PNNL-12191

Hanford Radiological Protection Support Services Annual Report for 1998

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Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

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Summary

During calendar year (CY) 1998, the Pacific Northwest National Laboratory (PNNL) performed its customary radiological protection support services in support of the U.S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford contractors. These services included: 1) external dosimetry, 2) internal dosimetry, 3) in vivo measurements, 4) radiological records, 5) instrument calibration and evaluation, and 6) calibration of radiation sources traceable to the National Institute of Standards and Technology (NIST). The services were provided under a number of projects as summarized here.

Along with providing site-wide nuclear accident and environmental dosimetry capabilities, the Hanford External Dosimetry Project (HEDP) supports Hanford radiation protection programs by providing external radiation monitoring capabilities for all Hanford workers and visitors to help ensure their health and safety. During 1998, the HEDP passed the U.S. Department of Energy Laboratory Accreditation Program (DOELAP) testing and was accredited for another two years. The HEDP was tested in 36 categories, including 10 new categories. The new categories included chipstrate extremity dosimetry, Hanford standard dosimeter (HSD) extremity dosimetry, and moderated and unmoderated neutron dosimetry for both the HSD and the Hanford combination neutron dosimeter (HCND), both alone and in mixture with photons. Also, the Performance Evaluation Program Administrator (PEPA) required that the HCND be treated as two separate dosimeters—one with and one without CR39. In total, over 1000 results were submitted to the PEPA for DOELAP performance testing this time. Processing volumes decreased in 1998 relative to prior years for all types of dosimeters, with an overall decrease of 29%. Recalibration of all HSD and HCND cards was started so that all cards issued after January 1, 1999, had newly determined element correction coefficients. HEDP computers and processors were tested and upgraded to become Year 2000 (Y2K) compliant.

The Hanford Internal Dosimetry Project (HIDP) provides for the assessment and documentation of occupational dose from intakes of radionuclides at the Hanford Site. During CY98, the HIDP struggled under an unusually high number of potential intake cases, which resulted in a backlog and longer-than-normal times to complete cases. One event in particular added 106 cases. Several new methods were developed for implementation under the HIDP. A new excreta bioassay analysis, for ^{243}Am, was developed and implemented by the excreta laboratory. A revised protocol for investigation of ^{137}Cs detected by whole body counting was developed and issued, as was a protocol for more rapid notification of contractors about high routine bioassay results. A new statistical method to determine that plutonium is present in an excreta sample was developed, and discussions toward implementation of the method by the excreta laboratory were started.

The Hanford Whole Body Counting Project (WBCP) provides the in vivo counting services for Hanford Site radiation workers. The 8,304 in vivo measurements performed in 1998 represent a 7% increase from 1997. The initial DOELAP accreditation was achieved in February 1998 after completion of corrective actions to address concerns noted during the onsite DOELAP assessment. The project staff participated in the Thyroid Radioiodine Intercomparison Program in preparation for future DOELAP performance testing in this category. Measurement quality control was implemented to ensure the validity of the calibration factors used to estimate the activity in the body. Several HPGe detectors were

repaired at the IVRRF saving out-of-service time and money compared with returning the detectors to the vendor. Significant progress was made in the customization of the commercial in vivo counting software being prepared for operation in CY 1999. In other project-related activities, the staff 1) completed the development of the thoron-in-breath monitor and performed a total of 26 measurements of nonexposed individuals, 2) collaborated with the United States Transuranium and Uranium Registry to perform additional follow-up measurements as part of the long-term assessment of an ^{241}Am inhalation intake, and 3) collaborated with the Carlsbad Environmental Monitoring and Research Center to evaluate the activity content of a lung phantom. There were 15 phantom loans made throughout the DOE Phantom Library in 1998, including two international loans.

The Hanford Radiological Records Project (HRRP) preserves and administers all Hanford records of personnel radiological exposure, historical radiation protection, and radiological dosimetry practices and policies. It also produces reports for DOE Headquarters, RL, Hanford contractors, individuals, and other authorized agencies and provides data for epidemiology and research projects. During CY98, the Hanford Site Contractor Assessment of the HRRP verified the correction of deficiencies noted during previous assessments. The Access Control Entry System, which electronically compares worker qualifications with controlled access requirements, was upgraded to become Y2K compliant. The software for the Radiological Exposure (REX) system was also upgraded or scheduled for upgrade to achieve Y2K compliance. The HRRP also supplied most of the personnel radiation exposure and Hanford Radiation Protection Historical Files and related indices to the National Institute of Occupational Safety and Health this year.

The Instrumentation Services and Technology Project (IS&TP) provides complete and reliable radiation protection instrument services for site contractors to ensure personnel safety in the Hanford workplace. During CY98, 14,500 calibrations were performed by project staff, a 12% decrease from 1997. Eighty-one instruments were found to be significantly out-of-tolerance upon return for calibration. A major improvement during the year was the unbundling of calibration costs, which allowed customers to select desired services without paying for undesired services. IS&TP also continued to support the Hanford Instrument Evaluation Committee by maintaining the approved instrument list and record files of all instrument evaluations completed for Hanford Site customers. IS&TP staff evaluated several radiation detection instruments used onsite to ensure that they were qualified and documented as appropriate for Hanford Site use. Project staff also purchased and acceptance tested instruments and equipment for the Chornobyl Shelter and Decommissioning Program's Shelter Dose Reduction Project. This was done in support of DOE's International Nuclear Safety Program.

The Radiation Standards and Calibration Project (RS&CP) maintains the radiological standards necessary to support the characterization and calibration needs of instrument and external dosimetry projects. This includes maintaining any necessary special instrument and dosimeter response-characterizing equipment and supplemental radiation reference fields. This project provides the means to characterize response to radiation fields encountered at Hanford and ensures that the calibration fields comply with and are traceable to recommended standards and guides (notably those of NIST). During CY98, the consistency of routinely used instrument standards was verified to ensure their accuracy for field measurements. RS&CP staff initiated the development of five International Standards Organization filtered X-ray techniques in anticipation of future dosimetry proficiency testing needs within both the

National Voluntary Laboratory Accreditation Program (NVLAP) and DOELAP. Three NIST interactions could not be fulfilled by NIST during the year due to facility maintenance and upgrades. These included 1) a measurement quality assurance evaluation for low-energy photon reference fields, 2) calibration of a ^{252}Cf neutron source, and 3) calibration of a reference ionization chamber to the newly developed ISO X-ray techniques. These objectives were postponed until 1999 and did not result in any perceived reduction of quality at PNNL. This was substantiated by a successful onsite assessment by NIST as part of the on-going NVLAP accreditation of the calibration laboratory maintained by the Calibration Research and Accreditation group.

Abbreviations and Acronyms

ACES	Access Control Entry System
ACL	Administrative Control Limit
AIC	air-equivalent ionization chamber
AIM	acquisition interface module
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
BHI	Bechtel Hanford Incorporated
BOMAB	bottle-manikin absorption
CAM	continuous air monitor
CAR	computer-assisted retrieval
CD	compact disc
CEDE	committed effective dose equivalent
CEMRC	Carlsbad Environmental Monitoring and Research Center
CFR	Code of Federal Regulations
CR&A	Calibration Research and Accreditation (subgroup)
CY	calendar year
DEC	Digital Equipment Corporation
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOELAP	DOE Laboratory Accreditation Program
DOT	U.S. Department of Transportation
DR&T	Dosimetry Research and Technology
EDF	Emergency Decontamination Facility
EFCOG	Energy Facility Contractors Operating Group
ERC	Environmental Restoration Contractor
ES	Enterprise Server
FDH	Fluor Daniel Hanford
FFTF	Fast Flux Text Facility
FY	fiscal year
GM	Geiger-Mueller
HCND	Hanford combination neutron dosimeter
HEDP	Hanford External Dosimetry Project
HEHF	Hanford Environmental Health Foundation
HIDP	Hanford Internal Dosimetry Project

HIEC	Hanford Instrument Evaluation Committee
HLAN	Hanford Local Area Network
HPDAC	Hanford Personnel Dosimetry Advisory Committee
HPGe	high-purity germanium
HPIC	Health Physics Instrument Committee
HPS	Health Physics Society
HQ	Headquarters
HRRP	Hanford Radiological Records Project
HSD	Hanford standard dosimeter
HSRCM	Hanford Site Radiological Control Manual
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiological Units and Measurements
ID	identifier
IODR	Investigation of Dosimetry Result
ISO	International Standards Organization
IS&TP	Instrumentation Services and Technology Project
IVRRF	In Vivo Radioassay and Research Facility
LaserREX	CD-ROM imaging subsystem to REX
LEPD	low-energy photon detector
LLNL	Lawrence Livermore National Laboratory
LMSI	Lockheed Martin Services Incorporated
LSR	Low-Scatter Room
MDA	minimal detectable activity
MDI	minimum detectable intake
MTL	minimum testing level
MQA	measurement quality assurance
NBS	National Bureau of Standards
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NPL	National Physical Laboratory
NRPB	National Radiation Protection Board (United Kingdom)
NVLAP	National Voluntary Laboratory Accreditation Program
PC	personal computer
PEPA	Performance Evaluation Program Administrator
PFP	Plutonium Finishing Plant
PHMC	Project Hanford Management Contractor
PNNL	Pacific Northwest National Laboratory

PTB	Physikalisch-Technische Bundesanstalt
PTW	Physikalisch-Technische Werkstäten
QA	quality assurance
QC	quality control
REX	Radiological Exposure (system)
R&HT	Radiation and Health Technology
RL	U.S. Department of Energy Richland Field Office
RS&CP	(Hanford) Radiation Standards and Calibrations Project
RWP	Radiation Work Permit
SBMS	Standards Based Management System
SCMP	Software Configuration Management Plan
SOW	Statement of Work
TIBM	thoron in-breath monitor
TL	thermoluminescent (dosimetry)
TLD	thermoluminescent dosimeter
TRU	transuranium radionuclide(s)
UK	United Kingdom
USTUR	U.S. Transuranium and Uranium Registry
WBCP	(Hanford) Whole Body Counting Project
Y2K	Year 2000

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1.0 Introduction

Specific radiation protection services are performed routinely by the Pacific Northwest National Laboratory (PNNL)[(a)] for the U.S. Department of Energy (DOE) Richland Operations Office (RL) and the Hanford Site contractors. These site-wide services are provided by projects in 1) external dosimetry, 2) internal dosimetry, 3) whole body counting, 4) radiation records, 5) instrument calibration and evaluation, and 6) calibration of radiation sources traceable to the National Institute of Science and Technology (NIST). The project work is performed by staff in the Radiation and Health Technology (R&HT) technical group, which falls under the purview of the Environmental Technology Division. The R&HT is comprised of the former Radiation Protection Services technical group and Dosimetry Research and Technology (DR&T) technical group. The former DR&T technical group is now an R&HT project that continues to be responsible for calibration of radiation sources traceable to NIST.

In addition to DR&T, R&HT is organized into four functional groups: 1) Dosimetry Services, 2) Instrumentation Services and Technology, 3) Radiation Records, and 4) Administration. The Dosimetry Services group includes the Hanford External Dosimetry Project, the Hanford Internal Dosimetry Project, and the Hanford Whole Body Counting Project, which includes the operational and technical staff at the In Vivo Radioassay and Research Facility (IVRRF); and the Dosimetry Operations Project, which includes all of the Dosimetry Services technician staff that perform the processing of dosimeters, handling of dosimeters and bioassay scheduling for the Project Hanford Management Contractor (PHMC) and RL, and Radiological Exposure (REX) data processing (which was transferred from the Hanford Radiological Records Project). The Instrumentation Services and Technology group was divided into three projects: Calibration Services, Instrument Repair, and Instrument Testing and Qualification. Last year's Information Services group was reincarnated as the Radiation Records group, which retained the Records Library, Exposure Reporting, and Data Administration tasks. Information Services policy and planning for R&HT were assigned to a staff position reporting directly to the R&HT manager. The Administration group is responsible for financial planning and secretarial support.

Although some of the projects described in this report are involved in activities funded by other sources, only those activities funded by RL, DOE Headquarters (HQ), or the Hanford contractors are addressed here. Services provided for non-RL activities are performed only to the extent that they do not adversely affect services to DOE and its contractors. These non-RL services provide funds that support the overall program and reduce costs to RL and to the Hanford contractors.

Each of the six primary projects of R&HT is described in a separate chapter of this report: 1) the Hanford External Dosimetry Project, 2) the Hanford Internal Dosimetry Project, 3) the Hanford Whole Body Counting Project, 4) the Hanford Radiation Records Project, 5) the Hanford Instrumentation Services and Technology Project, and 6) the Hanford Radiation Standards and Calibrations Project. Project descriptions include:

(a) Pacific Northwest National Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

- the routine program, including any significant changes and improvements
- investigations, studies, and tasks performed in support of the routine program
- other project-related activities, such as publications, presentations, and professional memberships.

During calendar year (CY) 1998, the Hanford contractors consisted of PNNL, Bechtel Hanford, Inc. (BHI, also referred to as the Environmental Restoration Contract team [ERC]), the Hanford Environmental Health Foundation (HEHF), and the PHMC. The PHMC included Fluor Daniel Hanford (FDH), six subcontractors, and six enterprise companies. The present six subcontractors are 1) Babcock and Wilcox Hanford Company; 2) Duke Engineering & Services Hanford, Inc.; 3) Dyncorp Tri-Cities Services, Inc.; 4) Lockheed Martin Hanford Corporation; 5) Numatec Hanford Corporation; and 6) Waste Management Federal Services of Hanford, Inc. The six enterprise companies are 1) Babcock and Wilcox Protec, Inc.; 2) Duke Engineering & Services Northwest, Inc.; 3) Fluor Daniel Northwest, Inc.; 4) Lockheed Martin Services, Inc.; 5) Waste Management Federal Services, Inc., Northwest Operations; and 6) Cogema Engineering Corporation. In general, the term PHMC will be used when referring to the contractor, subcontractors, and enterprise companies.

The PNNL and RL management structure and communication interfaces for each PNNL-operated project are shown in the organizational charts in Figures 1.1 and 1.2. Figure 1.1 shows the organization through September 1998; Figure 1.2 shows the organization since October 1998. The RL Science and Technology Programs Division is now responsible for PNNL services in this area.

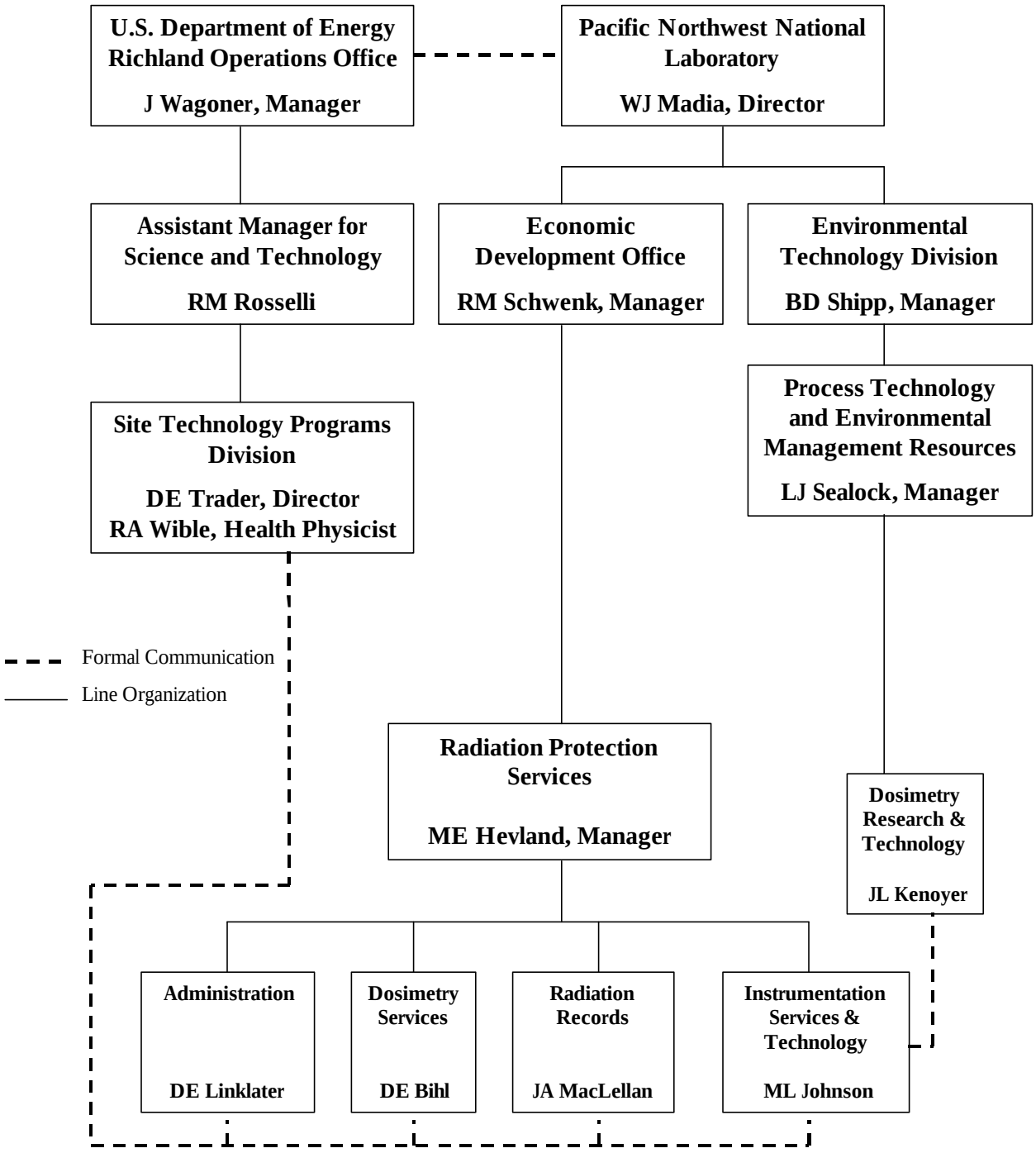

Figure 1.1. Management Structure and Major Communication Interfaces for Hanford Radiation Protection Services through September 1998

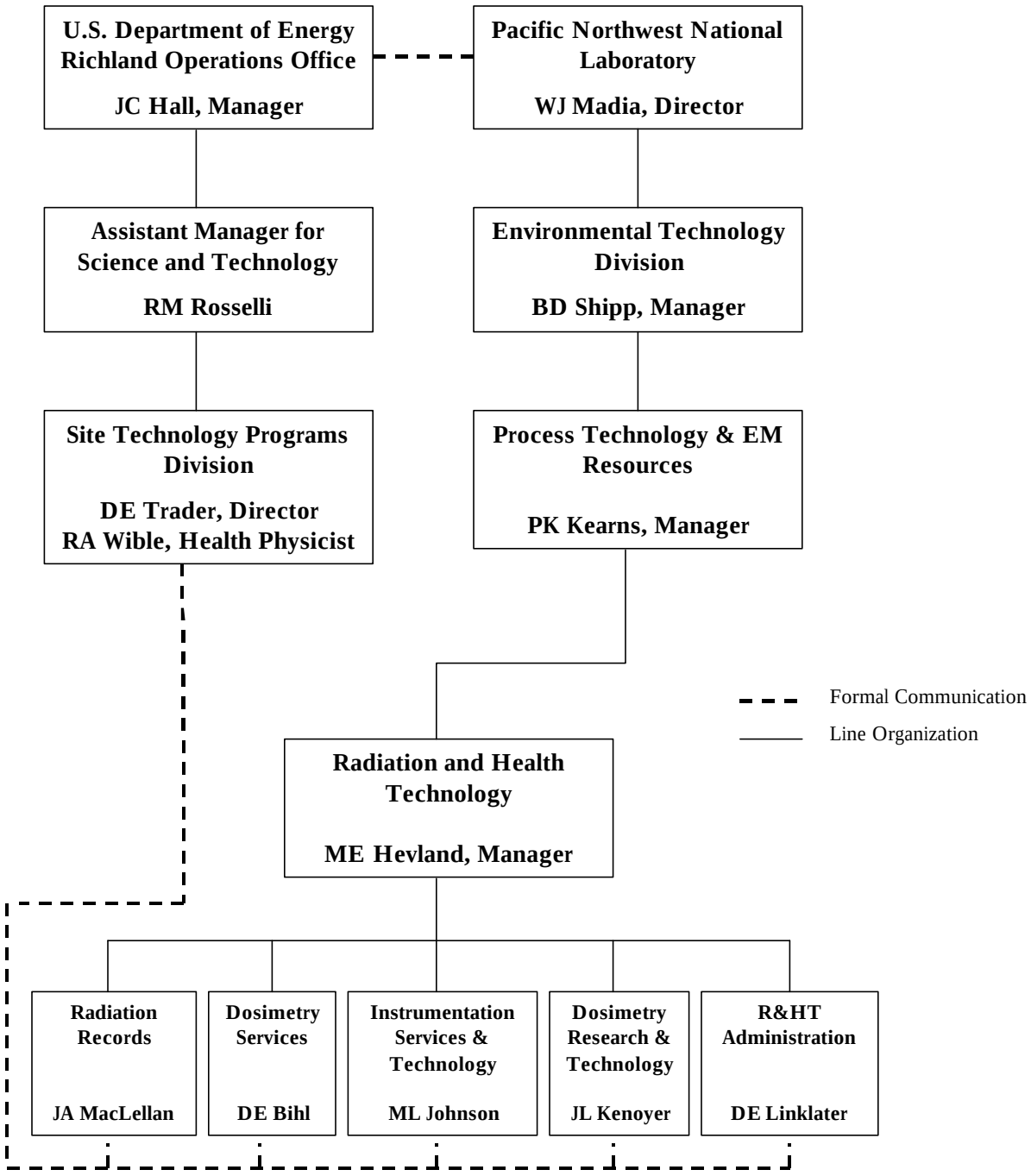

Figure 1.2. Management Structure and Major Communication Interfaces for Hanford Radiation Protection Services since October 1, 1998

2.0 Hanford External Dosimetry Project

The Hanford External Dosimetry Project (HEDP) has been an integral part of worker radiation protection for the Hanford Site since 1944 (Wilson 1987). The HEDP provides the official dose from external radiation for all Hanford personnel in support of Hanford radiation protection programs. HEDP dosimeter results provide the means used by contractor personnel to project, control, and measure radiation doses received by personnel. The project also provides site-wide nuclear accident and environmental dosimetry capabilities. The project operates in compliance with DOE requirements as set forth in 10 CFR 835, Occupation Radiation Protection (DOE 1993) and the *Hanford Site Radiological Control Manual* (RL 1994), and the project is accredited by both the Department of Energy Laboratory Accreditation Program (DOELAP) and the Department of Commerce National Voluntary Laboratory Accreditation Program (NVLAP).

The Hanford whole body personnel dosimetry system consists of a commercially procured thermo-luminescent (TL) dosimetry system (manufactured by Bicron/Harshaw).[(a)] Dosimeters include the Hanford standard dosimeter (HSD), the Hanford combination neutron dosimeter (HCND), an extremity dosimeter, and the Hanford environmental dosimeter. Personnel not exposed to neutrons receive the HSD, which may also be used as an extremity (wrist or ankle) dosimeter. The HSD also has a neutron response capability that will detect exposure to neutron radiation, although in 1998 the neutron dose was not considered official. If the HSD detected neutrons, the result was evaluated by contractor radiation protection staff to determine the official neutron dose. If personnel were potentially exposed to neutron radiation, then an HCND was assigned to them. Changes to this practice were being made in 1998 for implementation in 1999 (see Section 2.3.4). The HCND also has the provision for a CR39 track-etch dosimeter, although the track-etch was not used for personnel in 1998. The Hanford extremity personnel dosimetry system consists of a commercially procured Bicron/Harshaw "chipstrate" extremity dosimeter insert enclosed in an ICN/MeasuRing[(b)] ring casing.

2.1 Performance Evaluations

1998 was a busy year for assessments of the HEDP. There were three external and two internal performance reviews, as discussed in the following sections.

2.1.1 DOELAP Accreditation

Performance testing and an onsite inspection occur every two years for DOELAP, including 1998. Performance testing occurred from January through June 1998. The HEDP was tested in 36 categories, including 10 new categories. The new categories included chipstrate extremity dosimetry, HSD extremity dosimetry, and moderated and unmoderated neutron dosimetry for both the HSD and HCND, both alone and in mixture with photons. Also, the Performance Evaluation Program Administrator (PEPA) required that the HCND be treated as two separate dosimeters: one with and one without CR39. In total, over

(a) Bicron, Saint-Gobain/Norton Industrial Ceramic Corporation, Solon, Ohio.
(b) ICN Biomedicals, Inc., Costa Mesa, California.

1000 results were submitted to the PEPA for DOELAP performance testing. HEDP successfully passed all requested categories. Testing results for Hanford whole body and extremity dosimeters are summarized in Tables 2.1 and 2.2, respectively. Exposures included personnel and accident-level doses (as high as 500 rems) for personnel whole body dosimeters. Whole body and extremity dosimeter performance testing followed recommendations in American National Standards Institute/Health Physics Society standards HPS N13.11-1993, *An American National Standard, Personnel Dosimetry Performance - Criteria for Testing*, and HPS N13.32, *An American National Standard, Performance Testing of Extremity Dosimeters*, respectively (ANSI/HPS 1993; ANSI/HPS 1995a). Excellent performance was shown by the Hanford dosimeters, as indicated in Tables 2.1 and 2.2, by comparing the calculated

Table 2.1. DOELAP Performance Test Data for Hanford Whole Body Dosimeters

DOELAP Category Description	DOELAP Criterion	Performance[(a)]				
		HSD		HCND		HCND with CR39
		Shallow	Deep	Shallow	Deep	Deep
High Dose, Low-Energy Photons	0.3	NA	0.005	NA	0.029	NA
High Dose, High-Energy Photons	0.3	NA	0.015	NA	0.021	NA
Low-Energy Photons, General	0.3	0.080	0.192	0.093	0.150	NA
Low-Energy Photons, Plutonium Environments	0.3	0.132	0.173	0.141	0.181	NA
High-Energy Photons, ^{137}Cs	0.3	0.024	-0.004	0.021	0.001	NA
Beta Particles: General	0.4/0.3	-0.036[(b)]	NA	0.006	NA	NA
Neutron, Moderated ^{252}Cf	0.3	NA	0.132	NA	0.037	0.084
Neutron, Unmoderated ^{252}Cf	0.3	NA	0.062	NA	0.086	0.067
Mixtures						
Low-Energy Photons + High-Energy Photons	0.4	0.081	0.105	0.202	0.164	NA
Low-Energy Photons + Beta Particles	0.4	0.158	0.015	0.104	0.021	NA
High Energy Photons + Beta Particles	0.4	0.156	0.002	0.135	0.002	NA
Low-Energy Photons + Moderated Neutrons	0.4	NA	0.070	NA	NA	NA
High-Energy Photons + Moderated Neutrons	0.4	NA	0.072	NA	NA	NA
Low-Energy Photons + Unmoderated Neutrons	0.4	NA	NA	NA	0.093	NA
High-Energy Photons + Unmoderated Neutrons	0.4	NA	NA	NA	0.027	NA

(a) Performance quotients (P) for Hanford standard dosimeter (HSD) and Hanford combination neutron dosimeter (HCND) are calculated as $P = |B| + S - |E|$ where B is the bias from the known (delivered) dose, S is the standard deviation of the reported results, and E is the uncertainty in the delivered dose. Dosimeter performance quotients must be less than the DOELAP criterion in each category for satisfactory performance.

(b) For this category only, with ^{204}Tl beta radiation, the performance quotient is calculated as $P = |B| - |E|$ and the criterion is 0.4.

Table 2.2. DOELAP Performance Test Data for Hanford Extremity Dosimeters, Shallow-Dose

DOELAP Category Description	DOELAP Criterion	Performance (Shallow Dose)[a]	
		HSD	Ring
High Dose General Photons	0.3	0.067	0.184
Low-Energy Photons	0.5	0.146	0.139
High-Energy Photons	0.5	0.032	0.062
Beta Particles	0.5	0.126	0.167

(a) Performance quotients (P) for Hanford extremity dosimeters are calculated as $P = |B| + S$ where B is bias from the known (delivered) dose and S is the standard deviation of the reported results. Dosimeter performance quotients must be less than the DOELAP criterion in each category for satisfactory performance.

performance of the respective dosimeters with the DOELAP criterion in each irradiation category. In every category, the Hanford performance is well below the 0.3 or 0.4 criterion. Figures 2.1 through 2.6 illustrate the DOELAP performance for the HSD whole body dosimeter, the HCND whole body dosimeter, the Hanford ring dosimeter, and the HSD as an extremity dosimeter in the respective DOELAP exposure categories using Horlick diagrams.

The onsite technical program assessment was conducted June 15-16, 1998, to examine HEDP documentation and practices relative to the requirements of the DOELAP Handbook (DOE 1986). The assessment noted no deficiencies and five concerns.[a] The five concerns are paraphrased below.

