior to dilution in the receiving stream could cause a dose—via the water ingestion pathway (ingestion of 2 liters per day of the effluent taken from the point of discharge)—of greater than 100 mrem (1.0 mSv) per year. This is equivalent to exceeding the DOE Derived Concentration Guides (DCGs) at the point of discharge. As is the case in DOE Order 5400.5 and 10 CFR 834 for DCG determinations, releases of tritium are exempted from the Category I source determinations. Category I sources are considered intolerable and must be treated by the best available technology, per DOE Order 5400.5 and 10 CFR 834.

Category II Sources: Category II sources have annual potential emissions that at the point of discharge and prior to dilution in the receiving stream could cause a dose—via the water ingestion pathway (ingestion of 2 liters per day of the effluent taken from the point of discharge)—of between 4.0 and 100 mrem (0.04 and 1.0 mSv) per year. Category II sources include discharge points that have potential doses greater than 100 mrem (1.0 mSv) per year because of tritium emissions. Cate-

gory II sources are required to have—on the process streams than contribute greater than 10 percent of the potential dose—continuous monitoring (i.e., continuous online radiation detection instrumentation capable of producing an alarm signal and/or diverting the effluent stream if process alarm levels are exceeded) or to have the capability to be batch-released after sampling and radioanalysis. This type of source also requires continuous sampling, followed by laboratory radioanalysis, at the point of discharge to the receiving stream.

Category III Sources: Category III sources 1) have potential emissions that at the point of discharge and prior to dilution in the receiving stream could cause a dose—via the water ingestion pathway (ingestion of 2 liters per day of the effluent taken from the point of discharge)—of between 0.4 and 4.0 mrem (0.004 and 0.04 mSv) per year and 2) have facilities—with radionuclide inventories that exceed the limits shown in Table 3—emitting to them. Category III sources are required to have continuous sampling, followed by laboratory radioanalysis, at the point of discharge to the receiving stream.

Category IV Sources: Category IV sources 1) have potential emissions that at the point of discharge and prior to dilution in the receiving stream could cause a dose—via the water ingestion pathway (ingestion of 2 liters per day of the effluent taken from the point of discharge)—of between 0.4 and 4.0 mrem (0.004 and 0.04 mSv) per year and 2) have facilities—with radionuclide inventories that are less than the limits shown in Table I–1—emitting to them. Category IV sources also include discharge points with potential emissions of less than 0.4 mrem (0.004 mSv) per year but have facilities—with radionuclide inventories that exceed the limits shown in Table 3—emitting to them. Category IV sources are required to have monthly confirmatory measurements performed to confirm that emissions remain below 4.0 mrem (0.04 mrem) per year.

Category V Sources: Category V sources have no potential for releasing radioactive liquid effluents, as determined by historical information and/or process knowledge. Category V sources also include discharge points that 1) have potential emissions that at the point of discharge and prior to dilution in the receiving stream could cause a dose—via the drinking water pathway (ingestion of 2 liters per day of the effluent taken from the point of discharge)—of less than 0.4 mrem (0.004 mSv) per year and 2) have facilities—with facility radionuclide inventories that are less than the limits shown in Table 3—emitting to them. Category V discharge points require no radiological liquid effluent monitoring.

In Table 1, the radiological liquid effluent source categories are shown with their associated annual ingestion-pathway-dose ranges and total-lifetime-stochastic-risk ranges. Categories I and II are based on the DOE Order 5400.5 and 10 CFR 834 primary dose standard of 100 mrem (1 mSv) per year and are conservatively applied at the point of discharge to a surface waterway, per DOE Derived Concentration Guides (DCG) requirements. Categories III, IV, and V are based on the 40 CFR 141 (EPA 1975) and 10 CFR 834 drinking water dose standard of 4 mrem (0.04 mSv) per year and also are conservatively applied at the point of discharge to a surface waterway.

The International Commission on Radiological Protection (ICRP) Publication 60 (ICRP 1990) factor for total, lifetime, stochastic risk (per effective dose) was used to determine the annual risk ranges shown in Table 1.

Table 1 Radioactive Liquid Effluent Source Categories

Category	Annual Dose Range	Lifetime Risk from Dose in One Year
I	greater than 100 mrem (1.0 msV)	greater than 7.0×10^{-5}
II	greater than 4 mrem (0.04 msV) but less than100 mrem (1.0 msV)	greater than 3.0×10^{-6} but less than 7.0×10^{-5}
III	greater than 0.4 mrem (0.004 msV) but less than100 mrem (1.0 msV)	greater than 3.0×10^{-7} but less than 3.0×10^{-6}
IV	less than 0.4 mrem (0.004 msV) but radionuclide inventory is under limits	less than 3.0×10^{-7}
V	less than 0.4 mrem (0.004 msV) but radionuclide inventory is under limits	less than 3.0×10^{-7}

The ICRP–60 factor, which is 7.3×10^{-4} per rem (7.3×10^{-2} per sievert), includes factors for

- fatal cancers of 5.0×10^{-4} per rem (5.0×10^{-2} per sievert)
- weighted nonfatal cancers of 1.0×10^{-4} per rem (1.0×10^{-2} per sievert)
- weighted severe hereditary effects of 1.3×10^{-4} per rem (1.3×10^{-2} per sievert)

Recently, T.P. Grumbly (DOE Assistant Secretary for Environmental Management) initiated the use of a risk-based approach for establishing more credible decision making within DOE environmental management. It should be noted, however, that risk factors, which are useful for risk management decisions, usually are not valid for assessment of risk from actual exposures. Actual risks that are at levels of natural background and below are still unknown.

Many of the established federal limits that regulate radioactive (and nonradioactive) releases—including 10 CFR 834—correspond to limits on lifetime risks in the range of 10^{-5} to 10^{-6} (i.e., DOE's 100-mrem (1.0 mSV)-per-year standard, which equates to a risk of about 7.0×10^{-5}). Radiation exposures are reduced far below these limits by the application of As Low As Reasonably Achievable (ALARA) principles. This usually is accomplished by the establishment of environmental standards, limits on specific practices (i.e., DOE's and EPA's 10-mrem (0.1 mSv)-per-year standard for airborne releases), or effluent source constraints. Lifetime risks below the range of 10^{-6} are so small that further reduction of risks using ALARA usually are not warranted and often are not possible. Therefore, exempting Category V sources from radiological liquid effluent monitoring requirements on a risk basis is justifiable.

Also, the less-than-0.4-mrem (0.004 mSv) dose range for Category IV and V sources—which is equivalent to radionuclide concentrations that are 0.4 percent of the DOE Order 5400.5 and 10 CFR 834 (DCGs) and 10 percent of the EPA drinking water standard—corresponds to liquid effluent radionuclide concentrations that approach the detection limits of the standard radioanalytical procedures employed at SRS.

As an example of this, Table 2 compares 0.4 percent of the DOE DCG values—for several radionuclides of interest at SRS—against the SRS Environmental Monitoring Section's (EMS) lower limits of detection. Also shown are the current counting times employed by EMS.

The low radionuclide concentrations (0.004 times the DOE DCGs) associated with the 0.4-mrem (0.004 mSv) dose range further justify exempting Category V sources from radiological liquid effluent monitoring requirements. Also, employing 0.004 times the DCGs as a detection limit goal—which, for beta particle and photon emitters, is the same as the 40 CFR 141.25 analytical detection limit requirements—would provide technical justification for the establishment of laboratory lower limits of detection.

Facility Radionuclide Inventory Limits:

In addition to source category criteria levels, the proposed graded, risk-based program would establish limits on facility radionuclide inventories above which some type of radiological liquid effluent monitoring must take place at a discharge point, regardless of how low the maximum potential drinking water dose is determined to be.