1. Maintenance on the thermoluminescent dosimeter (TLD) readers was not being performed according to the frequencies specified in the procedures.

2. A method has not been established for accurately monitoring the etching temperature in the ovens used for CR39 electrochemical etching, and no tolerance has been established for oven temperature.

3. The procedure for electrochemical etching the CR39 needs to establish the number of times the etchant can be reused before it is discarded.

4. A method has not been established for monitoring the electrical voltage and frequency applied to the etch chamber used for CR39 electrochemical etching, and the procedure does not address what is done if the voltage or frequency falls out of tolerance.

5. The current method for subtracting background values from dosimeter element readings is not updated in the project documentation.

Resolution of concerns 1, 3, and 5 were completed in CY98 through revisions to procedures and the technical basis document and by reestablishing a schedule for routine maintenance of the readers. Resolution of concerns 2 and 4 required purchase, installation, and testing of equipment as well as major revision to the track-etch procedure. Significant progress on those actions had been made by year-end.

(a) Deficiencies are issues that can preclude obtaining DOELAP accreditation, and concerns are issues that require a formal corrective action plan.

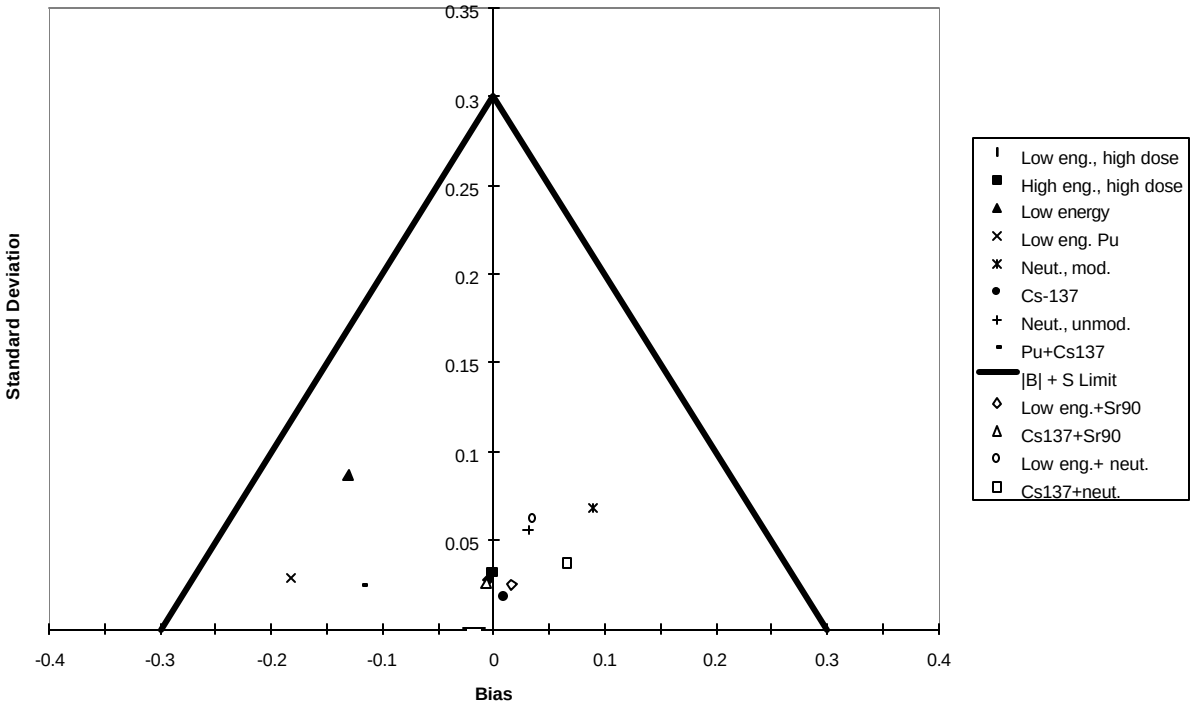

Figure 2.1. DOELAP Performance Results: HSD Whole Body Dosimeter, Deep Dose

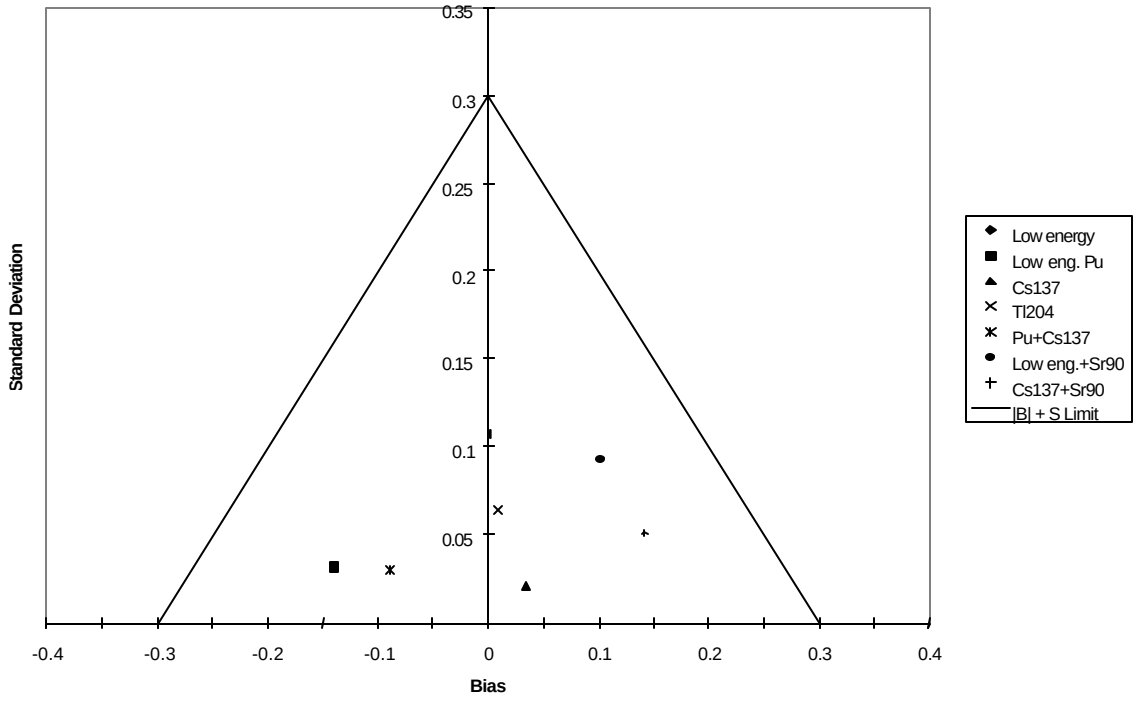

Figure 2.2. DOELAP Performance Results: HSD Whole Body Dosimeter, Shallow Dose

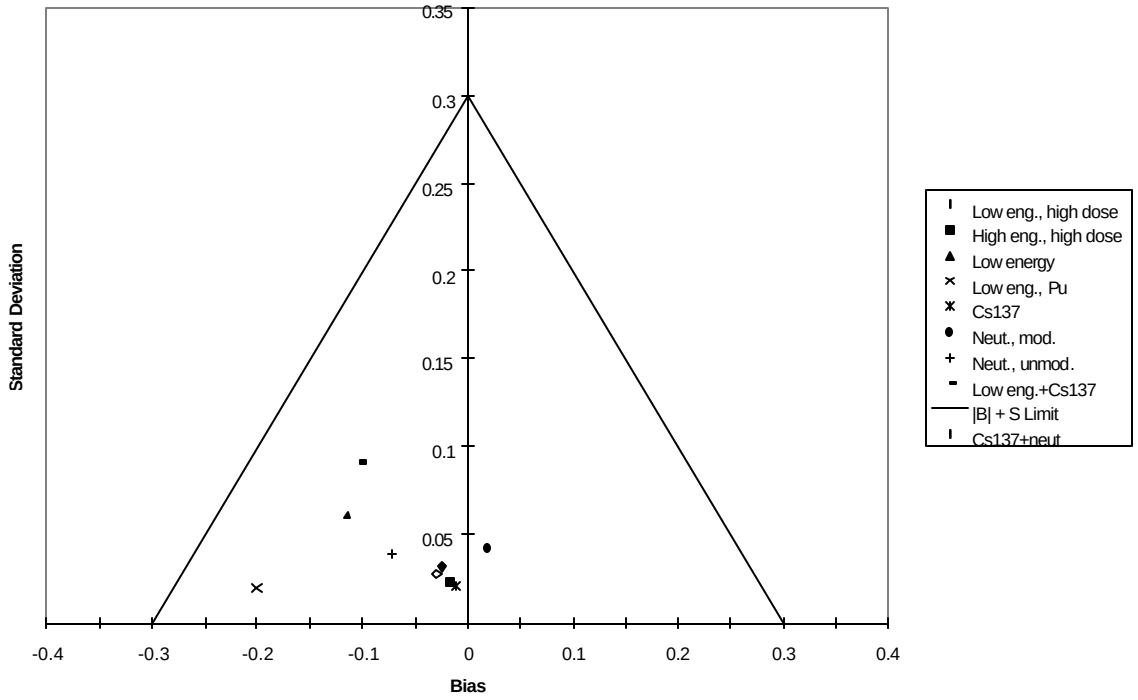

Figure 2.3. DOELAP Performance Results: HCND, Deep Dose

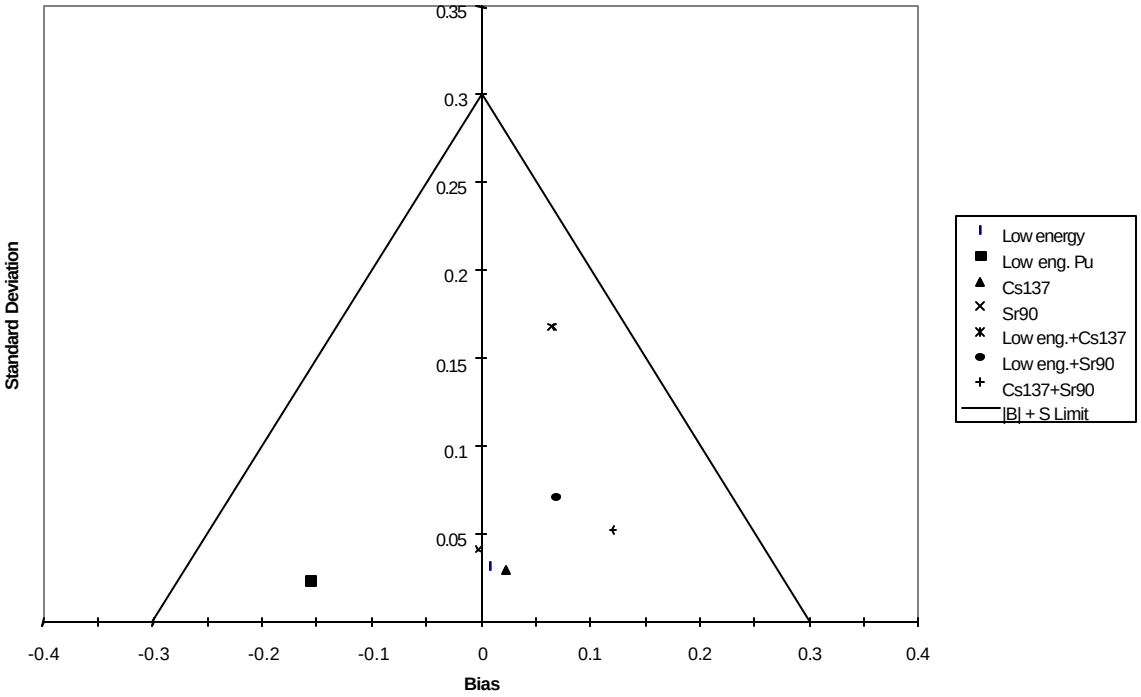

Figure 2.4. DOELAP Performance Results: HCND, Shallow Dose

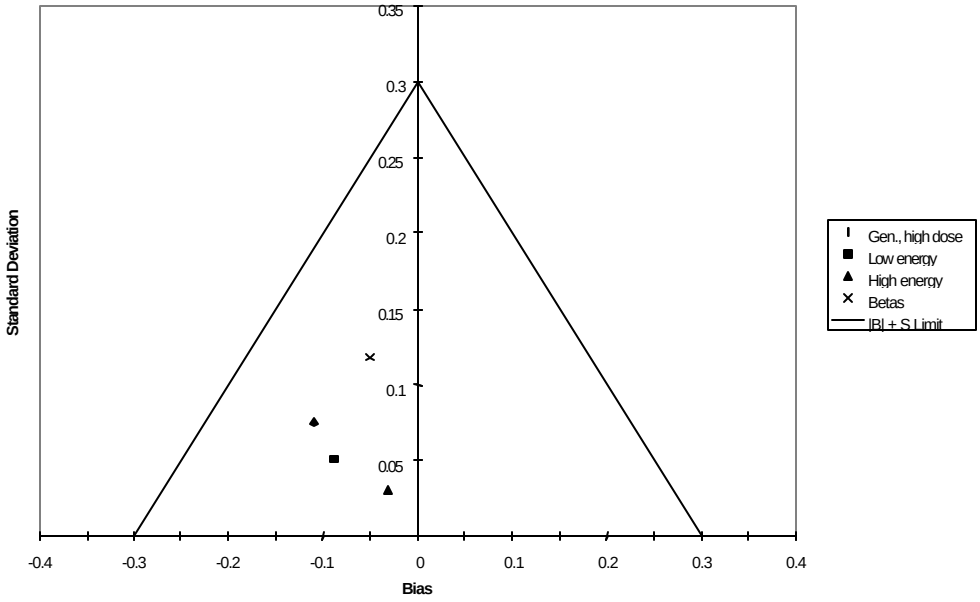

Figure 2.5. DOELAP Performance Results: Ring Dosimeter

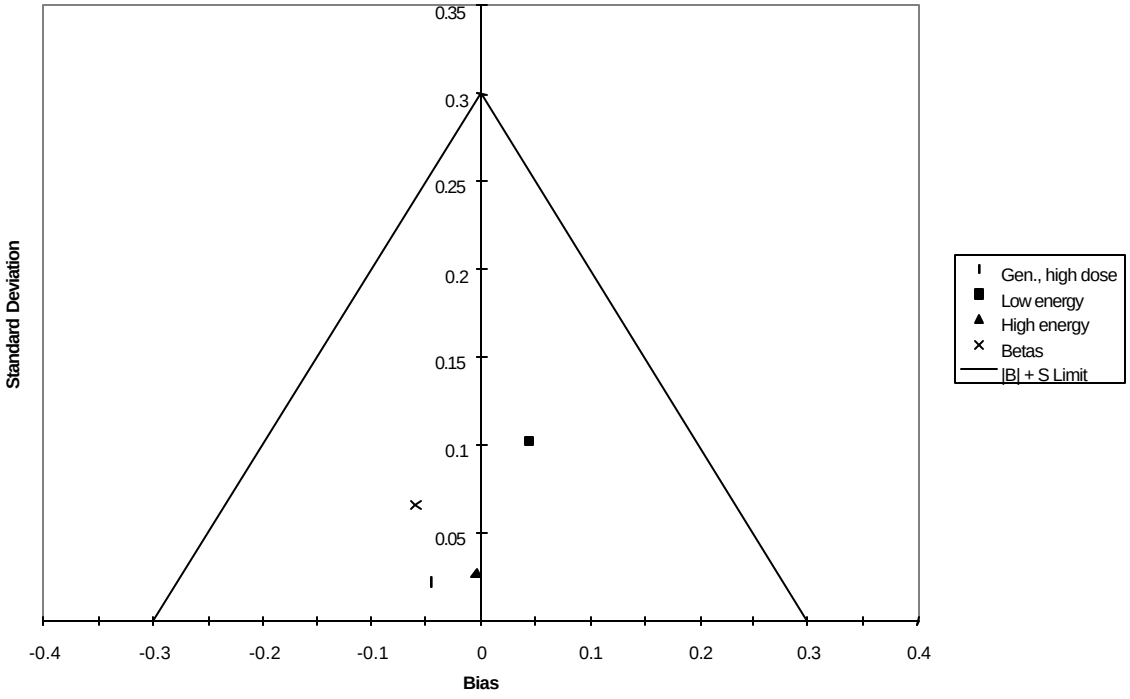

Figure 2.6. DOELAP Performance Results: HSD Extremity Dosimeter

2.1.2 10 CFR 835 Audit by Hanford Contractors

10 CFR 835.102 requires that all aspects of radiation protection programs be audited at least once every three years. Because external dosimetry is a fundamental part of the radiation protection programs of all the Hanford contractors, the contractors performed a joint audit of the HEDP in May to satisfy the 835.102 requirement. The scope of the audit also included requirements in the *Hanford Site Radiological Control Manual* (RL 1994). The audit concluded that the HEDP was in compliance with requirements of 10 CFR 835 and the *Hanford Site Radiological Control Manual*, but there were six areas in which compliance could be improved. Those observations are paraphrased below.

1. Project documentation needed to show equivalence for deep dose and eye dose between the units of mg/cm^2 in project documentation and the values in centimeters given in 10 CFR 835.

2. Skin dose procedures needed more detail for recording skin dose on a worker's record.

3. Documentation was not up-to-date concerning the calibration interval for the element correction coefficients.

4. A periodic review cycle was not established for the *Hanford External Dosimetry Technical Basis Manual*.[(a)]

5. Statements in the *Hanford External Dosimetry Technical Basis Manual* concerning selection of workers to be monitored needed to duplicate the requirements in 10 CFR 835.

6. There was no documentation specifying that records are required to be transferred to the DOE records repository.

Corrective actions were completed by year-end for observations 4 and 5, and documentation changes were in progress for observations 1, 2, and 3. In response to observation 6, a closer review of project documentation was conducted showing that the project was generally in compliance, but the same review revealed a weakness in archiving electronic versions of the software. A mechanism was then set up to make annual copies of the software for archiving.

2.1.3 RL Assessment

The Performance Assessment Division of RL performed an assessment of external dosimetry practices at the Hanford Site during the fall of 1998. The HEDP was included in the scope of the audit. Official results of the audit had not been released at year-end, although preliminary results indicated that there were gaps in the consistency between the project's letters to file and the project's manuals.

(a) Internal Manual, PNL-MA-842, Pacific Northwest National Laboratory, Richland, Washington (current version).

2.1.4 Self Assessments

Self (or internal) assessments of the HEDP are conducted annually. In 1998 two self assessments were conducted, one focussing on technical aspects and DOELAP and NVLAP requirements, the other focussing on software documentation.

2.1.5 DOE Environmental Dosimetry Pilot Testing

HEDP provides environmental dosimetry support to all Hanford contractors. The Hanford four-element environmental dosimeter is commercially procured from Bicron/Harshaw and consists of two LiF (TLD-700) and two $CaSO_4$ TL phosphors. These phosphors can be readily used in Hanford dosimeters and processed using existing readout equipment. Starting in 1997, DOE has funded pilot testing of draft HPS N13.29, *American National Standard, Environmental Dosimeter Performance Testing Criteria* (ANSI/HPS 1995b), for potential application to DOE facilities. The HEDP participated in the pilot test. Once the standard is finalized, DOE is expected to require compliance with the HPS N13.29 performance testing criteria. HPS N13.29 contains new requirements for measuring ambient and directional dose equivalent. These recommendations provide similarity between U.S. environmental dosimetry practices and the International Commission on Radiological Protection Publication 75 (ICRP 1997) operational quantities that are used internationally.

HEDP pilot test results were provided in a report (Klemic et al. 1998) and are summarized in Table 2.3. HEDP passed in all categories, and was one of only two participating labs that did so. The dose parameters required for the pilot test were different than those presently determined and reported routinely at Hanford so the test results are not strictly applicable to routine environmental dosimetry at Hanford.

Table 2.3. Hanford Environmental Dosimeter Results for the DOE Pilot Test

Test Category Description	Criterion	Results[(a)]	
		Ambient Dose Equivalent	Directional Dose Equivalent
High Dose General Photons	0.5	0.045	NA
High Dose, Beta Particles	0.5	NA	0.091
Routine Photons	0.5	0.036	NA
Routine Beta Particles	0.5	NA	0.117
H40 X-rays	0.5	0.089	0.091
H100 X-rays	0.5	0.079	0.079
^{137}Cs in Environmental Chamber (I)[(b)]	0.5	0.118	NA
^{137}Cs in Environmental Chamber (II)	0.5	0.129	NA
^{137}Cs in Environmental Chamber (III)	0.5	0.081	NA

(a) Performance quotients (P) for were calculated as P = |B| + S where B is bias from the known (delivered) dose and S is the standard deviation of the reported results. Dosimeter performance quotients must be less than the criterion.
(b) The three ^{137}Cs tests differed in the extremes and length of exposure to various temperatures and humidity.

2.1.6 Blind Audit Personnel Dosimeters

FDH routinely submits audit dosimeters to be processed along with PHMC personnel dosimeters. Audit dosimeters are submitted every month, and performance is analyzed each quarter for shallow, deep, and neutron dose, and dose to the finger ring dosimeters. HEDP successfully passed each of the quarterly evaluations in 1998 using DOELAP performance criteria. Documentation of HEDP results of these audits is included in the Hanford Radiation Protection Historical Files, which are maintained by the Hanford Radiological Records Project (HRRP).

2.1.7 Blind Audit Environmental Dosimeters

PNNL Environmental Surveillance Program staff routinely submit audit environmental dosimeters to be processed along with their quarterly exchanged environmental dosimeters. The given exposure ranges are typically between 15 and 30 mrems of ^{137}Cs gamma radiation. For the 12 audit dosimeters submitted during 1998, the overall bias in the reported dose compared with the delivered dose was 1.25%, with a range in the bias of individual dosimeters from -1.55% to 4.60%.

2.2 Hanford Dose Results During 1998

During 1998, 52,393 official personnel dose results were reported for Hanford customers. This processing volume represented a 29% decrease from the total of 73,980 processed during 1997. The annual number of dose results is illustrated in Figure 2.7 for 1993 to 1998 for each type of dosimeter. In

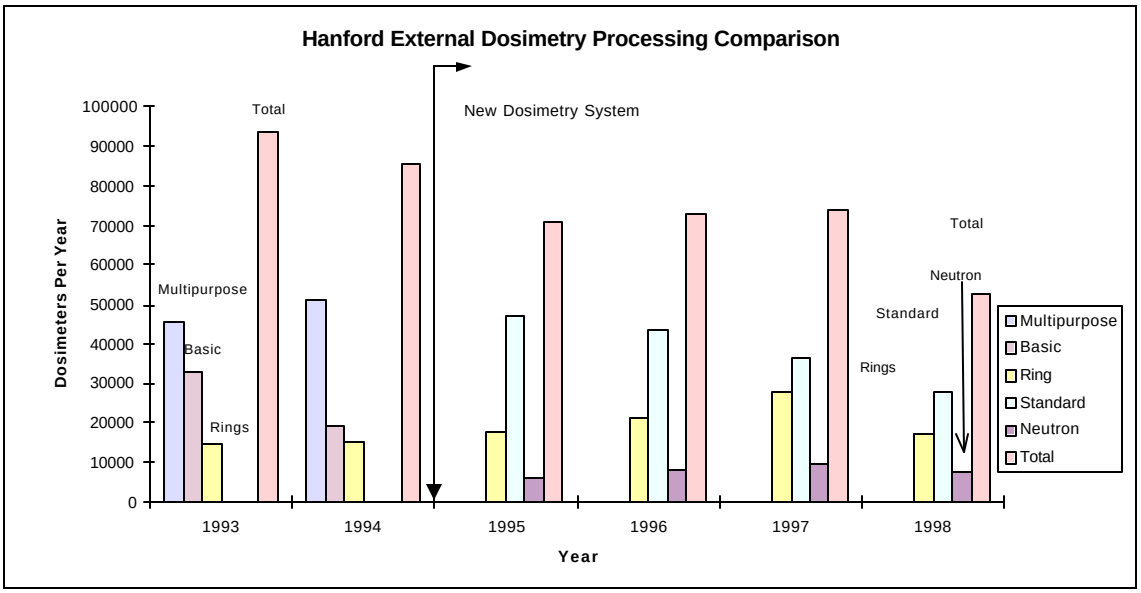

Figure 2.7. Trend in Reported Hanford Personnel Dosimeter Results

this figure, the comparison is complicated because the current whole body personnel dosimetry system was implemented in January 1995 and the current extremity dosimetry system was implemented in July 1996. Previously, the Hanford personnel dosimetry system included several thousand single-chip basic dosimeters, typically assigned to employees who had little potential for occupational exposure. The current personnel dosimetry system consists of multi-chip dosimeters, which are typically issued only to individuals with a potential for exceeding the 10 CFR 835.402 monitoring thresholds. The numbers in Figure 2.3 do not include internal quality control (QC) dosimeter cards or cards processed in support of DOELAP testing.

The volume decreased for all categories of personnel dosimeters (HSD down 24%, HCND down 21%, rings down 39%). The decreases were, in part, due to a change in the policy for when multiple dosimetry is required (see Section 2.3.1). This resulted in an immediate and large decrease in the number of multiple dosimetry packages worn by workers during work in nonhomogeneous radiation fields. Also, the allowable frequency of exchange for finger rings was increased from monthly to quarterly, and the contractors switched many of their workers to the quarterly frequency in July.

As in previous years, the CR39 track-etch capability of the HCND was not used. This action was recommended by the Hanford Personnel Dosimetry Advisory Committee (HPDAC) and was based on the relatively low-energy neutron spectra at the Plutonium Finishing Plant (PFP). Plutonium at PFP is primarily being stored awaiting DOE decisions about its eventual disposition. As such, the neutron energy spectra are greatly moderated because of the extensive shielding, and the neutrons are primarily less energetic than the approximate 100-keV energy threshold of the track-etch foil. Field measurements at PFP have shown consistent under-estimation of the actual neutron dose with the track-etch foil (Endres et al. 1996).

Statistics on external doses received by the Hanford workforce are provided in Table 2.4. This is the first year these statistics were gathered so there is no comparison with previous years. The highest external dose for an individual worker was 1204 mrems.

Table 2.4. External Doses Received by Hanford Workers in 1998[a]

Dose Range (mrems)	Number of Worker in Dose Range						
	ERC[b]	PHMC	PNNL	DOE	HEHF	Other	Total
<10	862	3962	1427	1005	32	974	8226 (82.4%))
10-99	138	645	205	34	1	204	1227 (12.3%)
100-249	36	202	43	2	0	30	313 (3.1%)
250-499	29	114	11	0	0	12	166 (1.7%)
500-749	13	19	4	0	0	0	36 (0.4%)
750-999	3	5	0	0	0	0	8 (0.1%)
1000-1999	3	0	0	0	0	0	3 (<0.1%)
>2000	0	0	0	0	0	0	0 (0.0%)

(a) For monitored workers.
(b) ERC = Environmental Restoration Contractor.

In addition to personnel dosimeters, the HEDP also processed 1,606 area dosimeters, 812 environmental dosimeters, and 87 fixed nuclear accident dosimeters.

Each year numerous internal audit dosimeters are processed to ensure the integrity of dosimeter processing. During 1998, 920 internal audit dosimeters were processed. A breakdown of the internal audit dosimeters is shown in Table 2.5.

Table 2.5. Audit Dosimeters Processed during 1998

Dosimeter Type	No. of Dosimeters
HSD	375
HCND	255
Rings	120
CR39 Track-Etch	170

Data analysis programs are used to statistically evaluate the performance for each of the audit dosimeter categories against DOELAP criteria. Reports are prepared for every dosimeter and radiation type for each of the 13 dosimeter processings (i.e., every month plus annual) conducted each year. A QC checklist is prepared for each processing. Copies of the checklists and audit dosimeter performance reports are provided to the Hanford Radiation Protection Historical Files.

Statistical tracking of dosimeters that were issued then subsequently lost or not returned for whatever reason was introduced in 1998 after being suspended for a couple of years. The data that follow apply to lost dosimeters issued during the period from January 1, 1995, through November 1, 1998. Because there are lag periods before unreturned dosimeters are declared lost, not all potentially lost dosimeters are included in these statistics. The lag periods are 60 days for monthly exchanged dosimeters, 180 days for quarterly exchanged dosimeters, and 465 days for annually exchanged dosimeters. In 1998, 606 dosimeters were declared lost, as follows: 325 HSDs, 22 HCNDs, 251 rings, and 8 area dosimeters. There were 733 Investigations of Dosimeter Results (IODRs) processed in 1998 as follows: 48 for DOE, 454 for PHMC, 166 for PNNL, and 65 for ERC.

2.3 Changes in Routine HEDP Practices During 1998

Modifications to HEDP practices are discussed during HPDAC meetings. Changes in project practices made during 1998 are described in the following sections.

2.3.1 Change in Criterion for Assigning Multiple Dosimetry

Based on recommendations from the HPDAC, the Radiological Control Forum approved a technical equivalency determination that allowed for using the effective dose equivalent to determine if multiple dosimetry is needed for work in nonhomogeneous radiation fields. The text of the technical equivalency determination was as follows:

Multiple whole body dosimetry should be worn when *either* of the following two criteria are met.