The following facility inventory limits are recommended:

- 0.5 curie (20 GBq) of tritium
- 0.1 curie (3.7 GBq) of carbon–14
- 0.1 curie (3.7 GBq) of all other radionuclides combined

These limits are set conservatively at 10 percent of the 10 CFR 834, 10 CFR 20, and SCR 61–63 annual limits on discharges to sanitary sewers. At SRS, these inventory amounts correspond to a maximally-exposed-individual dose—from all pathways and to the nearest off-site public receptor—of approximately 1.5×10^{-1} mrem (1.5×10^{-3} mSv), which is equivalent to a lifetime risk of about 1.0×10^{-7}. This dose assessment is based on the unlikely assumption that the entire, allowable, facility radionuclide inventory is discharged in one year and that a worst-case radionuclide (phosphorus–32) accounts for the entire 0.1 curie (3.7 GBq) of all other radionuclides combined.

Table 2 DOE DCG values versus EMS detection limits

Nuclide	DCG value	0.4 percent of DCG	EMS's detection limit
Tritium	2.0×10^{-3} μCi/mL	8.0×10^{-6} μCi/mL	1.3×10^{-6} μCi/mL (20 min) 4.5×10^{-7} μCi/mL (150 min)
Cesium	3.0×10^{-6} μCi/mL	1.2×10^{-8} μCi/mL	9.0×10^{-9} μCi/mL (10,000 s)
Strontium	1.0×10^{-6} μCi/mL	4.0×10^{-9} μCi/mL	1.9×10^{-9} μCi/mL (20 min)
Plutonium	4.0×10^{-8} μCi/mL	1.6×10^{-10} μCi/mL	4.3×10^{-12} μCi/mL (5000 min)

Considering the low potential doses and associated risks involved, exempting discharge points from more stringent radiological liquid effluent monitoring requirements on a facility radionuclide inventory risk basis is justifiable. In fact, on a risk basis, higher facility radionuclide inventory levels would be justifiable at SRS. However, the factor of 10 added conservatism ensures that—even using the highly unlikely assumption that entire facility radionuclide inventories are accidentally discharged at the same time—multiple, exempted, facility discharge points will not exceed the regulatory limits.

It is recommended that the facility radionuclide inventory limits be applicable to facilities that discharge to surface waters, as well as to facilities that discharge to sanitary sewers. The inventory limits are recommended to be applicable to all physical forms of the radionuclides. However, calibration sources that are sealed and in a solid form can be excluded from the facilities' inventory listing.

For a discharge point to be eligible for exemption from any liquid effluent monitoring requirements, it would have to be determined and documented that all facilities that discharge through that point are below the recommended facility radionuclide inventory limits. It is recommended that this determination be performed annually, at the same time as the annual review of source categorizations of liquid effluent discharge points.

Process for Determining Liquid Effluent Monitoring Requirements:

The flow chart process presented in Figure 1 shows how the inventory limit is used in conjunction with the source categorizations to determine radioactive liquid effluent monitoring requirements at SRS. The following is a description of the step-by-step method to be used to make these determinations.

Step 1 – Operations personnel shall identify each site liquid effluent discharge point to be assessed under the program.