1. The calculated effective dose equivalent is expected to exceed the deep plus neutron dose equivalent measured by the reference dosimeter by more than 30%, and is expected to exceed 100 mrems.

2. The calculated effective dose equivalent is expected to exceed the deep plus neutron dose equivalent measured by the reference dosimeter by more than 100 mrems.

The change to the effective dose equivalent approach, using weighting factors in 10 CFR 835, was based on recommendations in HPS N13.41, *Criteria for Performing Multiple Dosimetry* (ANSI/HPS 1997) and in the *External Dosimetry Program Implementation Guide* (DOE 1994a). The changes were incorporated in the *Hanford External Dosimetry Technical Basis Manual.*

2.3.2 Change in HEDP Documentation

During the October 1997 HPDAC meeting,[(a)] changes in HEDP documentation were discussed. The objective of planned changes was to eliminate externally distributed manuals that conflict with other site manuals or contain information or criteria outside of HEDP responsibilities. After approval by the HPDAC, the following three manuals were taken out of service in 1998:

- PNL-MA-568, *Hanford External Dosimetry Project Manual* (in September).

- PNL-MA-583, *Locations of Criticality Detectors and Nuclear Accident Dosimeters at Hanford* (in March).

- PNL-MA-865, *Hanford Site Criticality Incident Response Plan* (in March).

As a consequence of these actions, HEDP now maintains only two manuals for use by other Hanford organizations. These are

- PNL-MA-842, *Hanford External Dosimetry Technical Basis Manual*

- PNL-MA-859, *Hanford External Dosimetry Project Quality Manual.*[(b)]

(a) D. E. Bihl, "Minutes of the Hanford Personnel Dosimetry Advisory Committee Meeting held on October 15, 1997." (A copy is available in the Hanford Radiation Protection Historical Files.)
(b) Internal Manual, PNL-MA-859, *Hanford External Dosimetry Project Quality Manual,* Pacific Northwest National Laboratory (current version).

The HEDP plans to continue to use the following existing internal project manuals:

- *Quality Assurance Plan for Hanford External Dosimetry Project*, LSC-022,[a] used to identify quality assurance requirements
- PNL-MA-841, *Hanford External Dosimetry Project Procedures Manual*[b]
- PNL-MA-843, *Track-Etch Detector Analysis (TEDA) Users Manual*[c]
- PNNL-MA-844, *Hanford External Dosimetry Project Data Management Manual.*[d]

2.3.3 Element Correction Coefficient Recalibration

A study was conducted to determine if the sensitivity of the population of chips in the HSD cards had drifted from the time of initial generation of the element correction coefficients. A total of 556 routinely used HSD cards were recalibrated as a sample to observe the change in calibration over the period from 1994 to 1998. The cards had a usage history of between 12 to 18 readings. The study concluded that changes in the element correction coefficients were very small and that recalibration after six years of use was acceptable.

As a consequence of the study, a decision was made to start recalibration of all HSD and HCND cards such that all dosimeters issued after January 1, 1999, would have newly determined element correction coefficients. That task was carried out during the summer and fall of 1998 and the goal was met. Cards in use in 1998 and returned in 1999 will be recalibrated before being reissued.

2.3.4 Two Decisions Affecting Neutron Dosimetry

A study of the fade characteristics for the HCND over 14 months was concluded in 1998, and it showed that the fade was less than 30%. This was considered an acceptable degree of fade that could be accounted for in the dose calculation algorithm. A decision was made to allow an annual exchange frequency for the HCND with the recommendation that it be used for workers historically showing low neutron doses. The change was implemented with the January 1999 cycle.

Because the HSD was accredited for neutrons for the first time in 1998, it technically could be used to record neutron dose. Because it has only a single neutron-sensitive chip, the HSD can only be used in well-characterized neutron fields, and the HEDP generally recommends that it be used only as an

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(a) Internal Manual, LSC-022, *Quality Assurance Plan for Hanford External Dosimetry Project*, Pacific Northwest National Laboratory, Richland, Washington.
(b) Internal Manual, PNL-MA-841, *Hanford External Dosimetry Project Procedures Manual*, Pacific Northwest National Laboratory, Richland, Washington.
(c) Internal Manual, PNL-MA-843, *Track-Etch Detector Analysis (TEDA) Users Manual*, Pacific Northwest National Laboratory, Richland, Washington.
(d) Internal Manual, PNL-MA-844, *Hanford External Dosimetry Project Data Management Manual*, Pacific Northwest National Laboratory, Richland, Washington.

indicator of neutron exposure. Nevertheless, contractors requested changes so that neutron dose recorded on the HSD can be considered an official dose, if the dose is less than 100 mrems and if the neutrons are low energy. To accommodate this request, a new note code (NC59) was implemented. The NC59 alerts the contractor dosimetry representatives that neutron dose was measured on the HSD, but a written concurrence for the dose of record, using the Investigation of Dosimeter Result (IODR) form, is no longer needed to make the dose official. The change was implemented on January 1, 1999.

2.3.5 Background Subtraction

HEDP staff implemented a change in the method used to subtract natural background dose from personnel dosimeters. The change consisted of adopting a constant for the intrinsic chip background rather than using a value measured on a group-by-group basis from blank cards in the group. The effect on dose results was extremely small. The change was documented in both the technical basis document and the quality manual.

2.3.6 Cleaning of Holders

A subcontract was established with Columbia Industries in May for cleaning the routinely assigned whole body dosimeter holders. A sonic-based cleaning system was tested, purchased, and installed for cleaning temporarily assigned holders, and plans are to test the feasibility of using the sonicator for cleaning dosimeter cards.

2.4 Other Notable Activities

2.4.1 Year 2000 Preparations

The HEDP was determined to be mission critical according to DOE-HQ guidelines. Use of computers and processors by HEDP would have had to been tested and, if necessary, fixed, regardless of the mission-critical status by DOE; but being mission critical meant more rigor in documentation and more formal oversight. Both the model 8800 readers (for the whole body dosimeters) and the model 6600 readers (for the finger rings) were determined to *not* be Year 2000 (Y2K) compliant. Fixes for two model 8800 readers were procured, installed, and tested in 1998. The package to fix the Y2K problem also included upgrades to most of the hardware, so two of the model 8800 readers were completely overhauled. It is planned to request capital equipment funding for upgrades of the other two model 8800 readers over the next two years. Fixes for the two model 6600 readers were ordered. These fixes are simpler, involving only a new processing chip.

The VAX cluster was tested and found to be Y2K compliant. Arrangements were made to have verification and validation tasks performed by an outside expert independent of the HEDP. Arrangements were also made to perform final, end-to-end testing of all the systems while being observed by the outside expert. Those activities were scheduled for February 1999.

The contingency plan for failure of the processing equipment in the 318 Building was reviewed and enhanced as part of the various Y2K activities.

2.4.2 Using the Hanford Combination Neutron Dosimeter as an Area Dosimeter

Coding and labeling capabilities were put in place so that the HCND could be used as an area dosimeter. Routine use was implemented in May. The dosimeters are hung on 5-gal water-filled carboys as phantoms.

2.5 Skin Contaminations

Hanford skin contamination statistics are provided in Table 2.6. This is the first year these statistics were collected so no comparisons with previous years' statistics were available.

Table 2.6. Number of Skin Contaminations (Worker Events)[(a)] in 1998

Number of Skin Contaminations					
PHMC	**PNNL**	**ERC**	**DOE**	**Other**	**Total**
66	11	17	0	8	102
(a) Each contamination event for a single worker counted separately.					

2.6 Project-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1998 are listed in this section.

2.6.1 Activities

Jack J. Fix was involved in professional external dosimetry activities, outside of the Hanford Site, as follows:

- Conducted the DOELAP onsite technical assessment of the Lawrence Livermore National Laboratory from June 20 to 24, 1998, and Thomas Jefferson National Accelerator Facility from November 3 to 6, 1998.

- Participated as a member of the DOELAP Oversight Board during February 22 to 25 and September 14 to 16, 1998 meetings.

- Participated as a member of the dosimetry subcommittee in meetings of the International Agency for Research on Cancer (IARC) from March 29 to April 3, 1998, in Lyon, France, regarding a collaborative epidemiologic study of nuclear workers from fourteen countries. This study includes Hanford worker data.

Bruce A. Rathbone participated in professional external dosimetry activities, outside of the Hanford Site, as follows:

- Served as technical reviewer for papers published in the proceedings of the 12th Conference on Solid State Dosimetry.

2.6.2 Presentations

Rathbone, B.A. *Assessment of Ring Correction Factors for Use at Hanford*. PNNL-SA-29805, presented at Meeting the Global Needs of Dosimetry Symposium, San Diego, California, March 1998.

Rathbone, B.A. *Performance Testing of the Harshaw 8825 Dosimeter for Both Extremity and Whole Body Applications Using a Single Neural Network Algorithm.* PNNL-SA-29804, presented at Meeting the Global Needs of Dosimetry Symposium, San Diego, California, March 1998.

2.6.3 Publications

None.

2.6.4 Professional Memberships

Fix, J.J., Member of DOELAP Oversight Board.

Fix, J.J., Chair of Health Physics Society Standards Committee.

Fix, J.J., Consultant to ANSI N13.29, American National Standard for Dosimetry - Environmental Dosimetry Performance Criteria for Testing, and N13.37, *American National Standard for Dosimetry, Performance Testing and Procedural Specifications for Environmental Thermoluminescent Dosimetry*, working groups.

Rathbone, B.A., Member, Health Physics Society (HPS) Working Group for ANSI N 13.37, *American National Standard for Environmental Dosimeters*.

3.0 Hanford Internal Dosimetry Project

The Hanford Internal Dosimetry Project (HIDP) was initiated in 1946 to provide for the assessment and documentation of occupational doses from intakes of radionuclides at the Hanford Site. The project is administered in support of Hanford radiation protection programs, as required by 10 CFR 835, *Occupational Radiation Protection* (DOE 1993) and the *Hanford Site Radiological Control Manual* (HSRCM-1; RL 1994). Additional guidance is provided by the implementation guide (DOE 1994b). The project provides the following internal dosimetry services:

- administration of a routine excreta monitoring program
- investigation and assessment of potential intakes
- monitoring performance of the contract excreta bioassay laboratory
- selection and application of models, procedures, and practices for evaluating intakes
- technical support to RL and to Hanford Site contractors
- 24-hour, single-point-of-contact technical support for radiological incidents at Hanford ("PNNL Exposure Evaluator")
- bioassay scheduling for the PHMC companies and RL.

3.1 Routine Tasks

The operational details of the HIDP are described in the following documents:

- The technical aspects of internal dose calculations are established in the *Technical Basis for Internal Dosimetry at Hanford*, Rev. 1 (Sula, Carbaugh, and Bihl 1991).
- The protocols and practices for operation of the project and coordination with the Hanford Site contractors are established in the *Hanford Internal Dosimetry Project Manual.*[(a)]
- Detailed procedures are contained in the *Hanford Internal Dosimetry Procedures Manual*,[(b)] which was completely revised and reissued in 1995.

(a) Internal Manual, PNL-MA-552, *Hanford Internal Dosimetry Project Manual*, Rev. 3, Pacific Northwest National Laboratory, Richland, Washington.

(b) Internal Manual, PNL-MA-565, *Hanford Internal Dosimetry Procedures Manual*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

- Protocols for responding to radiological incidents are contained in the *On-Call Exposure Evaluator Manual*.[(a)]

- The *Quality Assurance Plan for the Operation of the Hanford Internal Dosimetry Project*.[(b)]

- The technical agreements with the excreta lab are established by a Statement of Work (SOW).

- The division of responsibilities for meeting internal dosimetry and bioassay requirements of 10 CFR 835 is specified in a memorandum of agreement between FDH and R&HT.

The practices and technical aspects of operating the Hanford Whole Body Counting Project are established in the *Whole Body Counting Manual*[(c)] (see Chapter 4.0). Individual assessments of internal dose are documented in each individual's file in the HRRP files. Bioassay measurement results and internal doses are maintained in the REX database, which is operated by the HRRP (see Chapter 5.0).

Intakes of radionuclides are generally prevented by containment or other protective measures; therefore, intakes are normally assumed to result from an acute intake. Dose assessment is based on this assumption, except for work with tritium. Tritium intake is generally assumed to occur chronically throughout the period of exposure, and urine samples are normally obtained at the beginning and end of discrete work periods. An exception to the assumption of acute intake occurred as a result of an investigation of a routine bioassay in December 1997. Ultimately the investigation revealed that two workers in the 306-W Building had been receiving low-level chronic intakes of uranium. Workplace procedures and controls were modified and follow-up bioassay showed that the chronic intakes had stopped.

The "bioassay needs review" flag referred to in last year's report, was not active in CY98 because of an error in the data kept in the Access Control Entry System (ACES) upon which the needs review was based. A major revision to the ACES software is under way and will resolve this oversight.

There were an unusually high number of potential intake cases in CY98, which resulted in a backlog and longer-than-normal times to complete cases. The system for tracking the status of all of the cases and obtaining all of the needed bioassay or workplace data became highly stressed. A new position for a junior dosimetrist was opened and filled in November in response to the higher workload.

3.1.1 Bioassay Capabilities

Bioassay monitoring is performed regularly for workers who might inhale, ingest, or absorb radionuclides into their bodies in the course of their jobs. Measurement types and frequencies are based on the

(a) Internal Manual, PNL-MA-857, *On-Call Exposure Evaluator Manual*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.
(b) Internal Manual, LSC-026, *Quality Assurance Plan for the Operation of the Hanford Internal Dosimetry Project*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.
(c) Internal Manual, PNL-MA-574, *Whole Body Counting Manual*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

radionuclides of concern, their anticipated physical and chemical form, the relative risks of intakes for workers, and the costs of the bioassay (both analysis cost and cost of the worker's time away from the job). Minimum detectable activities (MDAs) and screening levels for routine excreta and in vivo bioassay measurements are shown in Tables 3.1 and 3.2. MDAs for emergency and expedited excreta measurements are provided in Table 3.3.

Table 3.1. Specified Minimum Detectable Activities and Screening Levels for Routine Excreta Analyses During 1998

Analysis[a]	Contractual MDA[b,c]	Screening Level and Sampling Frequency [c,d]
^{238}Pu, ^{239}Pu	0.02 dpm	0.01 dpm (A)
^{238}Pu, ^{239}Pu (IPUL)	0.05 dpm	0.003 dpm (A)
^{90}Sr	10 dpm	26 dpm (A) 11 dpm (BE)
^{234}U[e], ^{238}U	0.02 dpm	0.15 dpm (A,Q)[f]
^{235}U	0.02 dpm	0.01 (A) 0.02 dpm (Q)
^{241}Am, ^{242}Cm	0.02 dpm	0.01 dpm (A)
^{243}Am	0.02 dpm	0.01 dpm (A)
^{228}Th, ^{229}Th, ^{232}Th	0.10 dpm	0.05 dpm (not established)
^{225}Ac, ^{227}Th	0.10 dpm	0.05 dpm (not established)
Elemental U	0.06 μg	0.2 μg (Q)[f]
Elemental U (QUS)	0.50 μg	11 μg (BW) 4 μg (M)
Tritium	20 dpm/mL	80 dpm/mL[g]

(a) Analysis of urine samples, unless otherwise indicated.
(b) Specified MDA based on Type I and Type II errors of no greater than 5%, as described in the SOW (a copy is available in the Hanford Radiation Protection Historical Files).
(c) Amount per total sample volume, unless otherwise indicated.
(d) Investigation of a potential internal exposure is performed when this value is exceeded (routine bioassay monitoring frequency: A-annual, BE-biennial, BW-biweekly, M-monthly, Q-quarterly).
(e) The lab cannot discriminate between ^{233}U and ^{234}U and reports the results as ^{234}U (beginning in 1994).
(f) Upper level of expected environmentally derived uranium in urine for the Hanford region.
(g) Special screening levels are established for short-term tritium work where beginning and ending work samples are obtained instead of monthly routine sampling.

Table 3.2. Minimum Detectable Activities and Screening Levels for Routine In Vivo Measurements During 1998

Measurement/Radionuclide [(a)]	MDA [(b)] (nCi)	Screening Level [(c)] (nCi)
Standup Whole Body Count		
^{60}Co	4	4
^{154}Eu	8	Any detected
^{137}Cs	4	Any detected
Coaxial Germanium Whole Body Count		
^{137}Cs	1.2	Any detected
Lung Count		
^{235}U	0.095	Any detected
^{238}U (by ^{234}Th)	1.6	Any detected
^{241}Am	0.18	Any detected

(a) For selected radionuclides. (The detection of radionuclides not listed resulted in follow-up, except for ^{214}Bi.)
(b) For each in vivo count, the decision levels (approximately half of the MDAs) were reported under the "detection limit" to REX, but, in terms of overall detectability for all measurements, the above MDAs were still applicable.
(c) Level for which an investigation of internal exposure was considered. Any detected activity above background (i.e., above the decision level) was reported to the HIDP.

The values for the excreta analyses were unchanged from 1997 values except that a new analysis for ^{243}Am was added in August; it involves using ^{241}Am as the internal tracer. This analysis provided a small challenge for the laboratory because normally ^{243}Am is used as the internal radiochemistry tracer for radioamericium analyses.

Although not listed in Table 3.2, a change in the method for handling ^{214}Bi in whole body counts was made in November because of weather conditions that led to especially high concentrations of radon progeny in the counting cells. After discussion with Hanford Site dosimetry representatives, the screening level for ^{214}Bi was increased from 6 to 10 nCi. There was no work being performed onsite with radium or radon, and all agreed that monitoring for radium is best performed using urine sampling.

Table 3.3. Specified Minimum Detectable Activities for Emergency and Expedited Excreta Bioassay During 1998

	MDA (per sample)	
Analysis[a]	**Urine**	**Feces**
Emergency Analyses[b]		
Isotopic Plutonium by Alpha Spectrometry	0.5 dpm	9 dpm
Isotopic Uranium by Alpha Spectrometry	1.0 dpm	12 dpm
^{241}Am by Alpha Spectrometry	1.0 dpm	20 dpm
^{241}Am by LEPD[c]	20 dpm	20 dpm
Total Radiostrontium	80 dpm	450 dpm
Elemental Uranium	7 μg	8 μg
Tritium	100 dpm/mL	
Expedited Analyses[d]		
Isotopic Plutonium by Alpha Spectrometry	0.08 dpm	3 dpm
Isotopic Uranium by Alpha Spectrometry	0.12 dpm	4 dpm
^{241}Am by Alpha Spectrometry	0.08 dpm	6 dpm
^{241}Am by LEPD	5 dpm	5 dpm
Total Radiostrontium	50 dpm	150 dpm
Elemental Uranium	0.5 μg	5 μg
Tritium	100 dpm/mL	

(a) For the more critical analyses only. The list does not contain all the analyses covered in the contract.
(b) Verbal reporting time generally within 8 hours after receipt of the sample; reporting times were even shorter for some analyses.
(c) LEPD = low-energy photon detector; direct counting of X-rays without radiochemical separation.
(d) Verbal reporting time by 9:00 a.m. on the second business day after receipt of the sample.

3.1.2 Excreta Bioassay Contract Activities

At the beginning of 1998, the bioassay contractor had problems completing analyses within the contract-specified times. The reported cause was a larger-than-normal load of priority samples coupled with many staff being on vacation over the holidays.

The number of sample results with unacceptably low chemical yields was also a problem. In March the failure rate more than doubled from 2 to 5%, to over 10%. The cause of the problem was traced to trained but inexperienced analysts. From April through November the failure rate returned to normal, but increased to around 25% in December. The cause of the problem was under investigation at the end of the year.

High blank plutonium QC results in the first part of the year prompted a thorough decontamination of the contractor's laboratories. The QC results were acceptable after that action.

At the end of the year, the bioassay contractor was in the middle of replacing all software that was not Y2K compliant. A major effort involved replacing the sample tracking software. The new system (Quantums) tracks samples corporate wide, rather than in just the Richland laboratory. This change will require modification of some Battelle systems because of the changes in tracking number logic.

The contract with the bioassay contractor was extended through the third and final option year (July 1998 to June 1999). For the third consecutive year bioassay unit prices were reduced; prices for the third optional year were about 2% less than the previous year.

An Inspection of Services was performed in June 1998 to review contract compliance. The audit team was headed by staff from Battelle's Quality Assurance (QA) group. The inspection was done independent of other Battelle contracts with the bioassay contractor to prevent our clients' confusion as to what program is responsible for identified problems. The inspection resulted in four findings and two observations.[(a)] All findings and observations primarily involved minor deviations from general QA practices. Corrective actions were submitted and accepted, and the audit was closed in October.

(a) A finding is a statement of fact relating to noncompliance with previously agreed-upon codes, standards, specifications, or other forms of contractual or legal obligation. An observation is a conclusion (usually based upon the auditor's experience) that presents the results of a generally subjective evaluation of implementation practices or management systems related to the area(s) under review. It may or may not relate to specific noncompliance(s) with agreed-upon requirements, but it is based upon the auditor's evaluation of factual evidence.

3.1.3 Excreta Quality Control Oversight Program

The Quality Control Report for the period from July 1, 1997 through June 30, 1998 was completed in January 21, 1999.[a] Urine analyses for tritium, ^{90}Sr, ^{238}Pu, ^{239}Pu, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, and elemental uranium; and fecal analyses for ^{238}Pu, ^{239}Pu, and ^{241}Am were tested. The QC samples submitted by PNNL during the report period represented about 1.5% of the total samples submitted. This is slightly less than the percentage for the 1997 report period. Although the number of QC samples submitted by HIDP was about the same, the percentage was significantly less because the sample load increased by almost 60% over the previous year.

Based on an evaluation of all QC data, all analyses met or exceeded statistical specifications in the SOW with the exception of the ^{241}Am MDA. The americium procedure was modified to correct this problem. The number of statistical outliers and false negatives were also within statistical expectations.

Artificial fecal samples were again part of the routine oversight program in 1998. Procedures for making and spiking artificial fecal matrix at Hanford were developed in 1996 (PNNL 1996). The plutonium and americium results on artificial fecal samples in 1998 were acceptable.

3.1.4 Policy and Documentation Changes

A revised protocol for investigation of ^{137}Cs detected by whole body counting was issued as Exhibit 3.6 of the project manual in June. The protocol included the recommendation that contractors should perform a work review identifying appropriate facility characterization data. If ^{137}Cs is used as an indicator for ^{90}Sr or Pu in those facilities, then additional special bioassay would be performed for those nuclides. For ^{90}Sr, the special bioassay is a urine sample. For Pu, the special bioassay is a urine sample (if there have been no off-normal workplace indicators of potential intake) or a urine and fecal sample (if there have been off-normal workplace indicators).

A brief technical basis was issued for neptunium and plutonium mixtures. The letter report[b] tabulated selected internal dosimetry data and provided guidance that 1) Np bioassay is not required if the Pu-alpha-to-Np-activity ratio exceeds 6:1 and Pu bioassay is performed, 2) Np bioassay be considered if Np purity exceeds 95% by weight (alternatively, Np bioassay is not likely to be required if Pu bioassay is performed and the Pu impurity exceeds 5% by weight), and 3) Internal Dosimetry will address specific mixtures as data are provided.

(a) J.A. MacLellan. January 21, 1999. Letter report to Distribution, "Results of the PNNL Excreta Bioassay Quality Control Oversight Program for July 1, 1997 through June 30, 1998." Copy available from the Hanford Radiation Protection Historical Files.

(b) E.H. Carbaugh. February 17, 1998. Letter report to Distribution, "Bioassay for Neptunium and Plutonium Mixtures - Brief Technical Basis." Copy available from the Hanford Radiation Protection Historical Files.

3.1.5 Proposal for a Change in the Decision Level for Excreta Analysis Using Alpha Spectrometry

A proposal was presented to and accepted by the HPDAC that will significantly change the method used to flag an excreta sample as a potential detection. The trigger level in question is referred to as the high flag level or the oral reporting level. The change applies to results from alpha spectrometry measurements excluding uranium measurements. The practice has been to have the oral reporting level be a fixed, contractually set level that represents an upper bound of the true decision level of the analysis, recognizing that the true decision level varies from time to time or from detector to detector. The oral reporting level was a fixed fraction of the contractual MDA. The proposed method provided for a way to determine the decision level that was a detector-specific value calculated using the exact Poisson probabilities for background counts. This means that the decision level may be different for every count.

As part of this approach, the alpha probability (Type I error) of the decision level is chosen as a matter of policy, and is not an intrinsic function of the measurement statistics. It is up to the bioassay program designers to determine how many false positive results should be investigated in the effort to ensure that small intakes are not missed. A retrospective study to assess the impact of this change determined that the current fixed oral reporting level of 0.01 dpm flagged 21 of the 1022 routine alpha spectrometry samples for further data evaluation last year. Fourteen of those samples were from individuals with known intakes, or the results were subsequently confirmed by recount. That left seven of the 1022 samples (0.7%) that were considered false positives. The impact of implementing the new method on the number of false positives that would have occurred in the same period was evaluated. It was found that using an alpha probability of 0.5% would allow both slightly increased sensitivity and still result in only 10 expected number of false positives.

The HPDAC concurred in setting the alpha probabilities for performance testing criteria at 5%, but using 0.5 for determining oral reporting levels for worker samples.

The lead time to implement the new method was very long because of its complexity. Negotiations with the laboratory were still under way at year-end.

3.1.6 Technical Basis Document Revision

Although it had been planned to make significant progress in CY98 on a total rewrite of the *Technical Basis for Internal Dosimetry at Hanford*, the heavy case workload and other activities interfered. A couple of chapters were drafted, and a new technical basis for ^{237}Np was written at the request of RL. The schedule for rewriting the technical basis document and converting it to manual format was revised to show completion of the most significant chapters by January 2000.

3.1.7 Faster Notification of Bioassay Results Exceeding the Reporting Levels

The sequence of actions taken to notify contractor dosimetry representatives when an unexpectedly high bioassay result is obtained was revised. At the request of the contractors, the emphasis was on shortening the time from when a worker is told he/she has an in vivo result exceeding the reporting level

to when the contractor dosimetry representative is notified. In the end, the rapid notification procedure was extended to include excreta bioassay results as well. Results to be reported by this protocol include the following: 1) any high routine results; 2) any measurement with a reason code of "Special," regardless of whether or not there is a high flag—the exception being "Special" or "Contractor Request" measurements processed using routine processing category that are not high-flagged; 3) any measurements for which recounts are ordered and performed. A single new electronic notification form was created, superseding the former In Vivo and Excreta Telephone Notification Forms. Target notification times were set at a couple of hours for in vivo results and four hours for excreta samples. Results obtained at the end of the business day are reported first thing the next morning. Exposure evaluators are still required to follow up the notification after their review.

3.2 Monitoring and Assessment Activities

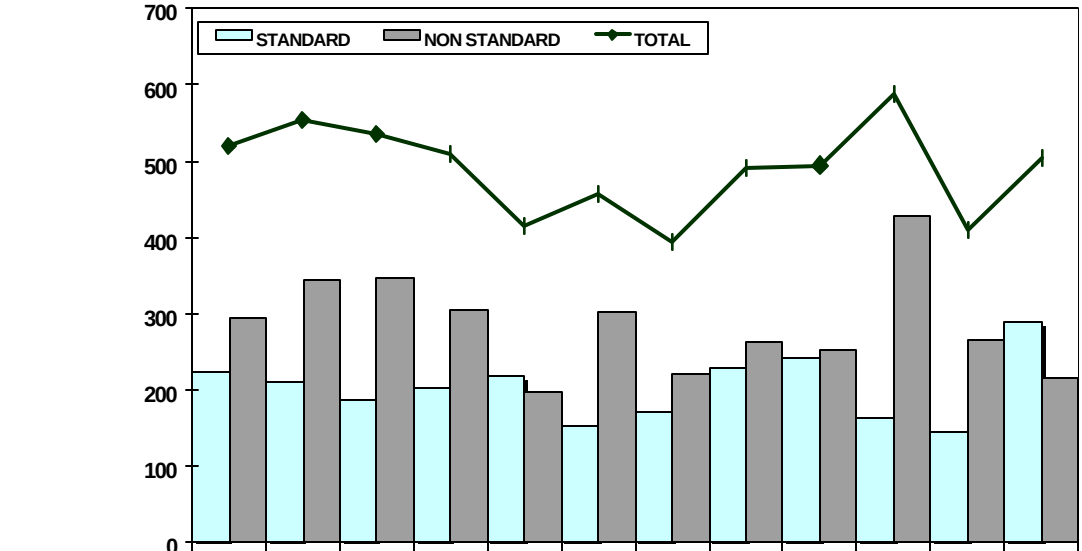
The HIDP excreta bioassay monitoring and internal dose assessment activities during 1998 are summarized in this section. The Hanford Whole Body Counting Project and its associated statistics are discussed in Chapter 4.0.

3.2.1 Excreta Bioassay Monitoring Activities

Sample requests can be categorized as standard or nonstandard. Standard requests are those generated by the REX system from a predetermined, routine schedule (e.g., a worker may be scheduled for an annual sample collected every April). These requests are downloaded from REX and electronically transferred to the analysis laboratory just before the start of each month. All other requests are considered to be non-standard requests. Contractors or HIDP staff manually enter the nonstandard requests into REX. HIDP staff check the nonstandard request file in REX for input errors and perform the electronic transfer of the requests to the laboratory. Figure 3.1 shows the monthly distribution of standard and nonstandard requests for 1998. In 1998, 5871 samples were requested, up 39% from the requests in 1997 and up 62% from requests in 1996 (which was a very low year historically). The increase, in part, reflects cleanup work in the 100 Area and concern for plutonium in the basin sediments. The pattern that began in 1997 whereby the nonstandard requests outnumbered the standard requests, continued in 1998. (Standard requests were only 41% of the total in 1998 and 45% in 1997, compared with percentages generally in the 60s for previous years.) It seems to reflect the new contracting trend to subdivide the work into smaller discrete contracts with a more mobile workforce moving between contracts.

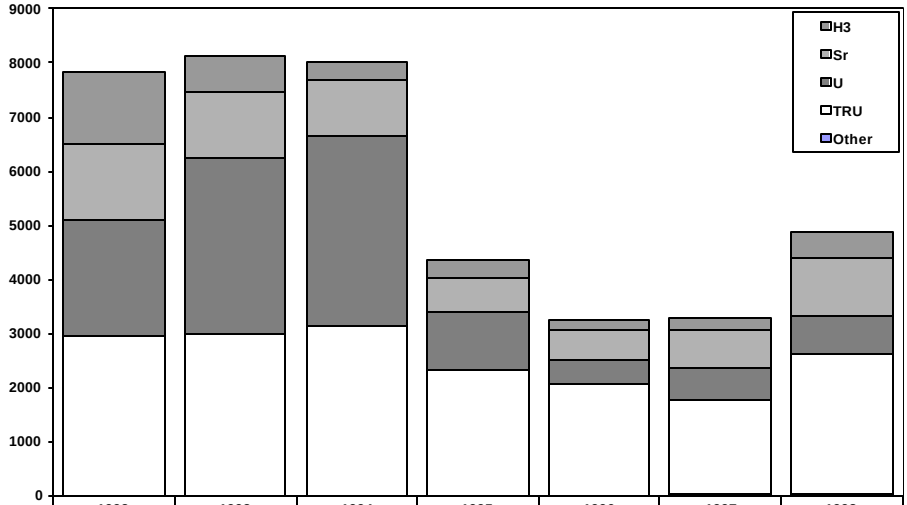
During 1998, 5301 excreta bioassay measurements were successfully performed in support of Hanford activities, excluding cancellations, no-samples, samples without valid results, and QC samples (isotopic results for each element count as one measurement). Of these, 92% were classified as routine (including measurements on visitors) and 8% were due to special circumstances, such as response to unplanned potential intakes or follow-up analyses to high routine measurements.

Figure 3.2 provides the trend in routine urinalyses since 1992. The figure shows that the number of routine measurements in 1998 rose 49% relative to 1997, but was still well below the high numbers in the first half of the 1990s. Major efforts were made in 1995 and 1996 to tighten the requirements for placing workers on routine bioassay schedules and to remove workers from routine schedules that were at



	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98
STANDARD	224	210	188	204	218	153	171	229	242	162	144	289
NON STANDARD	295	343	347	305	198	303	222	263	253	427	265	216
TOTAL	519	553	535	509	416	456	393	492	495	589	409	505

Figure 3.1. Standard and Nonstandard Excreta Requests by Month



	1992	1993	1994	1995	1996	1997	1998
H3	1348	644	334	327	188	235	497
Sr	1400	1248	1029	610	534	684	1061
U	2124	3248	3494	1080	468	603	728
TRU	2962	2980	3144	2321	2049	1716	2572
Other	0	0	0	0	0	40	26

Figure 3.2. Routine Urine Measurements Made from 1992 through 1998

negligible risk for intakes. The rise in 1998 relative to 1996 and 1997 applied to all groups of analyses, and the mix among the groups remained about the same. The rise probably reflected more cleanup work in contaminated areas, especially 100-N Reactor and 100-K Basins. Also, the "bioassay needs review" flag used to reduce unnecessary bioassays for PHMC workers in 1997, was not operable in 1998.

Details on all types of excreta measurements categorized by contractor are provided in Table 3.4. Overall, the total number of excreta measurements increased 54% over 1997 with special requests for ^{90}Sr and Pu showing major increases commensurate with the overall increase in internal dose evaluations. The percentages of excreta measurements for the three major contractors remained about the same.

Table 3.4. Worker Excreta Measurements Reported in 1998

Type/Reason	DOE	PNNL	ERC	PHMC	Other	Total
^{3}H-Urine						
Routine Schedule[(a)]	0	425	0	72	0	497
Special Request[(b)]	0	11	0	2	0	13
^{90}Sr-Urine						
Routine Schedule	14	228	279	539	1	1061
Special Request	0	3	3	117	0	123
Uranium-Urine						
Routine Schedule	20	288	86	334	0	728
Special Schedule	5	35	2	10	0	52
Plutonium-Urine						
Routine Schedule	54	308	582	1407	3	2354
Special Schedule	1	19	33	94	0	147
Other-Urine						
Routine Schedule	0	165	0	79	0	244
Special Schedule	0	36	1	25	0	62
TRU-Fecal						
Routine Schedule	0	0	0	0	0	0
Special Schedule	0	1	8	11	0	20
Analyses Totals	94	1519	994	2690	4	5301

(a) Routine measurements include those with reason codes of routine (PR), baseline (BL), contractor request (CR), ending work (EA), and termination (TM).
(b) Special measurements are those with reason code of special (SP), recount (R1 or R2), and reanalysis (RA and RB).

Not all excreta bioassay requests produce valid measurement results; these are referred to as no-samples. When a sample is not obtained, it has to be requested again. (Note: these statistics refer to the number of unsuccessful attempts made to obtain a sample; they do not relate to whether a valid sample was ultimately obtained or not) In 1998, 1060 excreta sample requests were designated as no-samples, up from 817 no-samples in 1997. In terms of percentage of total requests, the 1998 rate (18%) was similar to previous years (21%, 19%, and 19%, in 1997, 1996, and 1995, respectively). In addition, there were 330 canceled requests that also show in the records. Unsuccessful sample collections (their associated no-sample code and percentage of the total no-samples) were attributed to the following causes: kit not delivered (ND, 2%), no sample received (NS, 17%), lost container (LC, 46%), insufficient sample volume (IS, 14%), failed analyses (LL, 22%). The percentage of each type of unsuccessful sample is similar to previous years except that the failed-analysis category increased from 13% in 1998. There were a considerable number of failed analyses in December that pushed the statistic higher. (This problem continued into January 1999 and led to a shutdown and investigation of the Pu analyses in February 1999.)

There has been special interest in excreta samples ordered for workers terminating employment from one of the Hanford contractors. There were 107 workers that failed to provide termination excreta samples (or the analytical process failed in the lab), which is 23% of the total workers for which termination samples were requested. (This statistic does not include workers for whom a sample was eventually collected on subsequent attempts.)

3.2.2 Potential Intake Evaluations

Investigations of possible radionuclide intakes are performed following an indication from a routinely scheduled bioassay measurement (high routine) or for a potential intake incident identified in the workplace (incident). Potential intake incidents are identified by workplace indicators such as air sampling, contamination surveys, nasal smears, or smears from potentially contaminated wounds. Evaluations are also performed for newly hired workers who incurred intakes prior to their Hanford employment to ensure that the intake information is converted to dose in a manner consistent with DOE regulations (pre-Hanford). Reevaluations of internal dose are also conducted periodically for workers with significant long-term body burdens (reevaluations).

During 1998, 26 incidents with the potential for intake, involving 186 workers, were identified through workplace monitoring. One case was responsible for 106 of the workers (see Section 3.2.3). Of the 186 workers involved in the incidents, intakes were confirmed for only 5 workers. (Another 8 cases were still undetermined at the time of this report.) The highest calculated dose among the 5 workers was 740 mrems committed effective dose equivalent (CEDE). The radionuclides and groups involved included ^{137}Cs and/or ^{90}Sr (13 incidents with 148 workers), transuranic (TRU) radionuclides (10 incidents with 28 workers), and tritium (3 incidents with 10 workers). Table 3.5 shows the incident breakdown by contractor, area, and facility.

Table 3.5. Summary of Potential Intake Incidents During 1998

Facility		Custodian	Number of Incidents	Number of Workers	Worker Contractor	Principal Nuclide
Area	ID					
100	105C	ERC	1	4	ERC	^{137}Cs
100	105D	ERC	1	2	ERC	^{137}Cs
100	100N	ERC	2	2	ERC	Pu mix
200E		PHMC	1	106	PHMC	^{90}Sr
200E	102AY	PHMC	1	1	PHMC	^{137}Cs
200E	241AN	PHMC	1	7	PHMC	^{137}Cs
200E	241BY	PHMC	1	10	PHMC	^{137}Cs
200W	222S	PHMC	1	1	PHMC	^{137}Cs
200W	233S	ERC	2	2	ERC	Pu mix
200W	234-5Z	PHMC	3	11	PHMC	Pu mix
200W	241SX	PHMC	2	13	PHMC	^{137}Cs
200W	2336	PHMC	1	1	PHMC	Pu mix
200W	Z Crib	PHMC	1	7	PHMC	Pu mix
300	324	PHMC	2	2	PHMC	^{137}Cs
300	325	PNNL	5	16	PNNL	^{3}H, ^{137}Cs, ^{238}Pu
Offsite		PNNL	1	1	PNNL	^{137}Cs
		Total	26	186		

In addition to incidents, potential intakes can be discovered through the routine bioassay program, although in recent years very few actual (i.e., confirmed) intakes have been discovered this way. In 1998, 136 evaluations were started because of routine bioassay results that exceeded the criteria for investigation (excluding evaluations started because of intakes incurred prior to employment at Hanford). Intakes were assigned for 22 workers, which is more than normal. This is mostly due to some work with tritium done by PNNL and some ^{137}Cs intakes due to visitations at Former Soviet Union nuclear facilities. For all but one worker, the CEDEs were less than 10 mrems. The intakes for some may have been due to environmental sources of ^{137}Cs but no effort was made to prove this. For 14 workers, the dose assessments were still in progress at the time this report was drafted. Table 3.6 shows internal dose evaluations for 1998 resulting from high routine bioassay results. Figure 3.3 shows the workload in terms of open evaluations during the year. The top curve presents the total number of open evaluations as of the last day of each month. The number of new evaluations started outpacing the number of cases completed in a month in February. This situation continued pretty much throughout the rest of the year, leading to the

Table 3.6. Summary of Intake Cases Identified through the Routine Bioassay Program during 1998

Facility		Custodian	Number of Workers	Principal Nuclide
Area	**Building**			
100	105N	ERC	1	^{137}Cs
200E	Tank Farms	PHMC	2	^{137}Cs (a)
200W	221T	PHMC	4	^{3}H
200W	221T	PHMC	1	^{137}Cs
200W	222S	PHMC	1	^{137}Cs
300	306W	PNNL	1	U
300	324	PHMC	1	^{137}Cs (a)
300	325	PNNL	6	^{3}H
400	FFTF	PHMC	1	^{137}Cs (a)
Offsite		Foreign Country	2	^{137}Cs
Undetermined		ERC	1	^{137}Cs
Undetermined		PNNL	1	^{137}Cs
		Total	22	
(a) Occupational intake assigned; environmental source possible.				

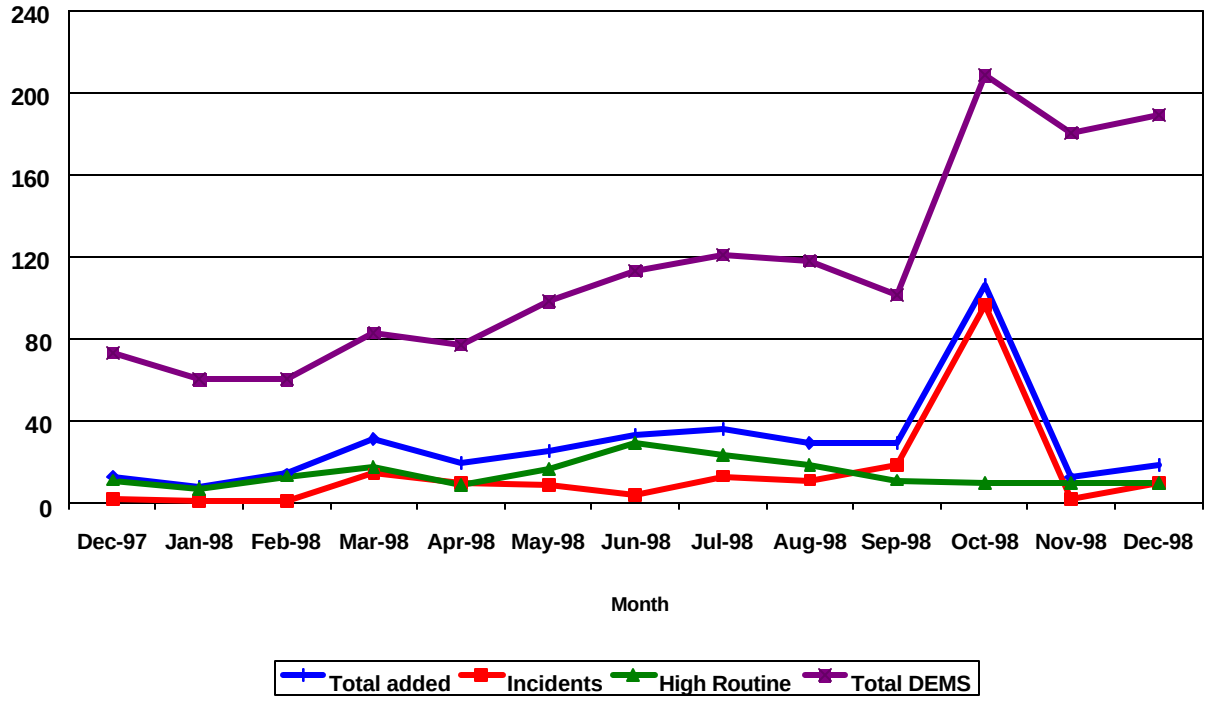


Figure 3.3. Number of Open Evaluations from December 1997 through December 1998 (Top curve shows number of evaluations open on the last day of each month.)

decision to add staff. The large increase in open cases in October resulted from the incident described in Section 3.2.3. Table 3.7 provides the trends in all types of potential intake evaluations since 1990.

The range of internal doses assigned to the Hanford work force in 1998 is summarized in Table 3.8.

Table 3.7. Comparison of Potential Intakes by Reason Code, 1991-1998

	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Incident, Total	90	30	51	33	51	42	51	186
Confirmed			17	7	12	11	12	5
Unconfirmed			34	26	39	30	33	173
Open								8
Unconfirmed but assigned[(a)]						1	6	
High Routine, Total	69	141	65	91	59	40	85	136
Confirmed			1	15	1	5	10	22
Unconfirmed			64	76	58	33	75	100
Open								14
Chronic Exposure, Total	30	4	6	0	0	0	2	0
Confirmed			0				2	
Unconfirmed			6				0	
Pre-Hanford, Total		20	3	35	9	12	10	13
Confirmed			3	31	9	11	10	6
Unconfirmed			0	4		1	0	4
Open								3
Totals	189	195	126	162	119	94	148	335
Confirmed			22	53	22	27	34	33
Unconfirmed			104	109	97	64	108	277
Open								25
Revaluation, Total	1	4	3	12	11	1	0	0
Initiated			0	8	17	1		
Completed						1		
Open								

(a) Unconfirmed by bioassay but dose assigned based on air sample data.

Table 3.8. Range of New Internal Doses Assigned to the Hanford Work Force in 1998

	Number of Workers				
Dose (mrem)[(a)]	**DOE**	**PHMC**	**PNNL**	**ERC**	**Total**
< 100	0	10	12	2	24
100 - < 500	0	0	1	0	1
500 - < 2000	0	2	1	0	0
2000 - < 5000	0	0	0	0	0
>5000	0	0	0	0	0

(a) CEDE, based on 1998 evaluations, although the intake could have occurred in any year; excludes reevaluations.

3.2.3 Unusual Set of Cases Involving Fruit Flies as the Contamination Vector

An unusual spread of contamination, principally in the 200 East Area, was discovered in late September and continued for the next several weeks. The event led to opening potential intake cases for 106 workers. It is likely that it was the largest number of cases associated with a single event in the history of Hanford. However, in the end no intakes were confirmed for any of the workers.

The event was initially discovered when beta-gamma contamination was found in an office trailer in an uncontrolled area. Contaminated objects included counter tops, cutting board, light switch plate, trash cans, and the dumpster. Subsequent surveys found spots of contamination over a 10-acre area and in trash taken to the Richland landfill and hazardous waste facility. Fruit flies were identified as transporting contamination from the 241-ER-151 diversion box, which had been coated with a sugar-based fixant. Radiochemical analysis of some of the flies identified the contaminant as principally ^{90}Sr with a small amount of ^{137}Cs.

3.3 Project-Related Professional Activities

HIDP staff presentations and professional memberships during 1998 are listed in this section.

3.3.1 Presentations

Carbaugh, E.H., and J.A. MacLellan. "Hanford Bioassay and Internal Dosimetry—1998 Status," PNNL-SA-29995. Presented at the Denver Meeting of the Energy Facility Contractors Operating Group (EFCOG), May 12, 1998.

Carbaugh, E.H. "How to Design and Run a Bioassay Program," PNNL-SA-30262. Professional Enrichment Program class presented at the Health Physics Society Annual Meeting, July 13, 1998, Minneapolis, Maryland. Class was repeated on August 27 at Hanford for site staff unable to attend the Minneapolis meeting.

Carbaugh, E., with J.A. MacLellan, and D.E. Bihl. "New Implications for Cesium-137 Whole Body Counting," PNNL-SA-229694. Presentation at the Health Physics Society Annual Meeting, July 15, 1998, Minneapolis, Maryland.

Carbaugh, E.H. "Urine Data Normalization for Bioassay Assessment," PNNL-SA-30531. Presentation at the DOE Bioassay and Internal Dosimetry User's Group Meeting, October 27, 1998, Gaithersburg, Maryland.

MacLellan, J.A. "Statistics of Excreta Bioassay Decision Levels," Department of Energy Bioassay/Internal Dosimetry Workshop, October 27-28, 1998, Gaithersburg, Maryland.

3.3.2 Professional Memberships

Bihl, D.E., Chair of the ANSI/HPS Standards Committee N13.39, *Internal Dosimetry Programs*.

Carbaugh, E.H., Member of the ANSI/HPS Standards Committee N13.25, *Internal Dosimetry Standards for Plutonium.*

Carbaugh, E.H., Treasurer of the Columbia Chapter of the Health Physics Society through June.

MacLellan, J.A., Member of the ANSI/HPS Standards Committee N13.30, *Performance Criteria for Radiobioassay*.

MacLellan, J.A., Chairman of the American Academy of Health Physics Appeals Committee.

MacLellan, J.A., DOELAP Technical Assessor.

4.0 Hanford Whole Body Counting Project

The Hanford Whole Body Counting Project (WBCP) has been an integral part of worker radiation protection for the Hanford Site since 1959. The WBCP provides for the detection of radionuclides in Hanford workers by direct (in vivo) measurement, and the associated management, operation, and maintenance of the onsite in vivo facilities and equipment. The project staff operate and maintain equipment in the 747-A Building, the 747-A Trailer, a mobile whole body counting trailer, and the Emergency Decontamination Facility (EDF) located next to Kadlec Medical Center in Richland, Washington. Collectively, the facilities are known as the In Vivo Radioassay and Research Facility (IVRRF). The project documentation includes the *Whole Body Counting Manual*,[(a)] the *Whole Body Counting Procedures Manual*,[(b)] and the *Quality Assurance Plan for the Whole Body Counting Project.*[(c)]

A summary of the project activities, which include routine measurements of Hanford workers, special studies, and measurement instrumentation development work, are described in this chapter. The primary function of the WBCP is to provide accurate, highly sensitive, well documented, and timely measurements of workers exposed to radionuclides from occupational sources at Hanford that are in a form that can be taken into the body. Measurement results are provided to the HIDP for use in quantifying potential intakes and estimating internal doses. All measurement results and calibration data are transmitted as permanent records to the HRRP. The results for personnel measurements are stored online in the REX database and the spectral data are sent to the HRRP for permanent storage. Information copies of the measurement records are maintained at the IVRRF.

Four measurement systems are used for routine counting at the IVRRF. The standup counter is used for screening whole body measurements and the Palmer Room contains a scanning coaxial high-purity germanium (HPGe) counting system designed to optimize detection of high-energy photons. The Iron Room and Stainless Steel Rooms each contain planar HPGe counting systems designed to optimize detection of low-energy photons. Additional HPGe detectors are housed in the lead room and are used for the less frequently performed measurements. Whole body and wound counting equipment are also maintained at the EDF. Routine counts are scheduled from 8:00 a.m. to 12:00 p.m. and 1:00 p.m. to 3:00 p.m. on weekdays. Upon request, the WBCP staff arranges to provide additional counting hours to help cover periods of peak demand. The WBCP staff are also available on an on-call basis for incident response during off-hours through the PNNL Exposure Evaluator.

4.1 Summary of 1998 IVRRF Measurements

There were 8,304 in vivo measurements performed for DOE and the Hanford contractors during CY98. This included 6,465 whole body counts, 1,819 chest counts, and 20 miscellaneous counts. The total number of counts represents a 7% increase compared with CY97. The number of whole body counts

(a) Internal Manual, PNL-MA-574, Pacific Northwest National Laboratory, Richland, Washington.
(b) Internal Manual, PNL-MA-554, Pacific Northwest National Laboratory, Richland, Washington.
(c) Internal Manual, LSC-021, Pacific Northwest National Laboratory, Richland, Washington.

performed in CY98 was 95 more than in CY97. There were 455 more lung counts performed in CY98 than in CY97. The statistical breakdown by contractor is shown below in Table 4.1. A summary of in vivo counts made from 1991 through 1998 is presented in Table 4.2 and depicted graphically in Figure 4.1. The "other" counts include wound, skeletal, thyroid, and liver counts.

During CY98, approximately 6% (58/910) of the persons scheduled for termination counts were not counted. However, these estimates may be biased low because estimates for the first three quarters used data from REX and names apparently could be removed from the REX no-show file without a recount necessarily being done during this time. During the fourth quarter, the WBCP staff kept the statistics on the number of persons who did not receive a scheduled termination count in order to report accurate information. Eventually, the information on the numbers of persons who do not keep their scheduled appointment will be permanently retained in REX.

Table 4.1. In Vivo Measurements Performed During 1998 and Entered in the REX Database

Count Type and Reason	PHMC	PNNL	ERC	Other (DOE and HEHF)[(a)]
Whole Body Counts				
Routine Schedule	4122	686	1183	231
Special Request	73	3	8	1
Contractor Request	29	101	13	15
Total	4224	790	1204	247
Chest Counts				
Routine Schedule	1293	275	121	34
Special Request	78	9	3	1
Contractor Request	0	4	1	0
Total	1371	288	125	35
Other				
Routine Schedule	0	1	0	0
Special Request	8	2	5	0
Contractor Request	1	3	0	0
Total	9	6	5	0
Grand Total	5604	1084	1334	282
(a) HEHF = Hanford Environmental Health Foundation				

Table 4.2. Summary of In Vivo Counts from 1991 through 1998

	Year							
Count Type	1991	1992	1993	1994	1995	1996	1997	1998
WBC	9,965	12,197	11,401	11,031	9,020	7,407	6,370	6,465
Chest	2,549	3,164	2,838	2,752	1,915	1,632	1,364	1,819
Other	66	56	38	82	27	26	3	20
Total	12,580	15,417	14,277	13,865	10,962	9,065	7,737	8,304

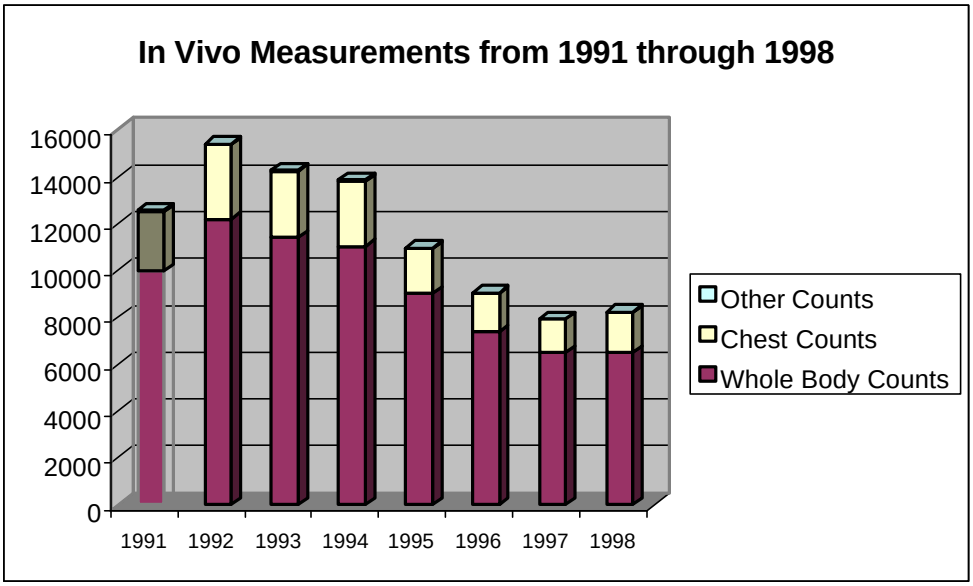


Figure 4.1. Summary of In Vivo Counts by Type, 1991 to 1998

4.2 Routine Program

During 1998, the project was operated within budget. The WBCP staff conducted Monday planning meetings to prioritize and schedule work at the IVRRF. Staff conducted monthly safety meetings specific to the operations at the 747-A Building on a rotating basis throughout the year and quarterly safety self assessments were also performed. No off-normal events related to the project were recorded in 1998. Formal presentations were made each quarter to RL and the contractors to summarize the progress, activities, and issues related to the operation of the WBCP. Quarterly reviews and trend analyses were performed on the daily QC data for each routine counting system.

The ongoing updates to the project documentation continued in 1998 including several operating procedures, the Records Inventory and Disposition Schedule, the QA Plan and the *Whole Body Counting Manual*. The latest revisions to the QA Plan and the *Whole Body Counting Manual* will be released in 1999. WBCP staff received training pertaining to the changes made to the procedures.

In response to a request from FDH to expedite reporting of positive results, the HIDP staff are now notified immediately after a positive result is confirmed. Previously, these results were reported at the end of the business day. The result sheet and the completed In Vivo Exam Questionnaire are faxed to HIDP immediately after the count and the HIDP staff member is contacted by phone.

A consensus was reached with the contractors' field dosimetry representatives that effective in February 1998 all routine scheduled WC whole body counts on the coaxial HPGe system are mandatory. This means that if a routine WC count cannot be performed then a standup whole body count (WB) is not adequate and the individual will be rescheduled for a WC count. The exceptions will be termination and visitor counts because those don't need the enhanced sensitivity. The increased sensitivity of the WC

count is required for persons working with material that contains mostly fission and activation product activity, but that also contains small amounts of TRU material. The TRU activity results in the largest dose but is not detectable using routine lung counting or urinalysis.

A proposal for modifying the nuclide libraries for routine in vivo counting was presented to and accepted by the HPDAC. The new libraries for whole body counting will be ^{40}K, ^{137}Cs, ^{60}Co, and ^{154}Eu. For chest counting three separate libraries will be used: 1) ^{241}Am only, 2) ^{234}Th and ^{235}U, and 3) ^{241}Am, ^{34}Th, and ^{235}U. Persons will be scheduled in REX for a specific type of analysis for their count. The new libraries will be used when the Abacos software is put into routine operation during CY99.

4.2.1 Program Audits

One narrow-scope audit of the WBCP was performed in 1998. A US Ecology representative conducted a one-day audit of the WBCP operations. No findings resulted from the audit, so consequently the WBCP remains on the US Ecology approved vendor list for in vivo counting services.

4.2.2 DOELAP Accreditation

In 1998, the WBCP staff completed the corrective actions to the 6 concerns and 10 observations that resulted from the DOELAP onsite assessment in October 1997. The initial accreditation was conferred in February 1998 and included three testing categories: fission and activation products in the whole body, ^{238}Pu in lung, and natural uranium in lung. The performance testing consisted of making a series of five measurements of the DOELAP phantoms and reporting the results. The results were within the bias (+50% to -25%) and precision (±40%) requirements prescribed by DOELAP. Later in the year, measurements were made on the ^{241}Am and ^{235}U DOELAP lung phantoms and these results also met the DOELAP performance criteria. The performance testing results, as reported by DOELAP, are summarized in Table 4.3.