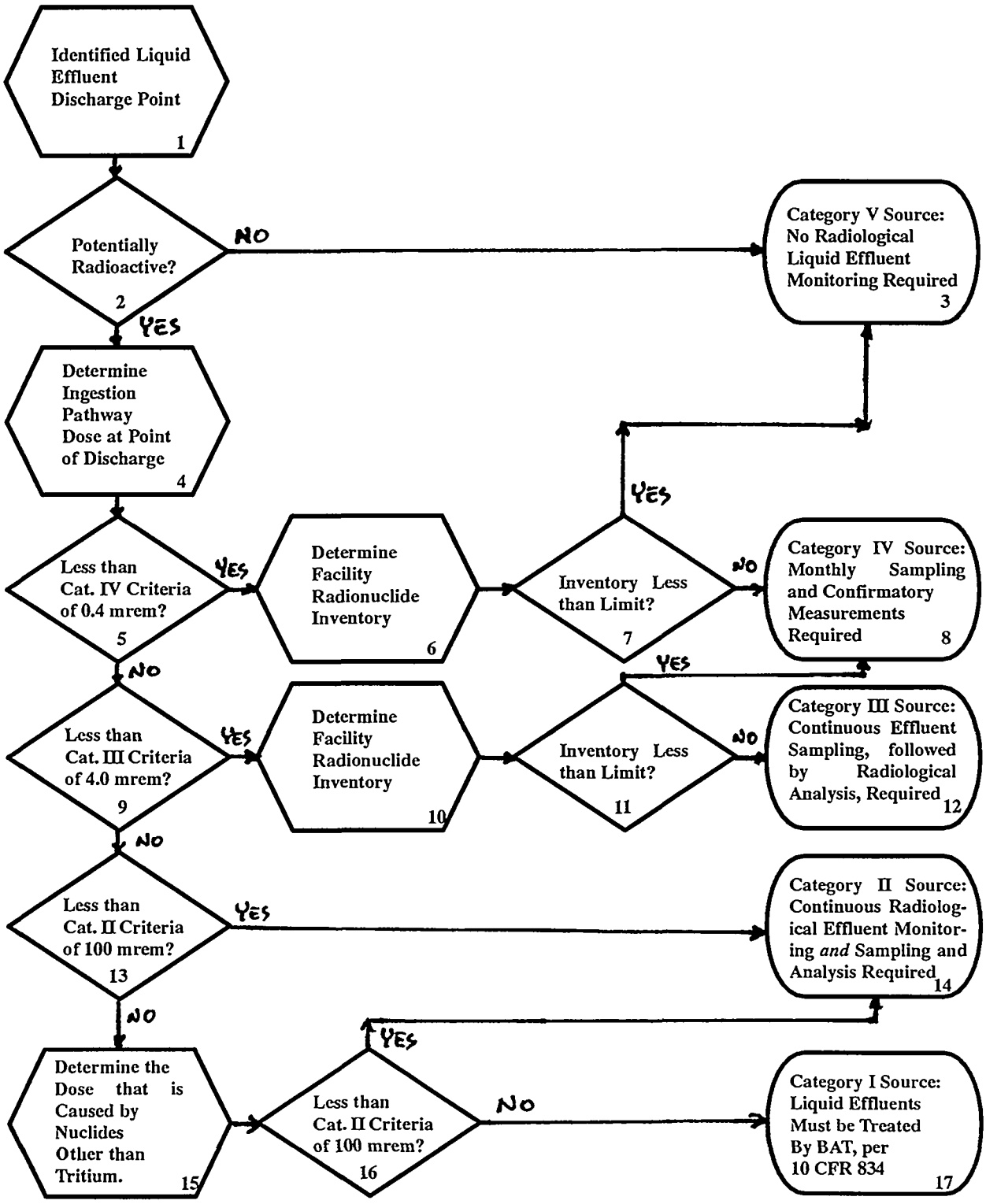
Step 2 – Based on historical information and/or process knowledge, Operations personnel are to determine the potential for radiological emissions from each of the identified liquid effluent discharge points. If a discharge point has no potential for radioactive emissions, then no radiological liquid effluent monitoring is required (Step 3). This information shall be documented (by reference) in the *SRS Environmental Monitoring Program,* (SRS EM Program), WSRC–3Q1–2, Volume 1, Section 1100. If a discharge point has a potential for radioactive emissions, then proceed to Step 4.

Step 3 – This is the decision-tree end point for Category V discharge points. Category V discharge points require no radiological liquid effluent monitoring.

Step 4 – For each radioactive liquid effluent discharge point, Operations personnel—assisted by Environmental Monitoring Section (EMS) and Environmental Technology Section (ETS) personnel—shall determine the maximum, annual, potential, ingestion-pathway dose—determined at the point of discharge. This information shall be documented (by reference) in the SRS EM Program.

Step 5 – If the maximum, annual, potential, ingestion-pathway dose is less than 0.4 mrem (0.004 mSv) per year, then proceed to Step 6; if it is greater than or equal to 0.4 mrem (0.004 mSv) per year, then proceed to Step 9.

Figure 1 Flow chart process for determining radioactive liquid effluent requirements



Step 6 – For a discharge point to be eligible for exemption from any liquid effluent monitoring requirements, Operations personnel must determine and document that all facilities that discharge through that point are below the recommended facility radionuclide inventory limits. This determination shall be performed each year, at the same time as the annual review of the source categorizations of liquid effluent discharge points. This information shall be documented (by reference) in the SRS EM Program.