Table 4.3. DOELAP Performance Test Results

Category	**Bias**		**Precision**	
Activity in Lungs	**Iron Room**	**Stainless Room**	**Iron Room**	**Stainless Room**
Transuranium Elements via L-X-Rays	-0.1418	-0.0967	0.0273	0.0304
^{241}Am	-0.0031	-0.0014	0.0213	0.0060
^{234Th}	-0.0729	-0.0372	0.0313	0.0268
^{235}U	-0.0264	-0.0358	0.0103	0.0103
Fission and Activation Products in Lung	Not Yet Completely Tested			
Fission and Activation Products in Whole Body	**Standup**	**HPGe**	**Standup**	**HPGe**
^{137}Cs	-0.0755	0.0058	0.1572	0.0182
^{134}Cs	-0.0919	0.0286	0.2120	0.0097
Radionuclides in Thyroid	Not Yet Tested			

A retest is required for the fission and activation product activity in the lung category. The original testing was done in 1996 with a smaller number of detectors than are currently being used in the Palmer Room. The original test nuclides were ^{144}Ce and ^{54}Mn. The ^{144}Ce activity had decayed below the minimum testing level (MTL) by the time the phantom was measured at the IVRRF. The results from the ^{144}Ce measurements were outside the bias parameters, but because the level had decayed below the MTL they could not be used to assess compliance with the testing criteria. Retesting will be done with ^{57}Co instead of ^{144}Ce due to problems with the availability of a quality source of ^{144}Ce in the United States. The ^{57}Co energies at 122 keV and 136 keV are similar to the 133-keV photon emitted by ^{144}Ce.

4.2.3 Calibrations and Quality Control of Routine Counting Systems

Each in vivo counting system requires calibration to convert the measured count rates from people to estimates of activity. This is accomplished by using phantoms that simulate the size, shape, and radiation interaction properties of the body. The phantoms contain a known amount of radioactive material(s) and are measured with the counting system. The calibration factor is calculated by dividing the count rate measured with the counting system by the phantom activity. The count rate from a person is divided by the calibration factor to estimate the activity. For lung counting, the calibration factors are expressed as a function of the thickness of the tissue overlying the lungs. The correct calibration factor is based on estimates of the individual chest wall thickness determined by an individual's weight-to-height ratio or the ultrasonically measured thickness if the result exceeds the detection level.

For each of the routine counting systems, daily QC measurements were made of a check source in a reproducible geometry to verify that the system was operating within the limits set at the time of the last primary calibration. A quarterly statistical analysis was performed of the daily source count results, including trend analysis to look for subtle changes in the systems' performance. Based on the QC results, the calibration factors used to estimate the activity in workers were traceable to the primary calibration using anthropomorphic phantoms.

In addition to the QC measurements, quarterly measurements of specific calibration phantoms were performed to verify current calibrations for the routine counting systems. The measurement results verified that the performance of the measurement systems remained stable through the year and that the calibration factors used to estimate activity were traceable to the primary calibration. The ^{137}Cs results from the standup and coaxial HPGe detector systems ranged from 90% to 101% of the activity in the phantom. The ^{40}K results from the standup and the coaxial HPGe systems ranged from 87% to 103% of the activity in the phantom. The ^{241}Am, ^{234}Th, and ^{235}U lung phantom results for the chest counting systems ranged from 95% to 103% of the activity in the phantom. The variability in the count results is due largely to the count-to-count variation in positioning the phantoms under the detectors.

The WBCP staff participated in the Thyroid Radioiodine Intercomparison Program sponsored by Lawrence Livermore National Laboratory (LLNL) during the year in preparation for future DOELAP performance testing in this category. The measurement results are contained in Table 4.4. Each quarter, samples were received that contained unknown amounts of ^{131}I and ^{125}I. The samples were measured in a plexiglas phantom that was constructed according to ANSI N44.3 specifications (ANSI 1973). Initially the measurement results were reported based on a calibration using a head and neck phantom. The

Table 4.4. Results from Thyroid Radioiodine Intercomparison Program

I-125 Result (dpm)	I-125 True Activity (dpm)	I-125 Bias	I-131 Result (dpm)	I-131 True Activity (dpm)	I-131 Bias
1st Quarter					
4.7 E+05 ± 2.6E+04	3.53E+05 ± 1.06E+04	0.33	5.6E+05 ± 3.2E+04	4.72E+05 ± 1.42E+04	0.18
2nd Quarter					
2.59E+05 ± 4.38E+04	2.65E+05 ± 7.95E+03	-0.02	9.53E+05 ± 1.61E+05	9.72E+05 ± 2.92E+04	-0.02
3rd Quarter					
1.99E+05 ± 3.37E+04	1.90E+05 ± 5.7E+03	0.047	1.78E+06 ± 3.01E+05	1.78E+06 ± 5.34E+04	0.00
4th Quarter					
1.93E+05 ± 3.27E+04	N.A.	N.A.	2.65E+05 ± 4.61E+04	N.A.	N.A.
N.A. = Not yet available.					

results for the first quarter of CY98 indicated that the calibration with the head and neck phantom provides results for the Plexiglas phantom that were within 20% of the true activity for ^{131}I and within ~30% of the true activity for ^{125}I. For the remaining three quarters of 1998, the calibration was based on an ANSI N44.3 style phantom. These results were within a few percent of the true activity for both nuclides. The true activities from the fourth quarter samples are not yet available.

4.2.4 Training

Project-specific training for the WBCP staff included training in procedures after revisions were made and at monthly safety meetings. Periodic training sessions were also held to address technical issues as they arose.

4.2.5 Equipment Maintenance

In 1998, six planar HPGe detectors required repairs. These detectors are used for routine lung counting and other organ counting for low-energy photons. The WBCP staff repaired all of the detectors at the IVRRF and no detectors had to be returned to the factory. One detector's degraded resolution was improved by using silicon rubber to insulate it from the microphonic vibrations transmitted through the detector holder assembly. Another detector exhibited a peak at 18.5 keV that was caused by a ground loop and corrected by electrically insulating the detector from the holder. Two detectors required thermal cycling and leak checking to reestablish the proper cryostat vacuum at ~10^{-5} millibars. Two detectors required reattachment of the retaining ring for the beryllium window; the rings were reattached without having to take the detectors out of service.

The photomultiplier tubes for the standup counter detectors were balanced in May. Only a small amount of drift was noted and no appreciable change in efficiency resulted after the rebalance.

Several improvements were made to the counting system electronics that resulted directly from the preventive maintenance program. Electronic noise was found to be associated with the +12 volt DC outputs on several Nuclear Instrument Module (NIM bins). Replacing the transceiver units that communicate between the acquisition interface modules (AIMs) and the multi-channel analyzers significantly reduced the noise. In addition, the older style AIMs did not filter the +12 volt DC output. The AIMs were subsequently modified to include the necessary filtering for the +12 volt DC output. Apparently, the lack of input filtering on the AIM +12 volt input line allowed the interference from the transceiver to be passed to the NIM bin +12 volt DC output.

The impedance of the coaxial signal output cables for the Iron Room and Stainless Steel Room were found to not be optimized for the RG-11 preamplifiers being used. The RG-59 (75 ohm) cable was replaced with RG-62 (93 ohm) coaxial cable to reduce the noise and improve the signal-to-noise ratio.

High-frequency oscillations were discovered coming from all seven preamplifier outputs of the detectors in the Palmer Room. The motor control unit for the motion control system caused the oscillations. The installation of a Faraday cage and a filter for the AC line voltage eliminated the interference.

An unacceptably low calibration result led to the photomultiplier tubes for the EDF shadow shield detector being unbalanced. After rebalancing the tubes, the calibration results were within specifications. It was also determined that the translator unit for the sled drive needs to be warmed up for 10 minutes before being used, otherwise the sled travel distance can be shortened.

Modifications to all of the Stainless Steel Room detector holders to stabilize the dewars were completed to reduce the levels of microphonically induced interference for chest counting. A metal strap completely encircles the liquid nitrogen dewar now in addition to the bolts that secure the bottom of the dewar to the base plate. The surfaces of the dewar are insulated from the detector holders and mounting assembly with silicon rubber.

The performance of the standup counter was problematic in November. Problems included resolution degradation, low-energy electronic noise, and instability of the gain settings. On occasions, a detector suffered a temporary gain shift and then returned to normal gain. This was enough to invalidate the results. All persons involved were recounted on the coaxial HPGe system. Several components including amplifiers, high-voltage power supplies, cabling, analog-to-digital converters, multiplexers, and preamplifiers were replaced during the month and the system remained stable during December.

4.2.6 Facility Issues

Power to the 747-A Building was interrupted for 1.5 hours on July 29. The uninterruptible power supplies functioned properly. However, due to the length of the outage, power was lost to the RS6000 and one VAX workstation. A corrupt archiver file on the RS6000 caused a 2-hour delay in bringing the

NEXEC system back online. Counting was performed with the VAX workstation while the RS6000 was brought online. None of the persons counted during this time had to be brought back for a recount. The backup calculations were updated to exactly match the current algorithms.

A leak was observed coming from a ceiling vent in the 747-A Building during a period of heavy rain. Investigation by IVRRF staff indicated that the cap from an inoperable roof exhaust had been removed. The cap was replaced to solve the immediate problem, and because the roof exhaust is no longer needed, this roof penetration will be sealed.

Unnecessary compressed air piping was removed from the 747-A Building and the piping connection with the adjacent 747 Building was severed. A small compressor located behind the counting rooms on the north side of the 747-A Building provides the motive force for operating the stainless steel room door. The shower stalls in the men's change room are rusted through at the base of the walls where they meet the shower floor. Requests were submitted to the building manager to seal the rusted areas until funding is identified to replace the rusted stall walls.

4.3 Supporting Investigations and Studies

The WBCP staff pursued six additional project-related activities during 1998, as described in the following sections.

4.3.1 ^{241}Am Inhalation Case

In collaboration with the United States Transuranium and Uranium Registry (USTUR) at Washington State University, a tenth set of lung, liver, and skeletal measurements was performed in October on an individual, identified as USTUR Case 0855, who sustained an inhalation of pure ^{241}Am oxide from a ruptured source in February 1996. The preliminary results are discussed below. A joint publication, more fully describing this case, is planned.

The clearance half-time from the lung is estimated to be 240 days in this case, which is consistent with a material having a solubility between Class M (moderate) and Class S (slow). The clearance from the lung and uptake by the lung skeleton are both adequately described by exponential functions. The uptake and clearance in the liver is adequately described using a polynomial function. Plots of these buildup and clearance curves are shown in Figures 4.2 to 4.4. The respective function, and least squares measure of fit (R^2) with collected data, are also shown in Figures 4.2 to 4.4.

Estimates of the skeletal activity were made based on measurements over the forehead, knee, wrists, and ankles. The curve in Figure 4.3 is based on the measurements over the forehead with two planar HPGe detectors. Skeletal estimates based on the three measurements generally agreed within 20% to 30% over the entire period since February 1996.

Support for this work was provided through the USTUR at Washington State University.

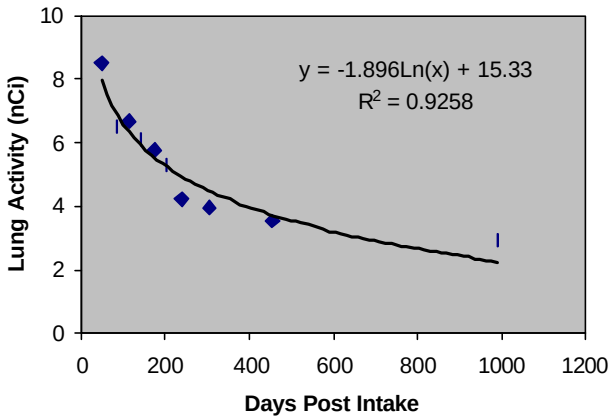


Figure 4.2. Clearance of ^{241}Am Oxide from the Lungs in USTUR Case 0855

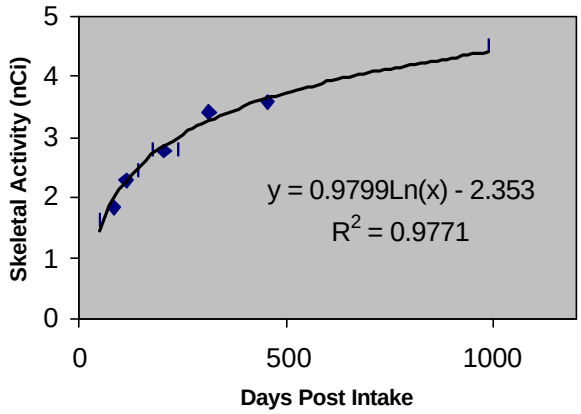


Figure 4.3. ^{241}Am Uptake in the Skeleton of USTUR Case 0855

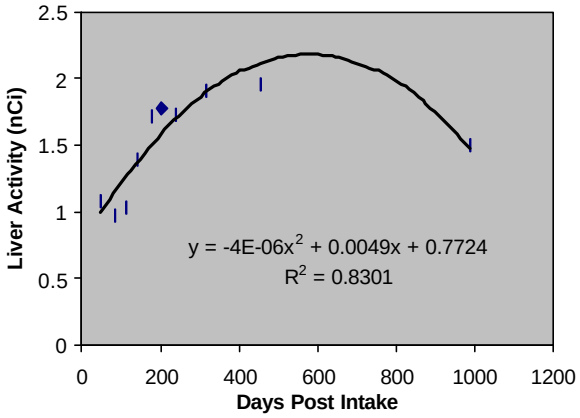


Figure 4.4. Uptake and Clearance of ^{241}Am in the Liver of USTUR Case 0855

4.3.2 Thoron-in-Breath Monitor

Development of the thoron-in-breath monitor (TIBM) was completed in 1998. The use of a dessicant to dry the exhaled air prior to entering the TIBM collection chamber was implemented to minimize the variation associated with humidity effects on collection efficiency. A model RSS 100 Research Spirometry (RSS) from Korr Medical Technologies, Inc. was purchased to reliably measure airflow. The computer-based system employs pneumotach sensors that measure differential pressure, which is converted to flow rate; the measurement precision at three standard deviations for this system is 1.5% of the measured value. This type of system is widely used for pulmonary function testing in the medical field.

A total of 26 persons who have no recorded occupational exposure to thorium have been counted with the TIBM. Based on these data a minimum detectable intake (MDI) of 100 Bq to 150 Bq of ^{232}Th is calculated. The MDI value is based on a measurement 365 days after an acute intake of a 1 μm Class Y ^{232}Th (in equilibrium with ^{228}Th) aerosol. The MDA for the counting system is ~1 Bq based on a 20-hour count.

Attempts to find persons in the United States with measurable amounts of ^{232}Th in the body and who would participate in the testing of the TIBM were unsuccessful. Numerous contacts were made in the United States and internationally. Exposed individuals were located in Brazil, Canada, and Russia.

4.3.3 DOE Phantom Library

WBCP staff supported the operation of the phantom loan program component of the DOE Phantom Library Program in 1998. The program is funded by DOE-HQ and loans calibration phantoms to bioassay laboratories for calibrating measurement systems. The phantoms are loaned to DOE and other facilities for the cost of round-trip transportation. The Phantom Library Program maintains the records and calibration information for the phantoms, provides technical assistance in the field of radiobioassay, and conducts validation measurements for organ phantoms.

The DOE Phantom Library includes an inventory of 22 lung phantoms, 8 liver phantoms, 8 bottle-manikin absorption (BOMAB) phantoms, two sets of lymph node phantoms, an ^{241}Am skeletal phantom, a fission product phantom, a LLNL torso phantom, and three thyroid phantoms. Fifteen phantom loans were made in 1998. Lung phantoms were loaned 11 times, a torso phantom (with chest overlays and a set of lung phantoms containing no radioactive material) was loaned once, and one thyroid phantom was loaned. Two international loans of the ^{241}Am skeletal phantom were also made.

4.3.4 Support of Carlsbad Environmental Monitoring and Research Center

The WBCP staff performed measurements of an ^{241}Am lung phantom from the Carlsbad Environmental Monitoring and Research Center (CEMRC) as part of an intercomparison study. The purpose of the study was to check the accuracy of the stated activity in the phantom. The lung activity was estimated to be 788 ± 12 nCi (1 sigma). The results were reported to CEMRC and helped confirm their measurements, which indicated that the stated activity in the phantom was underestimated.

4.3.5 New In Vivo Counting Hardware and Software

The development of the Abacos in vivo counting software on a Digital Equipment Corporation (DEC) Alpha Workstation continued in preparation for replacing the current system in 1999. Preliminary calibrations of the routine counting systems were completed.

- Command procedures and code were written to simplify the user interface for operating up to four counting systems simultaneously. Basic programs were written to interface the system with REX to receive the daily count schedule, to transmit the accountability file to REX at the end of the day, and to transfer the weekly record files

- VMS licenses were purchased for installation on the DEC-Alphastation (obtained from Dosimetry Services) because this system is currently running with a Unix operating system. These licenses will allow for the use of Open VMS 7.1 on this Alphastation. The Abacos software will be loaded onto this machine and it will become the backup system for the primary DEC Alphastation that is running Canberra's Abacos whole body counting software.

- A 9-gigabyte hard drive was purchased and installed in the primary DEC Alphastation to act as a user disk, the disk on which counting data are stored. Storage of count data on a disk other than the system disk allows for use of a disk backup method that does not involve shutdown of the system. The new disk's capacity is expected to allow for several years of spectra to be stored on disk.

- A second network card was purchased and installed in the primary DEC Alphastation. This second network card allowed connection to the Hanford Local Area Network (HLAN). The personal computers (PCs) and the primary Alphastation were connected over the HLAN. Communication between the DEC Alphastation and the PCs over the HLAN was established using the Excursion terminal emulation software. This configuration provides several parallel user terminals for operation.

During calibration of the chest counting detectors using Abacos, a discrepancy was discovered between the calibration using an $^{241}Am/^{152}Eu$ lung phantom and the calibration using a ^{235}U lung phantom. The activity of the ^{235}U lung phantom when calculated with Abacos was 30% higher than the stated activity in the phantom. A series of intecomparisons were made using phantoms from other in vivo counting facilities. All the ^{235}U results were consistently high based on the $^{241}Am/^{152}Eu$ calibration with Abacos. Only one other in vivo counting facility was experiencing this phenomenon. It was eventually determined that the high bias was being caused by true coincidence (as opposed to random summing due to high count rates) summing of the ^{152}Eu photons. When two photons deposit energy in the sensitive volume of the detector within the resolving time of the detection system a peak is produced that is equal to the sum of the two energies. This causes a "summing out" effect at the two original energies. This summing out effect causes the efficiency at the original energies to be decreased. The lower efficiency resulted in calculated activities that are biased high. The $^{241}Am/^{152}Eu$ calibration curve was compared with a calibration curve generated using the ^{241}Am, ^{234}Th, and ^{235}U lung phantoms that have been previously used for calibration. The $^{241}Am/^{152}Eu$ calibration curve values were 20% to 30% lower compared with the other curve from 100 keV to 230 keV. The decision was made to calibrate using the

three phantoms to eliminate the coincidence summing problem. The true coincidence summing is a function of the geometry of the detector and the source and is often seen in counting geometries where the detector is in contact with the sample.

4.3.6 Torso Phantom

The new torso phantom purchased in 1998 from Radiology Support Devices is shown in Figure 4.5. The phantom (CM-149-334) and the four chest overlays (CM-148-333) are made from 100% International Commission on Radiological Units and Measurements (ICRU) muscle equivalent polyurethane based plastic. The phantom is similar in design and composition to the C-108 torso phantom currently being used. However, the two sets of C-108 chest overlays are made from 87% fat/13% muscle and 50% fat/50% muscle. The thickness of the phantom in the positions directly under the four chest counting detectors will be determined in early CY99.

Figure 4.5. New Torso Phantom Purchased in 1998 from Radiology Support Devices

4.4 Project-Related Professional Activities

Staff activities, presentations, publications, and professional memberships during 1997 are listed in this section.

4.4.1 Activities

Timothy P. Lynch served as the lead assessor for the DOELAP onsite assessment of the bioassay programs at the Savannah Site from November 2-6, 1998.

4.4.2 Presentations

John R. Johnson presented the paper, *Method for Estimating Thorium Activity in the Body Using a Thoron-In-Breath Monitor (TP Lynch, JR Johnson, RL Traub)*, at the 44th Annual Conference on Bioassay, Analytical and Environmental Radiochemistry held in Albuquerque, NM, on November 15-19, 1998.

4.4.3 Professional Memberships

Lynch, T.P., Chairman of the working group developing the ANSI N13.35 standard, *ANSI Standard for the Bottle Manikin Absorption Phantom.*

Olsen, P.C., Chairman of ANSI N13.31 Working Group writing the ANSI Standard, *ANSI Standard for the Torso Calibration Phantom for In Vivo Radiobioassay*.

Olsen, P.C., Member of ANSI N13.35 Working Group writing the ANSI Standard, *ANSI Standard for the Bottle Manikin Absorption Phantom.*

Olsen, P.C., Member of ANSI N13.44 Working Group writing the ANSI Standard, *ANSI Standard for Thyroid Calibration Standard Phantoms.*

5.0 Hanford Radiation Records Project

The Hanford Radiological Records Project (HRRP) supports RL and Hanford contractor radiation protection programs, by administering and preserving radiological exposure records for all Hanford workers and visitors, past and present, and by providing specified and requested reports using these records. The program is also responsible for maintaining the Hanford Radiation Protection Historical Files; operating the computer systems and library equipment necessary to input, store, verify, and retrieve the records; and producing the required reports and downloads. Although data handling functions are now the responsibility of Dosimetry Services, data entry and validation and report issuance are reported in this section.

The Hanford Access Control and Entry System (ACES) was created to implement a system for computerized supplemental dose tracking and radiation area/hazardous waste site access control. It is a computerized access control program that electronically compares worker qualifications with controlled area access requirements. Although HRRP has data administration responsibilities of ACES, FDH retains ownership. However, the HRRP manager works closely with the FDH ACES manager and Lockheed Martin Systems (LMSI) personnel in the operation and maintenance of the system. In 1998, ACES was upgraded from a time-share system on a SUN SPARCserver 1000 minicomputer, to a client-server system. The upgraded ACES is hosted on an HP 9000 computer (four 180-MHz processors) using the Hewlett Packard Unix operating system and ORACLE software to manage the database and provide entry screens and reports. Users continue to access the server via PCs connected to the HLAN. However, the access software now resides on the users' (clients') computers, and is Windows based. As in the past, the database receives data from several other Hanford computer systems (e.g., PeopleSoft, REX, and PeopleCORE).

The REX system is a computerized database that maintains all of the radiological exposure records and supplementary and support data for individuals who have worked at the Hanford Site since 1946. The REX system contains the individual radiological exposure records on all Hanford DOE, contractor, and subcontractor employees as well as Hanford visitors. The system also contains other information used by site radiation protection organizations, such as individual skin contamination reports and bioassay schedules and delivery addresses. These data are readily retrievable via a system of PCs and terminals operated by the HRRP and Hanford contractor dosimetry staffs. The REX system also includes supporting exposure documentation on microfilm and compact disk that are indexed into computer-assisted retrieval (CAR) systems. The CAR systems allow for rapid retrieval of documents for any individual using identifiers (IDs), including payroll numbers, social security numbers, names, and/or REX IDs, which are unique numbers generated by the computer for each individual to tie all of their records together. The project also uses a compact disk imaging subsystem (called LaserREX). Since January 1, 1992, all hard-copy exposure records have been preserved on LaserREX. Hard-copy records generated prior to 1992 are maintained on microfilm. The LaserREX also stores the electronic records created by the REX transaction log subsystem, which logs all changes to the database data fields.

The REX database resides on the multi-user Enterprise Server (ES) operated by LMSI. Many major systems were removed from the ES in 1998, decreasing the processing volume by approximately 70%.

While the total site cost for the ES was significantly reduced, the costs to be borne by the remaining systems are expected to triple for 1999. Recommendations were solicited from two consultants on rehosting REX. Both proposed a client-server system similar to ACES. Hardware recommendations have been proposed, and redevelopment is expected to cost about $1M and take about one year after approval is received.

Records in the Hanford Radiation Protection Historical Files include documents such as policies, procedures, reports, and important communications that define the Hanford radiological dosimetry and radiation protection programs throughout their history. The historical records are microfilmed and indexed into an additional CAR system. These records are retrievable by author, date or range of dates, document number (if applicable), document title, and up to three keywords.

The program is operated under the applicable sections of 10 CFR 835 (DOE 1993); the *Hanford Site Radiological Control Manual* (RL 1994); ANSI N13.6, *American National Standard Practice for Occupational Radiation Exposure Records Systems* (ANSI 1972); as well as the following DOE Orders: 1324.5B, *Records Management Program* (DOE 1995a); and 231.1 *Environment, Safety and Health Reporting* (DOE 1995b). The program also complies with the applicable sections of the Privacy Act (1974) and the Freedom of Information Act (1966).

5.1 Routine Project

The HRRP is organized into four major functional areas: data administration, data handling, report issuance, and the Records Library.

Database administrators evaluate systems, troubleshoot, resolve system and user problems, train users, oversee system security, serve as liaison with the LMSI computer analysts, and initiate and test modifications of the databases for the REX system and ACES.

Data handling includes entering data into the REX database and validating all data entry. This function is actually the responsibility of Dosimetry Operations. Data validation is accomplished by reviewing field data entry, establishing audits to be matched to entries of results, resolving unmatched results, and interacting directly with contractor personnel. Data handlers also deal directly with contractor personnel and data suppliers to assist them and solve data problems. Dosimetry Operations also issues, tracks, and processes dosimeters for PHMC and DOE.

The report issuance function is shared between Radiation Records and the Data Processing Center. Dosimetry Operations is responsible for generating and issuing routine exposure status reports to the contractors, quarterly person-rem and annual statistical reports to DOE, and annual reports to employees. This function requires close contact with RL, the contractors, and other personnel dosimetry functions. Special reports requested by former employees, as well as those requested by the contractors, RL, the Uranium and Transuranium Registries, and Privacy Act and Freedom of Information Act petitions, are the responsibility of Radiation Records. Data handling and part of report issuance are performed by the HRRP Dosimetry Operations staff.

The Records Library maintains individual exposure records that are not reducible to database elements and backup documentation as well as the Hanford Radiation Protection Historical Files. The library staff scan, index, and retrieve hard-copy documents; prepare documents for long-term storage; and track and account for the documents through the imaging and indexing process. The library contains the individual exposure records of all Hanford personnel since Hanford's inception in 1944 (almost five million microforms), except for those individuals who transferred from Hanford when DuPont left in 1946. These exposure records and the Historical File microforms are retrievable through index systems that are maintained by the library staff.

Although the results from the dosimeter and excreta processing, as well as the in vivo counts, are received by electronic transmission, a large amount of data is entered manually by the field dosimetry organizations and the HRRP Data Processing Center staff. The hard copies are then sent to the library for preservation on the imaging systems. Table 5.1 presents CY98 statistical information on many of the documents that are entered into the database and indexed into LaserREX. Some documents, such as the Employee and Dosimetry Change Form, may contain several pieces of information that require data entry.

Table 5.1. Records Activity for Calendar Year 1998

Document Type	1997	1998
Personal Radiation Exposure History Form (used to document exposure history prior to Hanford and to initiate a record for a new or rehired employee)	2,485	2,142
Employee and Dosimetry Change Forms (used to document personnel data or dosimetry changes)	4,099	6,717
Termination Letters (used to document employee terminations, many changes were done electronically not requiring forms)	4,095	1,599
Temporary Dosimeter Assignment Forms (used for issuing temporary dosimeters to employees due to new hires, changes in dosimetry requirements, multiple dosimetry, or employees who forgot their dosimeters)	13,237	5,080
Visitor and Subcontractor Dosimeter Issue Forms (used to issue dosimetry to visitors and subcontractors not completing radiological worker training)	2,891	2,116
Investigation of Dosimeter Result Forms and Change Letters (used to estimate exposure for lost, damaged, or otherwise suspect dosimeter results)	2,275	614
Special Process Forms (used to document data for specially processed dosimeters)	8,796	1,547
Requests for Exposure Summaries (summaries requested for current and prior Hanford employees)	422	432
Letters Sent to Request Prior Exposure (to request summaries for new employees with prior exposure or existing employees receiving exposure at offsite facilities)	1,069	301
Total number of hard-copy records scanned and indexed into LaserREX[(a)]	39,751	32,642
(a) This total is for all of the hard-copy records scanned and indexed into LaserREX, some of which are not listed in this table.		

5.1.1 Assessments and Surveillances

The 1998 Hanford Site Contractor Assessment of the HRRP was conducted in October. It was a joint evaluation of the HRRP by PNNL, the PHMC, ERC, and HEHF, as required by 10 CFR 835.102. In addition, the deficiencies identified in the previous assessments in 1995 and 1997 were verified for completion.

The report identified six observations, although it stated that the overall implementation of radiological records program requirements appeared to be very good. An observation is a poor practice or weakness that, in the judgment of the assessor, does not pose the potential for significant safety or compliance consequences, but if not corrected could result in a finding. Observations should be corrected as soon as practical. The observations are listed as follows:

- The document control system used by HRRP does not adequately control the use of the most recent manual revisions.

  Response–REX-002, Revision 6, was in the historical file, but the hard-copy manual on the library shelf did not contain the most current revision. The hard-copy manual was updated and the manual copy was reinstated on the Document Control automatic revision list.

- HRRP is adding medical exposure records to the individual's file, which is contrary to the policy stated in the project manual PNL-MA-553, 4.1.4.

  Response–HRRP will discontinue adding medical exposure records to the historical file based upon receipt of the IODR written to describe the process to subtract medical dose from dosimeter result.

- HRRP has not been performing annual management assessments as required by HRRP-01, Procedure AD-09.

  Response–The last management assessment was completed in June 1997. Procedure AD-09 specifies that assessments shall be conducted at least annually (Note: Annually is defined in Procedure GL-01 as "Normally a period of 12 months, not to exceed 15 months.") The next assessment was due no later than September 1998. The Radiological Records Manager retired in May 1998, prior to the due date of the assessment. His replacement terminated in July 1998. The present manager will complete the next assessment by February 26, 1999.

- The semi-annual self assessment being performed on microfilm reels should be expanded to include records on all media.

  Response–The semi-annual self assessment on microfilm reels is limited to a check for physical deterioration of film. Compact disks are not subject to such damage under normal storage conditions, and do not require evaluation for deterioration.

- The record backup copy should be retained for a specified period of time depending on whether or not the backup copy is considered a record.

  Response–The backup copies are records and per 10 CFR 835.701(b) must be maintained until final disposition is authorized by DOE.

- REX-001, “Software Configuration Management Plan” (SCMP) is not being reviewed at the frequency established by the plan.

  Response–The REX SCMP (REX-001) was last reviewed and approved in January 1997. The next review should have been completed by April 1998. The SCMP will be assessed and approved by February 26, 1999.

5.1.2 ACES Database

The original version of ACES was determined to *not* be Y2K compliant. Therefore, an upgrade (Version 6.0) was initiated in 1998 that maintained the established functionality, but in a Windows-based client-server environment that is fully Y2K compliant. Preliminary testing was completed in December 1998, but implementation was delayed into January 1999. The ACES data administrator was very involved with testing screens and reports in Version 6.0 prior to release, and coordinating user field-testing.

The ACES data administrator provides monthly reports of entry and dose data to PNNL and PHMC. There were over 700 open Radiation Work Permits (RWPs) at the end of 1998. Upon request, the data administrator provides personnel qualification reports to federal and state regulators and adjusts the Administrative Control Limits (ACLs) for individuals in accordance with established policies. The data administrator also tracks and participates in the correction of identified problems with ACES operation.

5.1.3 REX Database

REX has always been Y2K compliant through a patch installed in the programming. A program inserted during its development converts all two-digit year entries to a four-digit number, and recognizes when 20XX should be used instead of 19XX. However, all REX software was upgraded or scheduled for upgrade in 1998 to remove the need for the patch. Testing of the upgraded database software (DB2) and programming software (COBOL) was completed in December 1998. The user interface (Gener/OL) and report facility (Platinum Report Facility) will complete testing early in 1999.

The REX database performed very well all year. The majority of the Software Change Requests issued during the year were for changes and enhancements to make operations more efficient and data entry less cumbersome. The REX User's Group, initiated late in 1993, was instrumental in proposing and defining many of the enhancements and changes. Some of the significant changes included the following:

- A daily update of bioassay data was established with BHI for in vivo measurements schedules, in vivo appointments completed, and excreta and in vivo measurements waived.

- Dosimeter Status Reports and ALARA Reports are now available in Insight (the sitewide reporting facility that replaced Y2K non-compliant Soft Reporting). Insight accesses the REX database, and reports may be run by the users, as needed.

- The PHMC changed their use of the organization code used by REX to a high-level cost code. In order to identify the correct managers and organizations to receive reports, REX had to change the logic in 26 screens and reports to use the first five characters of the department ID instead. This logic change was for PHMC only.

- The format of the results letter for special bioassays was modified to be more consistent with the routine bioassay results letter.

- A new instruction letter report was created for special termination bioassays. The kit is delivered to the worker's home as usual, but the letter instructs the worker to bring the kit to a specified onsite location for retrieval by the bioassay contractor. This procedure was initiated to reduce the number of uncompleted bioassay samples.

- A new report was created for "Waiver of Routine Annual Excreta Bioassay." The letter is placed in the worker's history file for documentation.

- The computer interface with the external dosimetry computer was modified to allow NC59 results (neutron indication on a Hanford standard dosimeter) to be accepted by REX and used as the record note code of the result. This change was initiated after the Hanford standard dosimeter was accredited for neutron dosimetry.

5.1.4 LaserREX Imaging System

The original LaserREX system consisted of two PCs (the compact disk [CD] writer that compiled images and created CDs and the CD controller that controlled the CD jukebox), and two computer workstations each with an optical scanner. A hardware upgrade in October 1998 replaced the CD writer and CD controller with a single 350-MHz dual processor Gateway ALR 7200 server using Windows NT. Intermittent problems were experienced with the new system until a faulty motherboard was identified and replaced in December. Problems with remote access (LRFind) and reporting functions continued into the new year because of persistent configuration problems.

5.2 Supporting Projects

The project for the National Institute of Occupational Safety and Health (NIOSH) was completed to supply NIOSH with most of the personnel radiation exposure and Hanford Radiation Protection Historical Files (over 2,000 microfilm reels) and their indices. The original microfilm negatives were copied onto new diazo film and the indexes put into an electronic form so that NIOSH could install them on their computer. The project was completed for about $12K (half the original estimate). The cost to provide paper copies of the 2,000 plus reels was originally estimated at $160,000.

5.3 Project-Related Professional Activities

Professional activities and/or memberships during CY98 are listed in this section.

MacLellan, J.A., Chairman of the American Academy of Health Physics Appeals Committee.

MacLellan, J. A., Treasurer, Columbia Chapter of the Health Physics Society.

6.0 Instrumentation Services and Technology Project

The Instrumentation Services and Technology Project (IS&TP) provides complete and reliable radiation protection instrument services for Hanford Site contractors to ensure personnel safety in the Hanford workplace. Specific tasks performed under this project during 1998 included calibration, maintenance, and repair of portable instrumentation; procurement and testing of new radiological control instruments; administration and technical support of the Hanford Instrument Evaluation Committee (HIEC); and maintenance of a pool of portable survey instruments available for use by site contractors.

6.1 Routine Program

Operation of a complete radiation protection instrument calibration and maintenance program is an integral part of the Hanford Site Radiological Control Program. During CY98, IS&TP continued to provide complete instrument services. As the Hanford Site's mission and scope continued to evolve to a more privatized, cost-efficient operation, IS&TP made required scope and operational changes. At the end of FY98, DOE made the decision to not privatize the services provided, in part, by IS&TP. Thus, the last few months of CY98 were spent making scope and operational changes required to return IS&TP to primarily support Hanford Site operations.

Calibration and maintenance of the Hanford pool of portable radiation protection instruments has historically been separate from the calibration and maintenance of contractor-owned instruments. During CY98 the transition was made to new unit prices, which effectively eliminated any differences between pool and contractor-owned instruments. Instead, unit prices are based on the complexity of the instrument calibration. In addition, instrument maintenance and non-calibration services, such as instrument testing and configuration control, provided by IS&TP were unbundled from the unit prices. Maintenance is costed at an hourly rate with the required parts and labor charged to the last contractor to use the instrument. The result is a cost structure that allows for a more direct comparison between IS&TP and commercial calibration services.

Procurement of new instruments is initiated by site contractors, or jointly by the contractors through the HIEC, and the procurement costs are charged to the contractor who uses the instruments. The Hanford contractors, through the evaluation, calibration, and maintenance programs of IS&TP provide the site with high-quality instrumentation that is reliable, accurate, and capable of performing at the level necessary to ensure personnel safety as required by 10 CFR 835 (DOE 1993) and the *Hanford Site Radiological Control Manual* (RL 1994). Calibrations are performed using the mandatory guidance in ANSI N323-1978, *Radiation Protection Instrumentation Test and Calibration* (ANSI 1978). IS&TP activities fall under several tasks. These tasks are: 1) administration of the Hanford Site pool of portable survey instruments; 2) calibration and maintenance service of Hanford pool, PHMC, PNNL, and BHI radiation protection instruments; 3) evaluation and publication to the site of all site portable survey instrument environmental parameters; 4) maintenance of a calibration records database; 5) maintenance of all the necessary radiological, electronic, and mechanical standards traceable to NIST; and

6) administration and technical support of the HIEC. These tasks and other important supporting activities performed in CY98 are described in this section.

6.1.1 Calibration Volume

During CY98, approximately 14,500 calibrations were performed by IS&TP. Table 6.1 details the number of instruments calibrated by calibration class and compares the volume to the number of calibrations performed last calendar year. Tables 6.2 through 6.5 provide additional detail on the number of calibrations performed each month during CY98. The same information is illustrated in Figures 6.1 through 6.4.

The total number of calibrations performed decreased from the number performed in CY97. The volume can not be easily compared with years before CY97 due to redefinition of the calibration classes.

6.1.2 Calibration As-Founds Out-of-Tolerance

Part of the calibration service provided by IS&TP is quantifying the as-found condition of each instrument when it is returned for calibration. The as-found condition is typically documented as the instrument's response to the calibration standards and is recorded before any adjustments are made to the instrument's response.

A total of 81 instruments calibrated during CY98 were found to be significantly out-of-tolerance when returned for calibration (that is; the instrument's response was not within ±20% of the conventionally true value of the calibration field). This total does not include instruments that were returned for calibration with flaws or defects that would render the instrument obviously unusable to the user. Nor does it include instruments that were repaired prior to calibration because any repairs would invalidate the as-found readings.

The number of as-found out-of-tolerance conditions reported by instrument type is summarized in Table 6.6.

Table 6.1. CY98 Instrument Calibrations by Unit-Price Category

Calibration Class	Description of Class	Number of Calibrations by Calendar Year	
		1997	1998
CAMs	Continuous Air Monitors	495	458
Exposure Rate	Exposure or Dose Rate Survey Instrument	2219[(a)]	1896
Detectors	Probe or Detector Only	3944	3670
Electronic Dosimeters	Direct Reading, Electronic Dosimeter	804	647
Full Calibration	Integral Meter and Detector	265	320
Meter only	Electronic Calibration of Meter or Readout	3973	3558
Pocket Ionization Chambers	"Pencil" Dosimeter	3946	3149
Smart Detectors	Stand-Alone Calibration of a "Smart" Detector	487	486
Sources	Certification of Source Activity or Emission Rate	386	324
Special Calibrations	Complex Calibrations Charged by the Hour	68	112
Total		16,637	14,620

Table 6.2. CY98 Calibration Volume for All Hanford Contractors

Calibrations Completed, by Month, for CY98												
Calibration Class	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Exposure Rate	180	168	208	177	172	154	102	177	139	173	101	145
Full	35	21	25	19	22	19	22	23	44	35	29	26
Meter	339	337	339	276	347	271	275	429	202	303	236	204
Electronic Dosimeter	21	97	73	57	53	44	37	71	72	62	22	38
Probe	312	333	394	324	371	229	270	379	196	358	250	254
Smart Probe	34	41	31	23	69	38	47	68	33	52	26	24
CAM	37	38	51	36	35	52	33	27	39	29	41	40
Pencil	142	112	154	143	273	157	371	463	214	588	358	174
Source	26	16	56	36	9	22	29	29	27	27	27	20
Special	0	27	9	9	7	6	6	7	7	10	13	11
Battery Change Only	11	14	18	13	15	18	16	18	15	0	0	0
Total	1137	1204	1358	1113	1373	1010	1208	1691	988	1637	1103	936

Table 6.3. CY98 Calibration Volume for the PHMC

Calibrations Completed, by Month, for CY98												
Calibration Class	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Exposure Rate	123	128	162	113	104	118	90	152	127	132	87	127
Full	28	21	22	10	20	18	18	19	26	31	26	22
Meter	246	244	253	186	287	174	180	300	153	231	179	175
Electronic Dosimeter	21	88	71	41	45	28	34	71	71	52	22	38
Probe	257	241	310	236	319	180	202	280	144	269	159	210
Smart Probe	0	0	0	0	0	0	0	20	0	14	0	0
CAM	31	33	40	25	29	48	30	23	35	26	37	35
Pencil	99	107	140	115	272	148	322	399	141	478	208	119
Source	22	16	53	33	8	19	29	27	27	24	25	14
Special	0	14	1	0	2	3	1	3	3	8	5	6
Battery Change Only	9	10	13	12	10	15	11	17	13	0	0	0
Total	836	902	1065	771	1096	751	917	1311	740	1265	748	746

Table 6.4. CY98 Calibration Volume for BHI

Calibrations Completed, by Month, for CY98												
Calibration Class	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Exposure Rate	39	29	11	18	18	6	1	6	5	12	1	7
Full	0	0	0	0	0	0	0	0	2	0	0	0
Meter	59	31	36	50	19	44	27	24	17	30	14	13
Electronic Dosimeter	0	2	2	3	5	14	3	0	0	10	0	0
Probe	33	33	30	41	19	9	11	12	5	20	14	6
Smart Probe	34	41	31	23	69	38	47	48	33	38	26	24
CAM	2	1	0	0	2	1	0	1	1	1	1	1
Pencil	10	0	1	0	0	0	43	40	49	0	23	5
Source	0	0	0	0	1	2	0	0	0	0	0	4
Special	0	3	0	0	4	0	2	1	0	1	6	0
Battery Change Only	1	2	1	0	0	1	3	0	0	0	0	0
Total	178	142	112	135	137	115	137	132	112	112	85	60

Table 6.5. CY98 Calibration Volume for PNNL

Calibrations Completed, by Month, for CY98												
Calibration Class	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Exposure Rate	18	11	35	46	50	30	11	19	7	29	13	11
Full	7	0	3	9	2	1	4	4	16	4	3	4
Meter	34	62	50	40	41	53	68	105	32	42	43	16
Electronic Dosimeter	0	7	0	13	3	2	0	0	1	0	0	0
Probe	22	59	54	47	33	40	57	87	47	69	77	38
Smart Probe	0	0	0	0	0	0	0	0	0	0	0	0
CAM	4	4	11	11	4	3	3	3	3	2	3	4
Pencil	33	5	13	28	1	9	6	24	24	110	127	50
Source	4	0	3	3	0	1	0	2	0	3	2	2
Special	0	10	8	9	1	3	3	3	4	1	2	5
Battery Change Only	1	2	4	1	5	2	2	1	2	0	0	0
Total	123	160	181	207	140	144	154	248	136	260	270	130

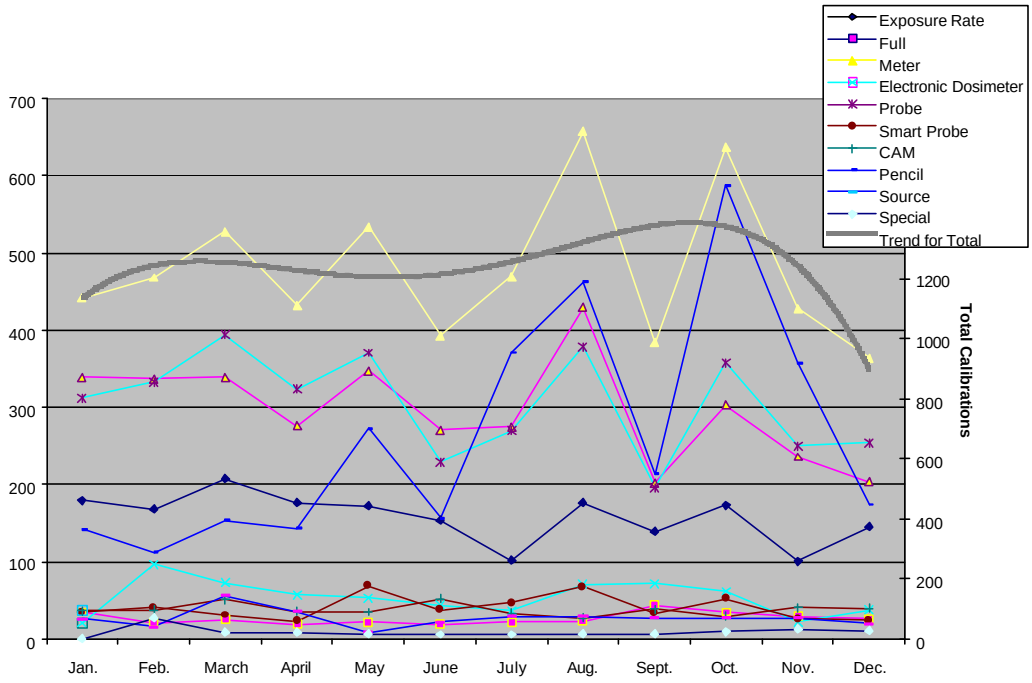


Figure 6.1. Hanford Calibrations during CY98

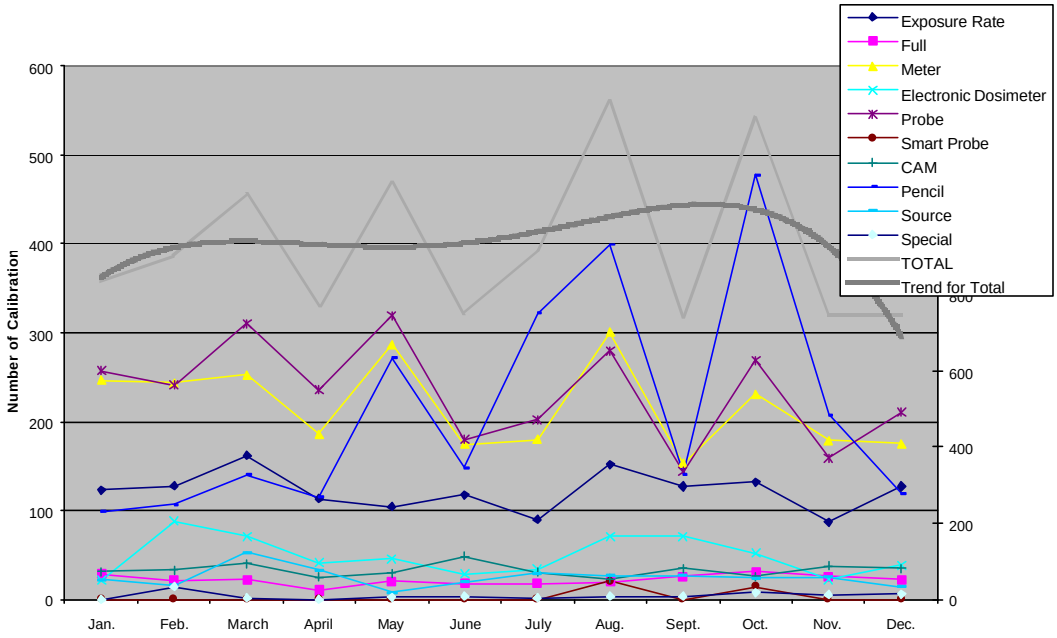


Figure 6.2. PHMC Calibrations during CY98

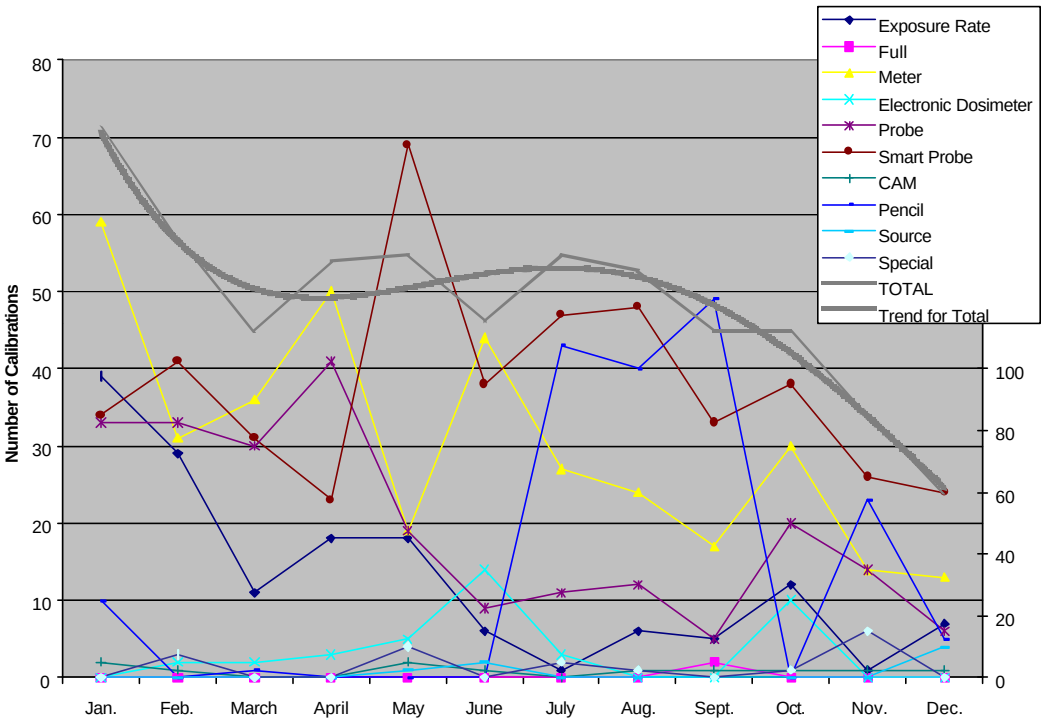


Figure 6.3. BHI Calibrations during CY98

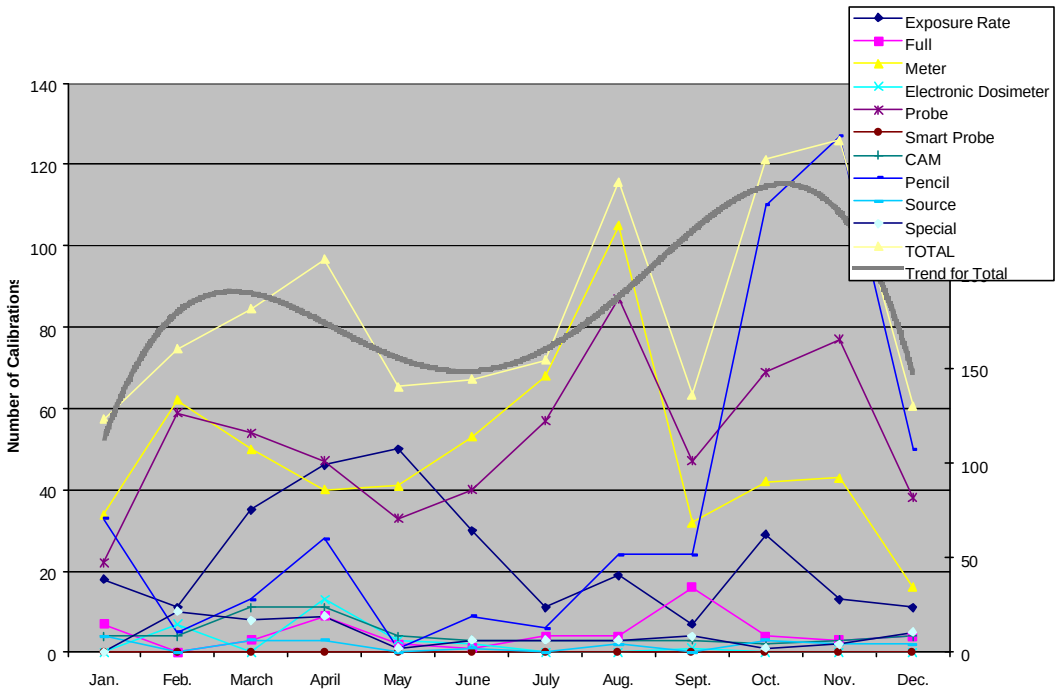


Figure 6.4. PNNL Calibrations during CY98

Table 6.6. Calibration Out-of-Tolerance Notifications by Instrument Type

Number of Out-of-Tolerance Reports	Instrument Type
9	Pencil Dosimeters
8	Air Flow Measuring Devices
13	Area Radiation Monitors
2	Air Sample Pumps
2	Beta Continuous Air Monitor (CAM)
1	Bench Monitor
14	Geiger-Mueller (GM) Count Rate Meters
1	Sample Counter
2	High-Range Exposure Rate Instruments (RO-7)
2	Alpha/Beta Contamination Detectors
1	Electronic Dosimeter
22	Ion Chamber Exposure Rate Survey Instruments (RO-3B; RO-20)
2	Neutron Dose Rate Monitors
2	Extendable, High-Range Exposure Rate Survey Instruments
81	**Total**

6.2 Project Improvements in Calibration and Maintenance Operations

A primary improvement during CY98 was the unbundling of the calibration costs for Hanford contractors. The traditional calibration charge has included numerous services beyond routine calibration. These services include instrument pick-up and delivery, records maintenance, and instrument configuration control. To allow customers to select desired services, and to not pay for undesired services, the individual services were separated from the base calibration charge.

Instrument evaluation and testing was also improved. The HIEC was established to provide a Hanford intercontractor information exchange mechanism to ensure that the highest-quality portable and semi-portable radiological protection instrumentation program is maintained at Hanford. Responsibilities of the committee include the following:

- Discuss and propose solutions to ongoing or potential radiological instrumentation problems and needs onsite.

- Identify new radiological instrumentation available from manufacturers that may be useful to Hanford Site operations.

- Oversee the procurement of the instruments and review the evaluations of the performance by contractor organizations.

- Establish or review minimum acceptable operational criteria for portable and semi-portable radiological instrumentation used for safety on the Hanford Site.

- Promote information exchange between contractors on radiological protection instrumentation usage and problems/resolutions.

Representatives from all of the Hanford contractors and a representative of RL are on this committee.

During 1998, the HIEC continued to perform evaluations on instruments identified as needing further evaluations before being approved and placed on the "approved instrument list." The "approved instrument list" was developed to meet HSCRM-1 (RL 1994) requirements that only approved instruments may be used onsite.

IS&TP supports the HIEC by serving as the organization's secretary and providing administrative and technical support. In this role, IS&TP maintains the approved instrument list and the record files of all instrument evaluations completed for Hanford Site customers. IS&TP also provides technical support in the areas of instrument testing and design.

6.3 Supporting Investigation and Studies

IS&TP provided technical support to two related projects this year as described in the following sections.

6.3.1 Testing to Qualify Site Instruments for Use in the Hanford Environment

In support of the site contractors' requirements for 10 CFR 835, several radiation detection instruments used onsite were evaluated for compliance with qualification and documentation requirements for use in the Hanford Site environment. The instruments evaluated and recommended for approval included a Bicron Micro Rem meter with an audible response and several models of Eberline smart detectors and count rate meters.

6.3.2 Chornobyl Neutron Monitoring System Technical Assistance

IS&TP provided technical support to DOE's International Nuclear Safety Program on several projects related to the Chornobyl Shelter and Decommissioning Program. These projects involved purchasing and acceptance testing instruments and equipment for the Shelter Dose Reduction Project. The equipment ranged from routine survey equipment to installed gamma spectroscopy, a beta secondary standard irradiation system, and whole body counters.

6.4 Project-Related Professional Activities

Staff presentations and external professional activities during 1998 are listed in this section.

6.4.1 External Professional Activities

Johnson, M.L., Co-Chairperson of the Working Group for ANSI N323C, *Radiation Protection Instrumentation Test and Calibration - Air Monitoring Instruments*.

Johnson, M.L., Member of the Working Group for ANSI N323A, *Radiation Protection Instrumentation and Calibration - General Requirements and Portable Instruments*.

Johnson, M.L., Member of the Working Group for ANSI N323D, *Radiation Protection Instrumentation and Calibration - Fixed Instruments*.

Johnson, M.L., Member of the International Electrotechnical Commission's Technical Advisory Group for IEC 45B, *Radiation Protection Instruments*.

Johnson, M.L., Past-President of the Columbia Chapter Health Physics Society.

Johnson, M.L., Member of the DOE Health Physics Instrument Committee (HPIC)

6.4.2 Patent

Fleming, D.M., Simmons, K.L., Froelich, T.J., and Carter, G.L.D. August 1998. “Alpha-Beta Radiation Detector.” U.S. Patent, 5,796,108.