Step 7 – If the facility radionuclide inventory is below the limits, proceed to Step 3; if it is greater than or equal to the limits, proceed to Step 8.

Step 8 – This is the decision-tree end point for Category IV discharge points. Category IV discharge points are required to have monthly confirmatory measurements performed at the point of discharge to the receiving stream to confirm that emissions remain below 4.0 mrem (0.04 mSv) per year. Operations personnel, assisted by EMS personnel, shall determine the sampling location, type, and frequency—as well as the analytical regime—to be used.

Step 9 – If the maximum, annual, potential, ingestion-pathway dose is less than 4.0 mrem (0.04 mSv) per year, then proceed to Step 10; if it is greater than or equal to 4.0 mrem (0.04 mSv) per year, then proceed to Step 13.

Step 10 – For a discharge point to be eligible for exemption from any liquid effluent monitoring requirements, Operations personnel must determine and document that all facilities that discharge through that point are below the recommended facility radionuclide inventory limits. This determination shall be performed each year, at the same time as the annual review of the source categorizations of liquid effluent discharge points. This information shall be documented (by reference) in the SRS EM Program.

Step 11 – If the facility radionuclide inventory is below the limit, proceed to Step 8; if it is greater than or equal to the limits, proceed to Step 12.

Step 12 – This is the decision-tree end point for Category III discharge points. Category III sources are required to have continuous sampling, followed by laboratory radioanalysis, at the point of discharge to the receiving stream. Operations personnel, assisted by EMS personnel, shall determine the sampling location, type, and frequency—as well as the analytical regime—to be used.

Step 13 – If the maximum, annual, potential, ingestion-pathway dose is less than 100 mrem (1 mSv) per year, then proceed to Step 14; if it is greater than or equal to 100 mrem (1 mSv) per year, then proceed to Step 15.

Step 14 – This is the decision-tree end point for Category II discharge points. Category II sources are required to have continuous monitoring (i.e., continuous online radiation detection instrumentation capable of producing an alarm signal and/or diverting the effluent stream if process alarm levels are exceeded) or to have the capability to be batch-released after sampling and radioanalysis. In addition, this type of source requires continuous sampling, followed by laboratory radioanalysis, at the point of discharge to the receiving stream. Operations personnel shall determine the type of continuous monitoring required. Operations personnel, assisted by EMS personnel, shall determine the sampling location, type, and frequency—as well as the analytical regime—to be used.

Step 15 – Operations personnel, assisted by Environmental Monitoring Section (EMS) and Environmental Technology Section (ETS) personnel, shall determine the maximum, annual, potential, ingestion-pathway dose caused by radionuclides other than tritium. This information shall be documented (by reference) in the SRS EM Program.

Step 16 – If the maximum, annual, potential, ingestion-pathway dose is less than 100 mrem (1 mSv) per year (excluding tritium), then proceed to Step 14; if it is greater than or equal to 100 mrem (1 mSv) per year (excluding tritium), then proceed to Step 17.

Step 17 – This is the decision-tree end point for Category I discharge points. Category I sources are considered intolerable and must be treated by the best available technology, per DOE Order 5400.5 and 10 CFR 834. Operations personnel shall perform and document the best available technology determination.

Annual Reassessment Procedural Requirement:

To ensure that changes in operations are accounted for, a reassessment of the source categorization for each liquid effluent discharge point, as well as of the facility radionuclide inventory limits, are recommended to be performed annually. Any changes in source categorization or facility radionuclide inventories, and any subsequent effluent monitoring changes, would be made and documented at that time. This program would be similar to the annual NESHAPs assessment requirements for airborne effluent discharge points.

Cost Benefits:

The following are the estimated ("ball park") annual cost ranges for each Attachment I source categorization level. They do not include initial equipment installation costs, which may be substantial.