7.0 Radiation Standards and Calibrations Project

The primary function of the Radiation Standards and Calibrations Project (RS&CP) is to maintain the necessary radiological reference fields to facilitate appropriate characterizations and calibrations within the Hanford IS&TP and HEDP. In support of this task, special instrument and dosimeter response-characterizing equipment and supplemental radiological reference fields are maintained, as necessary. This activity provides the means to characterize instrument and dosimeter response to various radiation fields encountered at Hanford and to ensure that calibration is done in accordance with recommended standards and guides. The RS&CP is coordinated by the Calibration Research and Accreditation (CR&A) subgroup of the D&RP technical group. This group also provides support to other Hanford entities as well as DOE-HQ, other departments of the U.S. Government, and the private sector. Much of this calibration laboratory support is provided under a NVLAP Secondary Calibration Laboratory designation, which the CR&A subgroup has maintained since 1994. Standards and methodologies developed in support of non-Hanford applications serve to enhance the capabilities available to the Hanford Site. Typical project activities include:

- providing a pathway of traceability for the calibration sources to the NIST
- maintaining radioactive sources, X-ray-generating devices, and instruments that serve as radiological standards
- reviewing calibration standards, regulations, and handbooks to ensure that calibration and characterization procedures agree with technically accepted methods.

Project activities conducted during CY98 are discussed in the following sections.

7.1 Performance Evaluations

Routine activities conducted by project personnel included maintenance of radiological standards, including reference class instruments and reference fields, traceable to national standards and the development of new and/or specialized capabilities. These existing and new capabilities support a variety of applications at the Hanford Site, within the DOE and other U.S. Government communities, and throughout the international radiological protection industry, both private sector and government programs. The activities related to radiological standards and capabilities and applications are discussed in the following sections.

7.1.1 Standards and Capabilities

The radiological reference fields maintained include gamma, beta, and neutron isotopic sources and X-ray generating devices. These standards and capabilities are configured to deliver well-characterized and easily reproduced quantities of radiation dose or exposure to environmental or personnel dosimeters, radiological survey instruments, and etc., for providing NIST-traceable calibration and/or response

characterization. In addition, a battery of reference-class instrumentation is maintained for the purpose of calibration, characterization, constancy verification, and traceability transfer.

Gamma Ray Reference Fields

Available photon sources include various activities of ^{137}Cs and ^{60}Co configured in either collimated-beam, well, or open-field geometries, and an ^{241}Am source configured for irradiation in a 2π geometry, as listed in Table 7.1. These sources are located in the 318 Building. The "open" sources listed in Table 7.1 are placed in the center of a circular, aluminum table via a pneumatic air-transfer system. Exposure rates at two discrete distances from the source are typically characterized. "Beam" sources, with the exception of 318-131, provide a continuum of exposure rates via use of an artifact positioning stand located on a sliding-rail system. Source 318-131 also includes a moveable stand, but is typically characterized and used only at the 1- and 3-m distances. Artifact placement for the most commonly used positions within these beam irradiation facilities is enhanced by laser alignment capabilities. "Well" sources also provide a continuum of exposure rates and facilitate instrument adjustments during irradiation with minimal exposure to personnel. Source-to-artifact distance is controlled by moving the sources, on a trolley system, up and down within the well via computer interface.

In addition to the sources listed above, a Nordion Model GB650 "high-intensity" gamma irradiator is available within the 331 Building; it produces high-energy gamma fields from ^{60}Co. This facility uses 12 sources that can be placed in a variety of geometries within tubes set in a circular pattern (see Figure 7.1). The exposure rate is adjusted by selecting a particular source or combination of sources and the specific orientation of the irradiation tube(s) in proximity to the item being irradiated. The range of available exposure rates extends from 30 to 10^7 R/h and has been applied to ultra high-range instrument calibration/ characterization, as well as evaluations of radiation fatigue for materials and components. The calibration of this facility is maintained traceable to the NIST through the use of reference standards and methods identical to those used for the 318 Building sources, as described elsewhere in this report. In addition, radiochromic QC dosimeters are provided, where necessary, for establishing a dose gradient within a sample volume or for confirming delivered dose within an irradiated item.

Table 7.1. Available Gamma-Ray Sources (1998)

Source	Geometry	Nominal Rate/Range (R[rem]/hr)	Location in 318 Bldg.	Reference No.	Primary Photon Energy (MeV)
^{60}Co	Open	2 / 6	Rm. 106	318-164	1.17/1.33
	Beam	3 – 1300	Rm. 8	318-037	
	Beam	180 – 50000	Rm. 8	318-353	
^{137}Cs	Well	10^{-4} - 0.130	Rm. 121	318-031	0.662
	Well	0.026 – 2.700	Rm. 121	318-030	
	Well	0.005 – 25.600	Rm. 121	318-288	
	Beam	0.080 – 25.600	Rm. 8	318-040	
	Open	0.400 / 2.000	Rm. 106	318-001	
	Beam	1 – 250	Rm. 8	318-044	
	Open	1 / 8	Rm. 106	318-029	
	Beam	3 / 30	Rm. 6	318-131	
^{241}Am	Open (2π)	0.125	Rm. 6	318-184	0.060

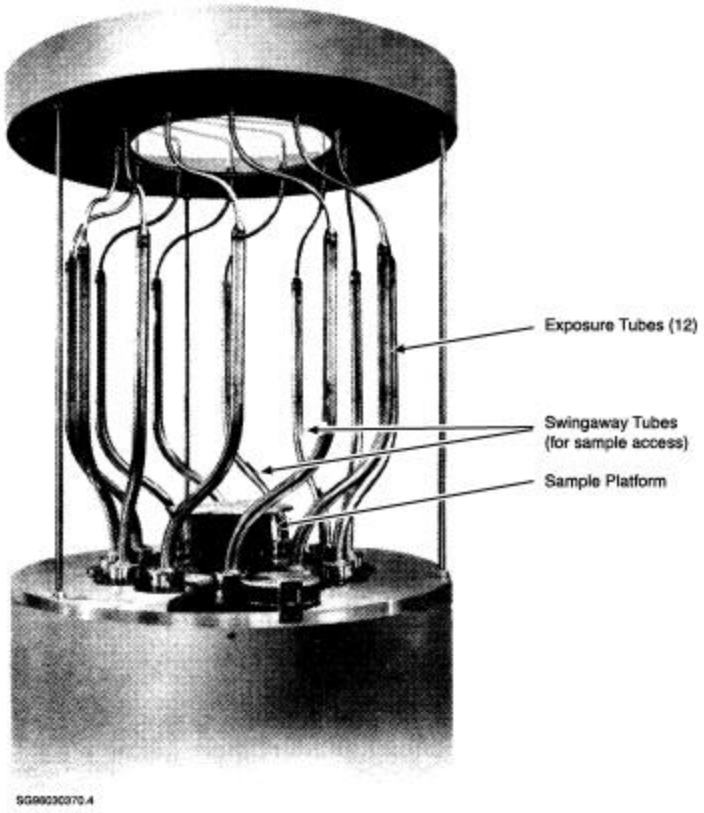


Figure 7.1. GB650 ^{60}Co Irradiator

X-Ray Photon Sources

Two identical Philips Model-324 tungsten-target X-ray machines are currently in use in support of the RS&CP. One machine is used to produce bremstrahlung (broad) photon spectra (e.g., NIST techniques M30, S60, M150, H150, etc.) while the second is configured for K-fluorescence technique (narrow) secondary photon spectra (e.g., ISO-4037 techniques F-Mo [17.5 keV], F-Cs [31.0 keV], F-W [59.0 keV], etc., [ISO 1996a; 1996b]) within a shielded enclosure. These reference fields are used for characterization of dosimeter or instrument photon energy dependence in the general region of 10 to 200 keV. The NIST techniques are titled based on the characteristics of the filters used to modify the primary X-ray beam, where "M," "H," and "S" indicate moderate, heavy, and special filters, respectively. In general, M and S techniques are characterized by broader spectra and consequently lower homogeneity coefficients. The average energy listed for such techniques is only a rough indicator of the beam energy. H technique spectra are typically narrower and their energy can be described more readily as an effective photon energy (i.e., compared with a gamma source with a photon energy of the same half value layer). As such, they are well suited, and recommended by NIST, for evaluations of dosimeter or instrument photon energy dependence. K-fluorescence techniques have highly discrete peak energies and are also well suited for energy characterization studies, although the maximum energy currently available is 59 keV.

Figure 7.2 shows an example of several X-ray techniques that have a similar quoted average or effective energy. Tables 7.2a and 7.2b provide a complete list of currently available techniques, their characteristics or production methods and the nominal exposure rates available. Both of these systems are equipped with laser alignment capabilities to aid in detector/dosimeter positioning.

During 1998, development of five additional ISO-4037 filtered X-ray techniques was initiated. Filter assemblies were constructed to produce high air kerma rate techniques H-60 (37.3 keV), H-100 (57.4 keV), and H-250 (122 keV), and narrow spectrum techniques N-150 (118 keV) and N-250 (208 keV). These techniques are being developed to match current NIST efforts and in anticipation of future dosimetry proficiency testing needs within both the NVLAP and DOELAP accreditation programs. The original development schedule included the calibration by NIST of a suitable secondary reference class ionization chambers during 1998; however, NIST was unable to provide this due to a modification effort of its own X-ray calibration facility. It is anticipated that characterization and NIST-traceable calibration will be completed in 1999.

Neutron Sources

Two configurations of ^{252}Cf neutron sources are available. One configuration allows the use of available sources within a pneumatic transfer system in the 318 Building Low-Scatter Room (LSR).

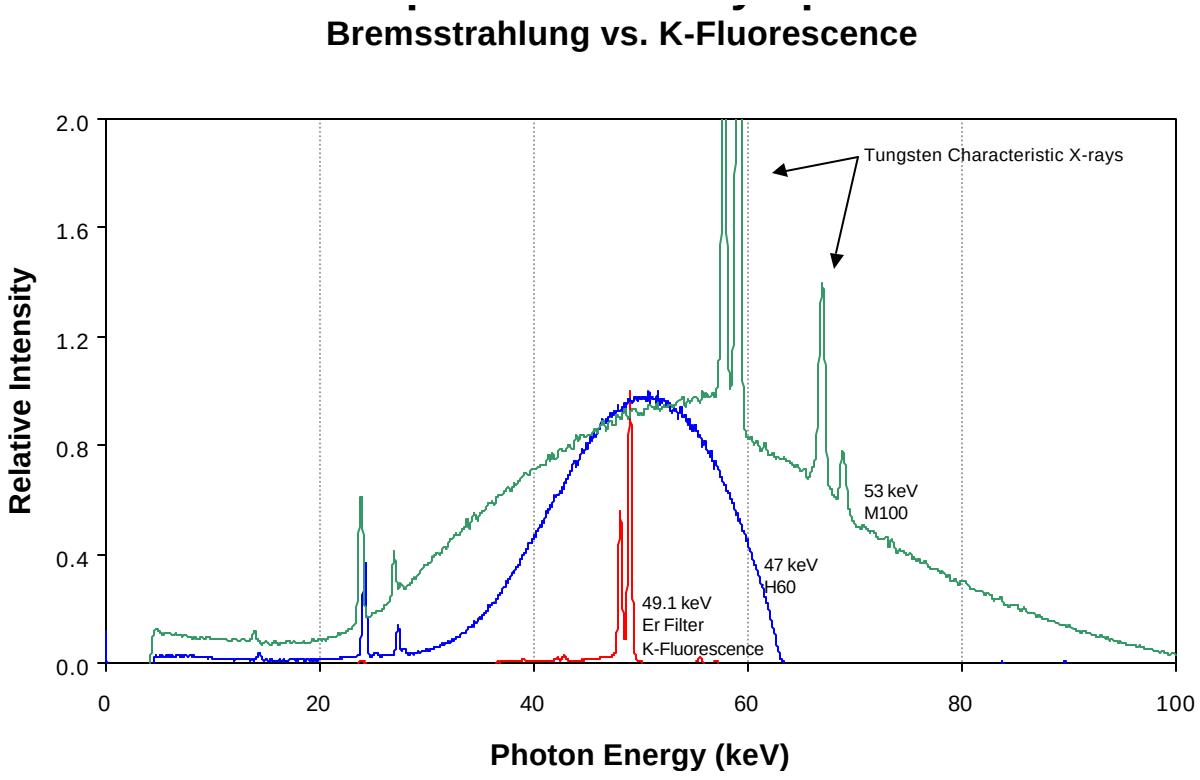


Figure 7.2. Example Spectrum of X-Ray Configurations (peak or average energy normalized to 1.0)

Table 7.2a. Available Bremstrahlung X-Ray Reference Fields (1998)

Technique	Energy (keV)[a]		Half Value Layer (mm Al)			Homogeneity Coefficient			HVL & HC Last Assessed	Demonstrated Traceability[d] (Last Year Tested)	Exposure Rate (R/hr)[a]	
	Average	Effective	PNNL[b]	NIST[c]	% Diff.	PNNL	NIST	% Diff.			Minimum	Maximum
M20	14		0.150	0.152	-1.3	0.79	0.79	0.0	10/86	No	2.9	288.6
M30	20		0.3521	0.36	-2.2	0.6287	0.64	-1.8	8/93	Yes (1992)	3.2	326.1
M50	29		1.005	1.02	-1.5	0.643	0.66	-2.6	8/93	Yes (1995)	3.4	350.9
M60	35		1.598	1.68	-4.9	0.690	0.68	+1.5	3/95	No	3.2	310.0
M100	53		4.949	5.0	-1.0	0.721	0.72	+0.1	3/95	Yes (1992)	1.5	305.0
M150	73		9.90	10.2	-2.9	0.85	0.87	-2.3	9/97	Yes (1997)	3.8	391.4
M200	100		(e)	14.9	(e)	(e)	0.95	(e)	(e)	No	4.3	431.0
S60	38		2.659	2.8	-5.0	0.768	0.75	+2.4	3/95	Yes (1989)	0.6	119.6
S75	40		1.817	1.86	-2.3	0.61	0.63	-3.2	7/93	No	4.6	472.2
H40	33		(e)	2.9	(e)	(e)	0.94	(e)	(e)	No	0.02	4.20
H50		38	4.102	4.2	-2.3	0.922	0.92	+0.2	6/86	No	0.05	9.40
H100		80	13.472	13.5	-0.2	0.964	1.00	-3.6	6/86	No	0.02	3.07
H150		120	17.09	17.0	+0.5	1.003	1.00	+0.3	9/97	Yes (1995)	0.12	16.5
H200		166	20.22	19.8	+2.1	0.994	1.00	-0.6	6/86	No	0.09	9.22
H250		211	22.48	22	+2.2	0.987	1.00	-1.3	6/86	No	0.09	8.50

(a) Nominal.
(b) All PNNL techniques are characterized and referenced at a distance of 100 cm.
(c) Most NIST techniques are characterized and quoted at a distance of 50 cm if distance is critical to the quality of the spectra.
(d) Demonstrated traceability is established through measurement QA interactions with the NIST. In most cases, NIST arbitrarily selects one or more techniques for intercomparison approximately every other year.
(e) Projected full characterization in 1999.

Table 7.2b. Available K-Fluorescence Reference X-Ray Fields (1998)

Technique[a]	Theoretical Peak Energy (keV)[a]	Production Method				Demonstrated Traceability[c] (Year Tested)	Exposure Rate (R/hr)[b,c]	
		Pre-Filter	Radiator/Attenuator	Filter	kVcp		Minimum	Maximum
F-Zn	8.6	Not Used	Zinc	------	50	No	0.13	19.8
F-Zr	15.8	Not Used	Zirconium	$SrCO_3$	80	Yes (1986)	0.02	3.2
F-Mo	17.5	Not Used	Molybdenum	Zr	80	No	0.02	3.4
F-Sn	25.3	Not Used	Tin	Ag	100	No	0.02	3.5
F-Cs	31.0	Not Used	Cesium	TeO_2	100	Yes (1986)	0.02	3.2
F-Nd	37.4	Not Used	Neodymium	Ce	110	No	0.009	1.4
F-Sm	40.1	Not Used	Samarium	CeO_2	120	No	0.01	1.4
F-Er	49.1	Not Used	Erbium	Gd_2O_3	120	No	0.005	0.8
$F\text{-}W_c$	59.3	Not Used	Tungsten	Yb_2O_3	170	Yes (1986)	0.005	0.8
$F\text{-}W_m$	59.3	Not Used	Tungsten	Yb	170	No	0.006	0.9

(a) As identified by ISO/DIS 4037-3:1996. Subscripts on F-W Techniques differentiate between filters made of chemical compound (c) and pure metal (m).
(b) Nominal
(c) Minimum/maximum estimated at 0.1/15.0 mA
(d) Demonstrated traceability is established through measurement intercomparison with the NRPB.

During use, these sources are placed near the geometric center of a room 10 m wide, 14 m long, and 8.8 m high, such that a low-scatter environment is established. Sources may be used bare or moderated by a sphere of deuterated water (D_2O) 15 cm in radius, enclosed within a thin stainless steel shell and covered by 0.051 cm of cadmium. These provide neutron fields useful for instrument calibrations as well as for dosimeter characterization in accordance with the specifications of DOE/EH-0027, the *Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems* (DOE 1986); HPS N13.11, *Personnel Dosimetry Performance-Criteria for Testing* (ANSI/HPS 1993); and International Standards Organization (ISO) Standard 8529, *Neutron Reference Radiations for Calibrating Neutron-Measuring Devices Used for Radiation Protection Purposes and for Determining Their Response as a Function of Neutron Energy* (ISO 1989). In addition, a D_2O-moderator sphere, similar to the one described above, is available without the shell of cadmium. This sphere, while originally intended as a backup, has been used to provide neutron test fields with a larger component of thermal neutrons.

The second configuration involves a ^{252}Cf source placed in a well to facilitate easy access for instrument calibration. This source provides a fission spectrum that is significantly altered by the scattering from the concrete sides of the well; however, its calibration is established such that instrument calibrations will be referenceable to bare ^{252}Cf under free-field conditions, for selected instruments. During 1998, a larger activity source was rotated into this well to restore the calibration range capability needed to calibrate the neutron survey instrument of prevalent use on the Hanford Site.

Beta Particle Sources

Beta particle sources (^{147}Pm, ^{204}Tl, and $^{90}Sr/^{90}Y$) are maintained for dosimetry and instrument characterization. Available sources are listed in Table 7.3 and include those manufactured by Amersham-Buchler and calibrated directly by the Physikalisch-Technische Bundesanstalt (PTB), Germany's national physical standards organization, and those manufactured in the United States by Amersham and Isotope

Table 7.3. Available Beta Reference Fields (1998)

Geometry	Isotope[a] (Source No.)	Window Material and Areal Density (mg/cm^2)	Protective Coating Material and Areal Density (mg/cm^2)	Residual Maximum Energy -E_{res} (MeV) (M-Measured, T-Theoretical)	Absorbed Dose Rate[b] (rad/h) (Calibration Distance (cm))
Point	^{147}Pm (318-290)	n/a	Titanium (2.3)	0.1504 (M)	0.12 (20)
	^{204}Tl (318-109)	Silver (20)	Gold (5)	$0.53 \leq E_{res} \leq 0.76$ (T)	0.007 (30)
	^{204}Tl (318-192)	Glass (6.6)	Kapton (~0.8)	0.608 (M)	0.965 (35)
	^{85}Kr (318-009)	Not Available	Not Available	Not Available	3.08 (50)
	^{90}Sr/^{90}Y (318-013)	Silver (50)	Stainless Steel (~75)	$1.80 \leq E_{res} \leq 2.274$ (T)	0.49 (30)
	^{90}Sr/^{90}Y (318-102)	Titanium (100)	Aluminum (20)	Not Available	0.46 (35)
	^{90}Sr/^{90}Y (318-012)	Silver (50)	Stainless Steel (~75)	2.046 (M)	19.28 (30)
	^{90}Sr/^{90}Y (318-103)	Titanium (100)	Not Available	2.085 (M)	13.51 (35)
Distributed	^{14}C (318-032)	Not Available	PMMA[c]	Has not been measured for these sources.	2.2 (0.2)
	^{147}Pm (318-113)	Not Available	Kapton (1.5)		0.37 - 0.006 (0.2 -15)
	^{204}Tl (318-128)	Not Available	Kapton (9.5)		0.70 - 0.03 (0.2 - 30)
	^{90}Sr/^{90}Y (318-129)	Not Available	Kapton (23.5)		4.09 - 0.16 (0.2 - 30)
	^{106}Ru/^{106}Rh (318-130)	Not Available	Kapton (30.7)		<0.01 (0.2)
	Depleted Uranium (318-166)	Not Available	Aluminized Mylar (7)		0.204 (0.15)

(a) Routine calibration maintained only for shaded techniques. All others are calibrated as needed.
(b) Nominal at 7 mg/cm^2 as of mid-year (1998)
(c) The source is polymerized with the Polymethylemethacrylate. Sheet thickness is approximately 1 mm with activity uniformly distributed throughout.

Products Laboratory. Currently available Amersham-Buchler ^{147}Pm sources have decayed to the extent that renders them useless for most dosimeter irradiation or instrument characterization purposes. A higher activity replacement was procured; however, during its characterization, photon contamination was suspected. An investigation of this continues prior to its acceptance for general use. Measurements have been made of all Amersham-Buchler sources and the Amersham-U.S. ^{90}Sr/^{90}Y sources to verify satisfactory compliance with HPS N13.11 (ANSI/HPS 1993); DOE/EH-0027 (DOE 1986b); and ISO Standard 6980, *Reference Beta Radiations for Calibrating Dosimeters and Dose Rate Meters and for Determining Their Response as a Function of Beta Radiation Energy* (ISO 1984).

7.1.2 Applications

The capabilities maintained, in part, via the RS&CP and under the custodianship of the CR&A subgroup can be subdivided into general areas of support for passive and active radiation measurement and dosimetry. These areas are described below.

Traceability Transfer

The radiological reference fields and reference class instruments available within the RS&CP suit the function of establishing or extending traceability to NIST. Most importantly under this project, this applies to the calibration/characterization of working class reference fields such as the Well calibrators and panoramic gamma calibration fields available within the 318 Building and the calibration of dosimeter devices used in support of external dosimetry efforts (e.g., calibration/testing of dosimeters, dosimeter readers, and automated dosimeter irradiation devices).

Similar transfers of traceability are available to those outside of the immediate facility as well. These are facilitated by the submission of dosimetry devices or reference instruments for irradiation/calibration within the NIST-traceable reference fields. These irradiations serve to establish implied traceability for the user/owner reference field or dosimetry analysis capabilities.

Traceability Confirmation

The radiological reference fields are used to provide a blind evaluation of performance, either in the area of instrument calibration or external dosimetry analysis. Such measurement quality assurance (MQA) tests help ensure that the participant uses NIST-traceable artifacts consistently and, if necessary, appropriately addresses external influences characteristic of related analytical equipment and/or the calibration environment.

Unique Calibration or Investigative Needs

Traceable radiological reference fields may be configured specifically to meet or approximate the needs of a select application for evaluation of field instrument response, reference class instruments, and dosimetry. Historically, reference fields have been structured to account for alternate radiation field geometries, special beta source attenuation configurations, and interpolation of detector response to atypical calibration energies, short-lived nuclides, and mixed fields.

Characterization/Type Testing

Reference fields are used to evaluate lower level of detection; neutron, beta, and photon energy dependence; the influence on detectors of contaminating radiations fields; response linearity; angular and geometry dependence; and acceptance testing.

1998 Summary

During 1998, efforts were focused in most of the above described work scopes. Within the scope of traceability transfer, calibration of Well, High Exposure Facility, and LSR gamma sources were performed or verified, as necessary. A stronger neutron source was installed and calibrated within one of the Well calibrator systems. Beta sources and X-ray reference fields were reassessed. Also, CR-39 dosimeter films were exposed for the purpose of establishing NIST traceability of the analysis system.

In support of traceability confirmation, Hanford dosimeters were exposed on a monthly, quarterly, and annual basis to provide audit and QC evaluations of the PNNL external dosimetry analysis system. In addition, the PHMC contracted for exposed dosimeters on a monthly basis as an independent evaluation of the PNNL external dosimetry analysis system. In all, approximately 720 Hanford dosimeters were exposed to controlled doses of radiation for this process.

Characterization and type testing efforts during 1998 supported both external dosimetry and instrument calibration efforts. Collectively, approximately 680 dosimeters were exposed to investigate long-term neutron fade, lower level of detection, angular response, and energy response for Hanford

whole body and/or extremity dosimeters. Electronic dosimetry devices have been irradiated in support of photon, angular, and energy dependence testing and evaluations of sensitivity to beta and neutron radiation.

7.2 Traceability to National Standards

Maintaining radiological reference fields traceable to national standards is one of the primary goals of this project. The traceability pathway has been evolving over the history of this effort and was initially discussed in the *Hanford Radiological Protection Support Services Annual Report for 1993* (Lyon et al. 1994). Because the method of traceability is often unclear and can vary periodically, the current pathway for PNNL radiological reference fields is provided here.

7.2.1 Philosophy

Traceability to national standards infers an assurance that calibration fields are established and used in a manner that is consistent with those standards. There are two accepted types of consistency measurements that are commonly used to infer traceability: 1) implied consistency, which is established through the use of a laboratory standard submitted to NIST for calibration within radiation fields applicable to the laboratory; and 2) demonstrated consistency, which can be established through a MQA interaction with NIST. This latter method is akin to a performance test administered by NIST and is instrumental in verifying measurement traceability, as opposed to simply obtaining or maintaining a traceable source or reference instrument. A disadvantage of traceability based only upon implied consistency is the lack of demonstration to indicate that measurements made of traceable sources or using reference instruments are consistent with those made of or using national standards. Traceability based upon demonstrated consistency provides the assurance that traceable instruments and/or sources are being used properly (whether to calibrate additional sources [or reference fields] or laboratory instrument standards) so that traceability is appropriately extended as desired.

NIST supports the use of both techniques in maintaining traceability, but favors the practice of performing MQA interactions on a routine basis coupled with providing infrequent instrument or source calibrations. The RS&CP mirrors the NIST philosophy where possible; however, there are some limitations of the NIST capability that require a variance in the normal process. The following descriptions provide the traceability pathway for each of the radiation types applicable within this project.

7.2.2 Photon Standards

Photon sources (i.e., gamma sources and X-ray techniques) are maintained traceable via both implied and demonstrated consistency verifications. On an as-needed basis, one or more selected laboratory standards (air-equivalent ionization chambers [AICs]) are submitted to NIST for calibration to specific radiation fields. Prior to 1998, five commonly used AICs had been submitted for calibration to ^{137}Cs, ^{60}Co, and many of the available NIST X-ray techniques, including all but one (M20) of the bremstrahlung techniques listed in Table 7.2. In addition, one low-energy chamber was submitted to NIST for calibration to select low-energy X-ray techniques; however, this unit has not been shown to be as stable as desired in using it as a transfer standard. In calibrating these instruments directly to NIST "primary standard"

reference fields, they are deemed “secondary standards” and are used in the process of calibrating other radiological reference fields and/or reference instruments for use as tertiary or working standards. The most common traceability pathway currently in use is depicted in Figure 7.3. In some cases, secondary standard instruments have been used to calibrate or verify the constancy of working standard radiation fields such as the well calibrators. This practice is acceptable and, in fact, tends to slightly reduce the calibration uncertainty; however, it exposes the valuable secondary standards to increased use and the potential for damage. This practice is, therefore, gradually being reduced.