- Category I Sources – Liquid effluent must be treated by best available technology
  Estimated cost range = $150,000 plus (dependent on treatment specified)
- Category II Sources – Continuous online monitoring *and* sampling/analysis required
  Estimated cost range = $50,000 to $150,000 (dependent on monitoring required)
- Category III Sources – Continuous sampling followed by laboratory radioanalysis
  Estimated cost range = $25,000 to $50,000 (dependent on analyses performed)
- Category IV Sources – Monthly sampling followed by laboratory radioanalysis
  Estimated cost range = $10,000 to $25,000 (dependent on analyses performed)
- Category V Sources – No liquid effluent monitoring requirements
  Estimated cost range = 0 to $10,000 (dependent on inventory determination effort)

As can be seen, the estimated cost range associated with each source categorization level declines exponentially with the severity of the specified effluent monitoring requirements. Therefore, employing the recommended graded, risk-based program would allow for the best utilization of resources while still conservatively requiring monitoring at discharge points where risks are higher.

CONCLUSION:

The graded, risk-based program recommended for determining radioactive liquid effluent monitoring requirements at SRS is a conservative extension of liquid effluent requirements given in DOE Order 5400.5 and 10 CFR 834. Used in conjunction with each other, the recommended source category criteria levels and facility radionuclide inventories would allow for the best utilization of resources and provide consistent, technically justifiable determinations of radioactive liquid effluent monitoring requirements. To ensure that future changes in operations are accounted for, the potential dose from each source, as well as the facility radionuclide inventories, would be reassessed annually.

Because of the recommended conservative source categorization requirements—especially the requirement for using the highest annual radionuclide concentrations from the previous five years of operations—few of the existing 26 radiological liquid effluent discharge points at SRS would be eligible for changes in effluent monitoring requirements. Depending on their facility radionuclide inventories, only two discharge points are currently eligible—under the recommended source categorization program—for less stringent effluent monitoring requirements.

In the future, however, as facilities remain shut down, as radionuclide inventories are consolidated, and as decontamination and decommissioning efforts are accelerated, other site liquid effluent discharge points may become eligible for less stringent effluent monitoring requirements. Also, new low-risk facilities and existing—*potentially* radioactive—low-risk facilities would benefit from implementation of the recommended graded, risk-based program.

REFERENCES:

DOE, 1988a *General Environmental Protection Program*, DOE Order 5400.1, U.S. Department of Energy. (November 1988).

DOE, 1988b *Internal Dose Conversion Factors for Calculation of Dose to the Public*, DOE/EH–0071, U. S. Department of Energy, Washington, D.C. (1988)

DOE, 1990 *Radiation Protection of the Public and Environment*, DOE Order 5400.5, U.S. Department of Energy (February 1990).

DOE, 1991 *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH–0173T, U.S. Department of Energy, Washington, D.C. (1991).

DOE, 1993 *Radiation Protection of the Public and the Environment: Proposed Rule*, 10 CFR 834, U.S. Department of Energy, Washington, D.C. (1993).

EPA, 1975 "National Primary Drinking Water Regulations," *U.S. Code of Federal Regulations*, Title 40, Part 141, U.S. Environmental Protection Agency, Washington, D.C. (1975).

EPA, 1989 "National Emission Standards for Hazardous Air Pollutants; Radionuclides," *Code of Federal Regulations*, Title 40, Part 61, U.S. Environmental Protection Agency (December 1989).

ICRP, 1990 ICRP Publication 60, International Commission on Radiological Protection, Pergamon, New York, N.Y. (1990).

NRC, 1977 "Standards for Protection Against Radiation," 10 CFR 20, U.S. Nuclear Regulatory Commission, Washington, D.C. (1977).

SCDHEC, 1976 South Carolina Department of Health and Environmental Control, "Air Pollution Control Regulations and Standards," SCDHEC R.61-62, South Carolina Department of Health and Environmental Control, Columbia, S.C. (1976).

WSRC, 1992 "National Emission Standards for Hazardous Air Pollutants; Quality Assurance Plan," WSRC–IM–91–60, Westinghouse Savannah River Company (1992).

This paper was prepared in connection with work conducted under Contract No. DE-AC09-89SR18035 with the U.S. Department of Energy.