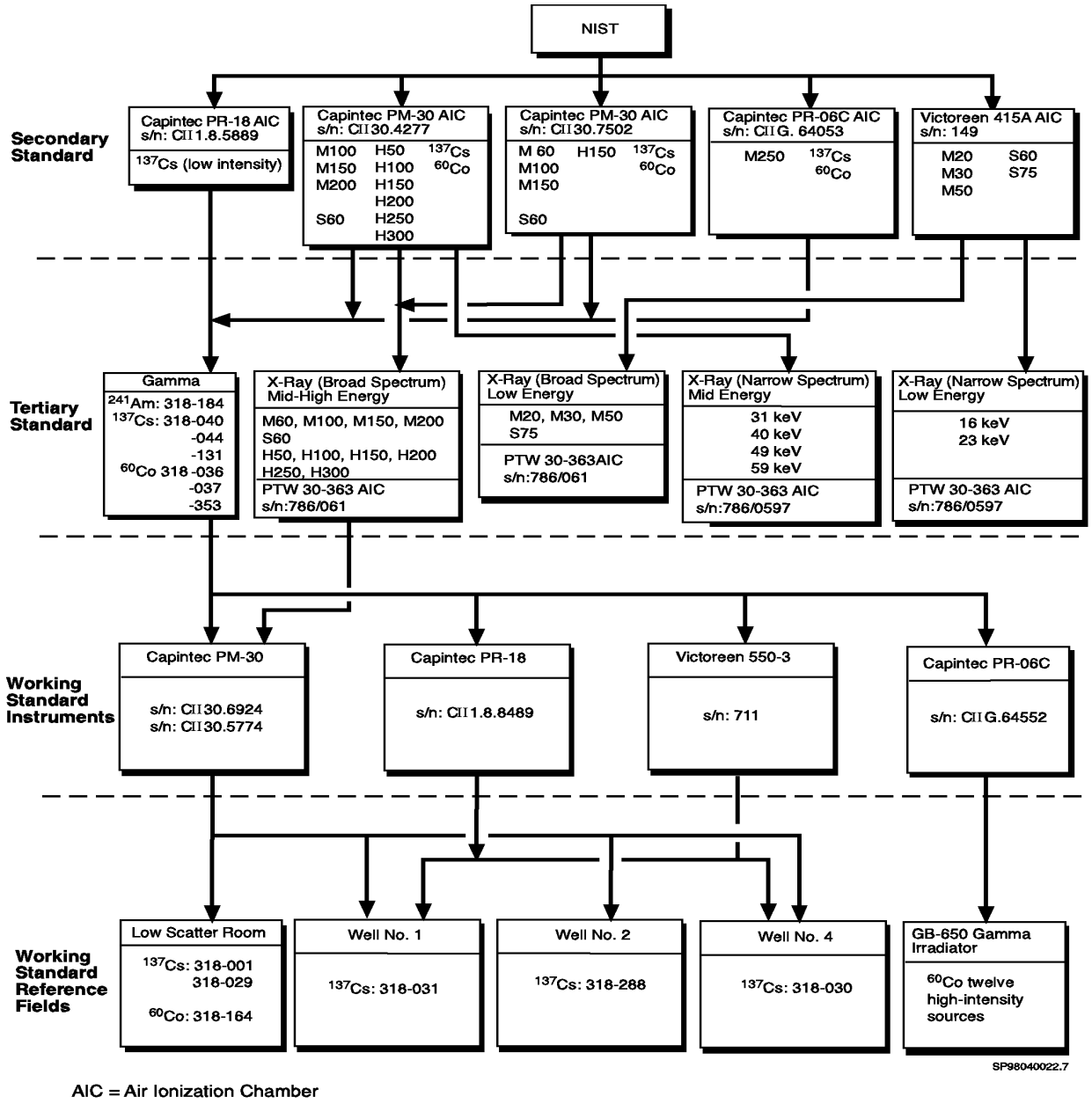


Figure 7.3. Typical Traceability Pathway for PNNL Photon Reference Fields

To achieve demonstrated consistency, NIST has conducted MQA assessments of PNNL photon reference fields since 1984, each time selecting a subset of the available sources and/or X-ray techniques for intercomparison. In 1998, NIST planned to perform another MQA evaluation; however, maintenance of the NIST X-ray facility precluded the availability of this intercomparison. Consequently, the MQA evaluation was postponed until 1999.

Currently, NIST does not maintain capabilities for K-fluorescence X-ray or ^{241}Am reference fields. Although traceability for these fields has been established using two additional AICs and a pathway similar to that identified in Figure 7.3 for a limited number of fluorescence techniques, the primary reference fields are maintained by the National Radiation Protection Board (NRPB) of the United Kingdom (UK). Traceability for irradiations and calibrations made using these reference fields are implied. The accuracy of these reference fields is confirmed via long-term trending of the transmission chamber output and/or reference standard AIC measurements.

7.2.3 Neutron Standards

Neutron traceability for all irradiations and measurements performed using PNNL sources is currently only implied. The primary pathway to NIST is through direct calibration of PNNL ^{252}Cf sources, in terms of neutron emission rate, within the NIST Manganous Sulfate Bath Facility. Free-field dose-equivalent rates are calculated for these sources in their bare and moderated configuration based on NIST recommendations provided in the National Bureau of Standards (NBS) Special Publication 633, *Procedures for Calibrating Neutron Personnel Dosimeters* (DOC/NBS 1982). A Nuclear Research Corporation Model NP-2 portable neutron monitor (SNOOPY) and an Eberline NRD neutron probe are maintained as tertiary standards, which are used to convey the free-field dose-equivalent rate established in a low-scatter environment to a calibration well equipped with a bare ^{252}Cf source. The calibration well is currently established as a working standard specifically for use with these two detector configurations of survey instruments. Use of the well for calibrating any other neutron survey instrument would not necessarily preserve any implied traceability. The traceability pathway for neutrons is shown in Figure 7.4.

MQA interactions are especially desirable for neutron sources as a means to confirm that various parameters are properly determined and/or are accounted for in the use of these sources. Influences such as air scatter, room return (scattered neutrons from walls, ceiling, and floor), source anisotropy, and inherent photon contribution must be properly characterized, either by measurement, calculation, or both. Source aging is a concern due to the magnitude of isotopic contaminants (primarily ^{249}Cf, ^{250}Cf and ^{251}Cf), which are difficult to eliminate during source manufacture and are not directly identifiable via a single NIST calibration. Also, when configured with the D_2O moderating sphere, there are concerns about subtle differences between the NIST design, which almost completely surrounds the source and upon which the calculations of dose equivalent are based; and the PNNL assembly with an inherent void, which allows for placement of the sphere around the end tube of the pneumatic transfer system. Monte Carlo modeling suggests that the effect of this void is substantial; however, reliable measurements that can substantiate this model have not been completed. Until measurements confirm or refine the magnitude of this effect, the calculated value will continue to be treated as a component of uncertainty rather than being used as a correction factor applied to the dose equivalent rate.

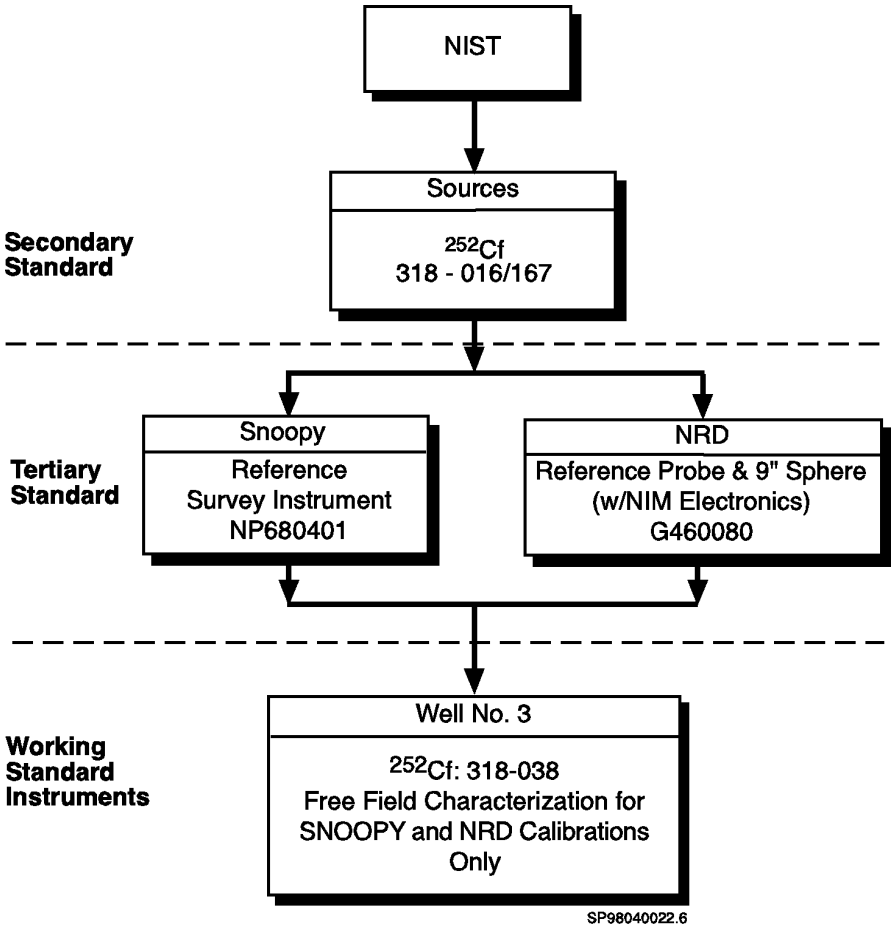


Figure 7.4. Typical Traceability Pathway for PNNL Neutron Reference Fields

During the past several years, numerous joint efforts have been made between NIST and PNNL to establish a suitable method for neutron MQA intercomparisons in order to demonstrate traceability. These intercomparisons have steadily improved as sources of uncertainty are reduced or better understood; however, there continues to be a bias in intercomparison results induced, in theory, by the acknowledged differences in the PNNL source configurations versus those of NIST. A clear explanation and resolution for the measured bias is not a trivial matter and will continue to be investigated.

7.2.4 Beta Sources

The NIST-traceability of beta reference fields is based upon both implied and demonstrated consistency. Highest order in the PNNL reference field hierarchy are the PTB sources identified in Section 7.1.1, including $^{90}Sr/^{90}Y$ (318-012 and 318-013) and ^{204}Tl (318-014 and -109). These sources are considered secondary standards because they were initially calibrated and are certified through the PTB

and continue to be periodically intercompared with NIST via MQA interactions. The NIST maintains a similar set of sources at its facility that have been characterized/verified both quantitatively and qualitatively.

PNNL maintains a Physikalisch-Technische Werkstäten (PTW) extrapolation ionization chamber for use in performing measurements of absorbed dose rate from the various sources. This chamber is generally considered to be an absolute standard; however, in conforming with the methods used for other radiation fields within the laboratory, it is designated as a tertiary standard. As such it is the primary link between the PTB sources and all other beta sources. In 1998, equipment and software were procured from the National Physical Laboratory (NPL) of the UK to automate the use of the extrapolation ionization chamber. This effort will eventually facilitate more thorough calibrations and characterizations for both beta and photon reference fields. Although the equipment was obtained, there were neither sufficient remaining funds nor time during the year to accomplish the assembly and final configuration of this system. This effort was postponed until 1999.

In many cases, beta irradiations/calibrations are performed using alternate point sources of similar isotopic distribution as the PTB sources, but with subtle differences in construction material and/or activity, including 318-102, -103, and -192 (see Table 7.3). The $^{90}Sr/^{90}Y$ sources (318-102 and -103) were calibrated directly by NIST (source 318-102 [74 MBq] in 1986 at NIST and source 318-103 [1.85 GBq] at PNNL by a visiting NIST scientist). The latter source was calibrated with PNNL's PTW extrapolation ionization chamber. Based on the level of these calibrations, source 318-102 is also considered a secondary standard and source 318-103 is relegated to the tertiary level. The traceability pathway for beta reference fields and the extrapolation chamber is shown in Figure 7.5.

The periodic MQA intercomparison that NIST conducts with the PNNL calibration laboratory involves the use of a NIST transfer standard. Intercomparisons were made from 1984 to 1985 and again from 1991 to 1992 between the NIST and PNNL Amersham-Buchler (PTB-style) sources. These sources were selected to preserve similar geometry, encapsulation, and activity, because it is suspected that the transfer standard used for these measurements may be sensitive to differences in these parameters. No beta MQA measurements were performed during 1998.

7.3 Calibrations and Constancy Checks

Following initial or annual calibrations, periodic verification measurements are performed to ensure the constancy of characteristics and magnitude for most radiation reference fields maintained by the RS&CP. Historically, the philosophy has been to perform extensive annual calibrations and less-involved constancy verifications, typically on a quarterly frequency. The stability of reference fields demonstrated for previous years, along with continuing efforts to reduce costs, has prompted consideration of a revision of this methodology. Revised protocols take into consideration, as a minimum, the following criteria:

- the general content (including possible impurities) of the source material
- the half-life

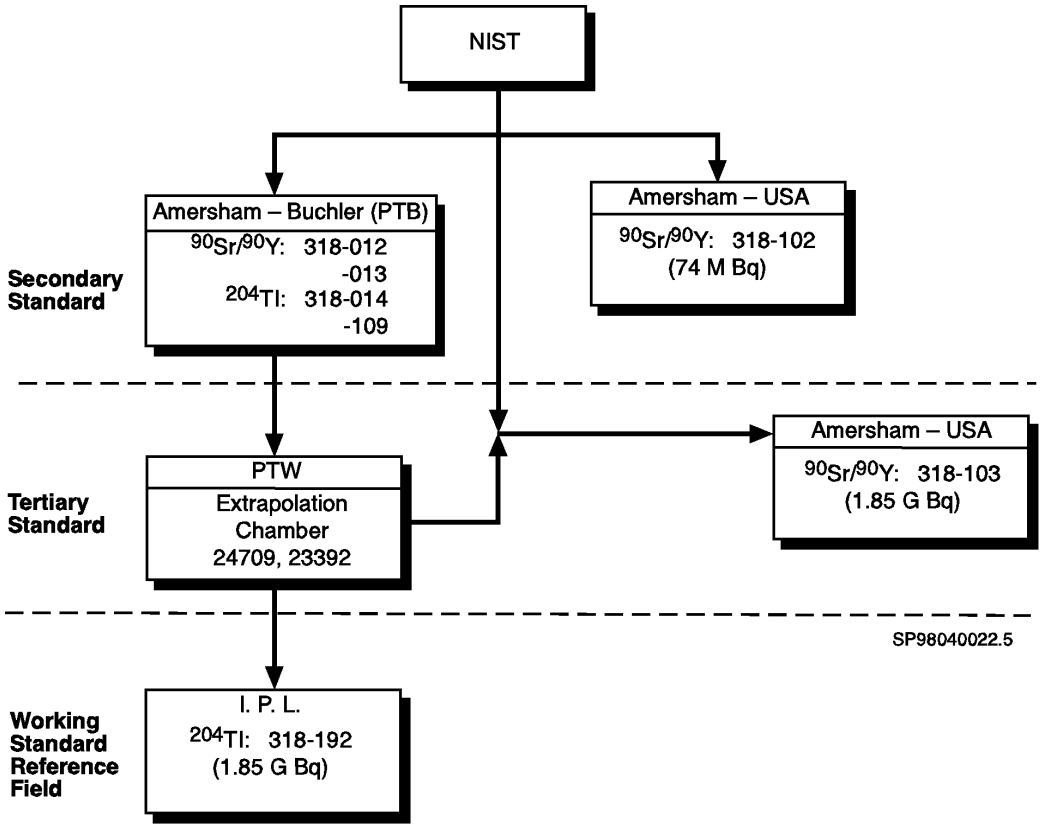


Figure 7.5. Typical Traceability Pathway for PNNL Beta Reference Fields

- the age and/or historical stability
- whether or not an automated positioning system is used to obtain a continuum of exposure/dose equivalent rates and, if so, the stability of such a system
- the stability and/or reproducibility of the source position or positioning system
- the constancy of ambient conditions (e.g., addition of major structures, equipment, or other sources of potential scatter).

For X-ray reference fields, criteria for consideration will include the following:

- the constancy/stability of the X-ray equipment
- the quantity of use
- the properties of the materials used within the various beam filters

- the constancy of ambient conditions (e.g., addition of major structures, equipment, or other sources of potential scatter).

The format for source verifications in 1998 are summarized in the following sections.

7.3.1 Photons

Most gamma source verifications proceeded as in prior years with commensurate frequency and rigor to ensure constancy. During the course of the year, revisions were made to the protocol used for open (panoramic) geometry gamma sources and for those sources used along with an automated source/artifact positioning system. In both cases, the revised verification protocol led to a significant reduction in measurement effort and, in the case of Well and High Exposure Facility sources, resulted in a more comprehensive system verification. It is anticipated that these protocols will be documented as CR&A Technical Notes (technical basis documents), following minor refinement, in 1999.

Only one complete recalibration of a source was judged to be necessary during 1998. The Well 2 positioning transducer was replaced during the latter part of the year. Due to this replacement the Laboratory Monitor considered it prudent to completely re-evaluate the positioning function. Therefore, a complete set of 60 measurement points were evaluated (30 unattenuated and 30 with a lead attenuator). All other gamma sources were found to be consistent with prior measurements.

X-ray field calibration protocols were also revised during 1998. In prior years, a quarterly calibration of the transmission chamber exposure-to-charge (Roentgen per Coulomb) output was performed for each commonly used X-ray technique. A review of the calibration history showed the machine to be quite stable. Consequently, it was decided to decrease the frequency of calibration to six-month intervals and perform the calibration for the complete inventory of techniques. This protocol will continue for approximately four to five cycles, during which time, the data will be reviewed for trends and consistency. If the data appear to be consistent after that time, the calibration interval may be extended to one year for each technique, or for a selected subset of techniques, along with other suitable evaluations to ensure consistency of the X-ray machine output energy and linearity.

During 1998, commonly used X-ray techniques received two complete recalibrations, while the infrequently used techniques received at least one recalibration during the complete-inventory assessment. The historical data for each technique are shown in Figures 7.6a through 7.6c.

7.3.2 Neutrons

There was a significant evolution of ^{252}Cf neutron sources during 1998. Source 318-167 was moved to Well 3 and recalibrated in that geometry using both the NRC-SNOOPY and Eberline-NRD tertiary standards instruments. This move was necessary to restore upper end calibration capability for the NRC-SNOOPY survey instrument inventory.

Source 318-038 was removed from the well and placed into a shipping/storage cask. Original plans included submitting this source to NIST for recalibration of its neutron emission rate using the

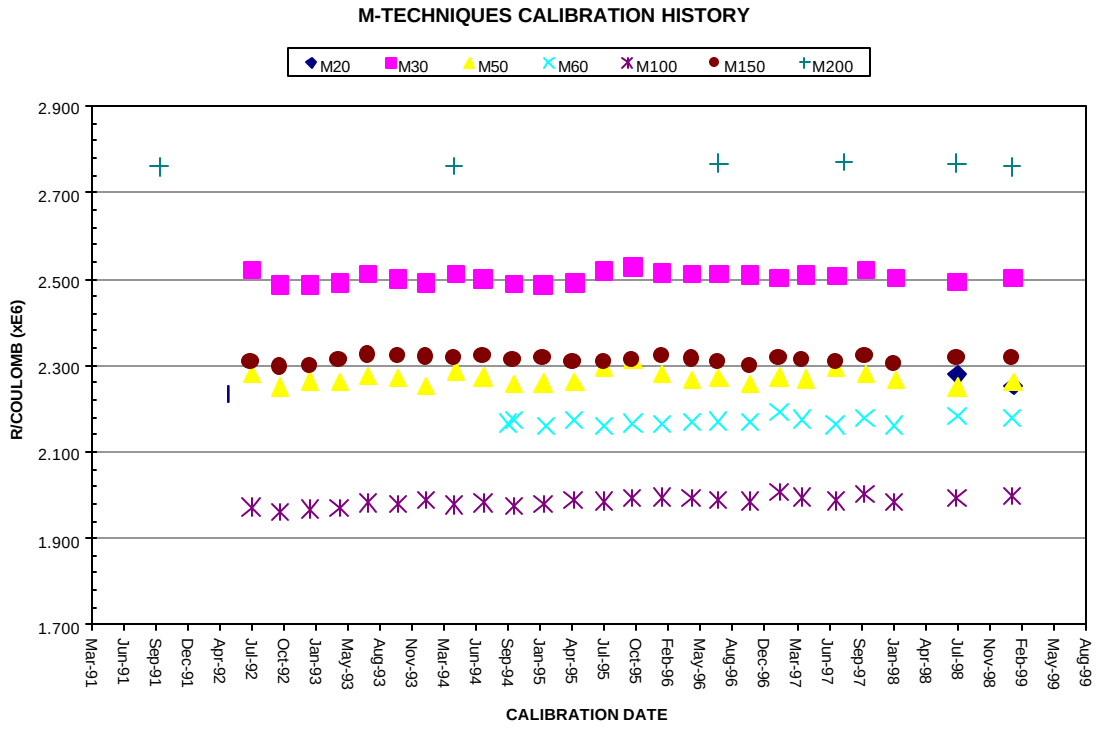


Figure 7.6a. Long-Term Stability of X-Ray Reference Fields, M-Techniques

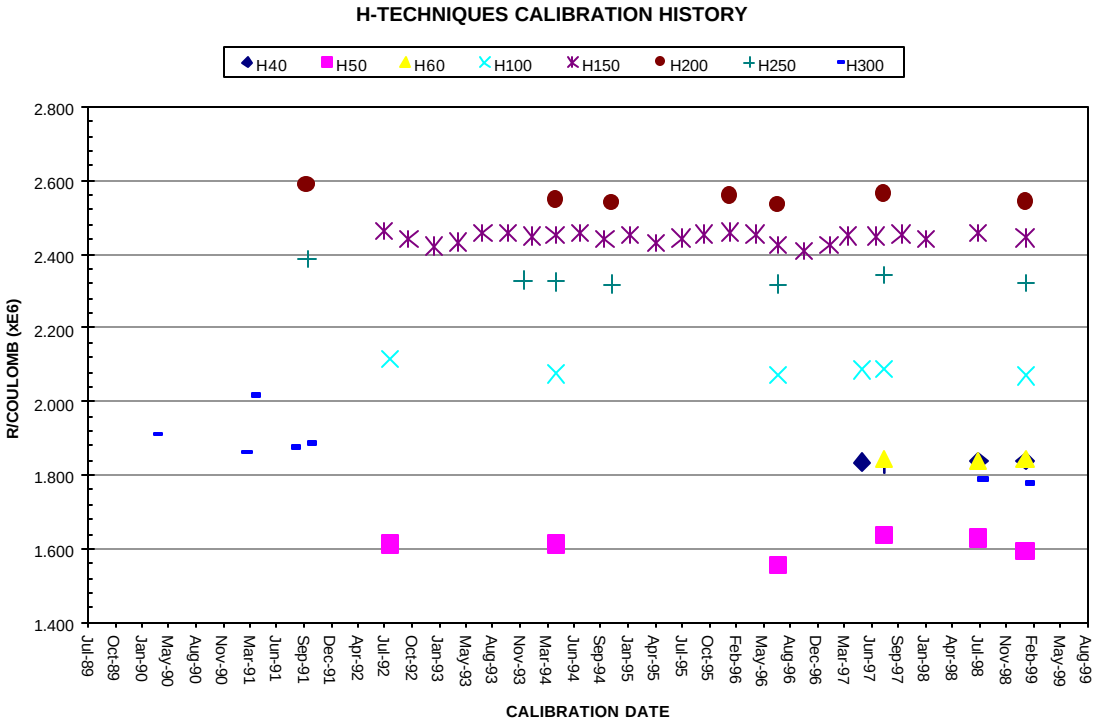


Figure 7.6b. Long-Term Stability of X-Ray Reference Fields, H-Techniques

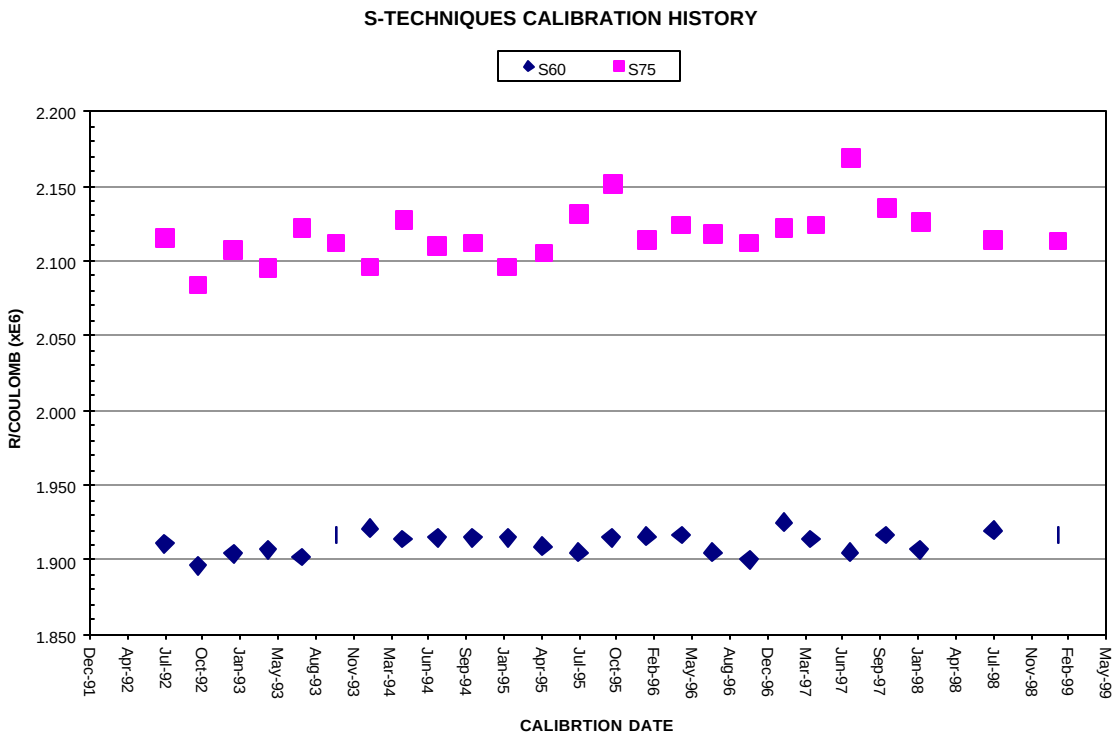


Figure 7.6c. Long-Term Stability of X-Ray Reference Fields, S-Techniques

Manganous Sulfate Bath method, followed by installation into the LSR pneumatic transfer system as a mid-range calibration source. However, there were several holdups. First, this source required RL approval prior to offsite shipment. While a one-time amendment to Battelle's authority to do this was considered, it was decided to include this source type on the Blanket Battelle Request letter beginning in FY99 which is submitted to RL for approval annually. This would enable shipment of this and future sources to NIST for recalibration without need for special approval. Second, the clear documentation of the shipping cask U.S. Department of Transportation (DOT) rating and the Special Forms testing of the source capsule needed to be obtained. Third, NIST was in the process of performing a major overhaul on the Manganous Sulfate Bath Facility and would not have been able to perform the calibrations as requested by the September deadline for available funding. Consequently, the calibration of this source was postponed to 1999.

Source 318-016, which was recalibrated at NIST in 1997, was installed into the LSR pneumatic transfer system in place of 318-167. This source is needed to fulfill low dose-equivalent free-field calibration needs. The highest activity ^{252}Cf source, 318-356, was used for the first time to perform the periodic verification of the NRC-SNOOPY and Eberline-NRD tertiary standards.

7.3.3 Beta Sources

Absorbed dose rates from all commonly used beta sources were verified using an extrapolation chamber at fixed distances to ensure constancy with original calibration data. Included in these verifications were $^{90}Sr/^{90}Y$ sources 318-102 and 318-103, ^{204}Tl source 318-192, and the depleted uranium slab 318-166.

7.3.4 Reference Standard Instruments

Routinely used instrument standards were verified for consistency, as necessary, to ensure their subsequent accuracy for measuring reference fields. These included various AICs used to perform photon reference field measurements, the PTW extrapolation chamber used to assess beta reference fields, and the reference NRC-SNOOPY survey instrument used to convey calibration to Well 3. The Eberline NRD transfer probe, used in calibrating Well 3 was also verified in 1998.

7.3.5 Uncertainties of Reference Calibration Fields

Efforts continued in 1998 to update and refine the estimates of uncertainty for the various calibrated reference fields. The methods used to determine uncertainty were referenced from NIST Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results* (DOC/NIST 1994). This document is an interpretation and abridgement of the ISO *Guide to the Expression of Uncertainty in Measurement* (ISO 1993). Various uncertainties are categorized, based on whether they are determined by statistical or other means. Type A evaluations of uncertainty involve a statistical analysis of a series of observations. Type B evaluations are determined by means other than a statistical analysis of a series of observations and are usually based on scientific judgment using all of the relevant information available (e.g., previous measurement data, manufacturer's specifications, reference data taken from handbooks, etc.). For the calibration of each reference field, the various components affecting uncertainty are determined using Type A and/or B evaluations. The uncertainties within each category are propagated as recommended in the NIST Technical Note to arrive at a total estimated value for each. These two categories of uncertainty are summed in quadrature and adjusted using a coverage factor so that they represent approximately a 95% confidence level.

The analysis of uncertainty is an on-going effort that involves the continual identification of sources of error and refinement of estimated values for each identified component. Furthermore, it involves an effort to reduce individual components, where feasible, via refinement of measurement protocol and/or capabilities. The current uncertainty estimates for commonly used reference fields are provided in Table 7.4.

Table 7.4. Summary of Uncertainties (1998)

Reference Field	Total Uncertainty (95% C.L.)	Notes
Shepherd ^{137}Cs (318-131)	±1.5%	Distance = 1 m
HEF ^{137}Cs (318-040, -044)[a]	±1.9% to ±4.1%	Dependant on distance, total charge collected from the ion chamber and standard error of replicate readings
HEF ^{60}Co (318-037, -353)[a]		
^{241}Am (318-184)	±5.2%	Distance = 0.5 m; No correction for room scattered photons
^{252}Cf:Bare (318-167)	±14%	Distance = 0.5 m; No correction for source anisotropy
^{252}Cf:D_2O-Moderated (318-167)	±22%	Distance = 0.5 m; No correction for source anisotropy; No correction for effect of D_2O-moderator void
PTB ^{90}Sr/^{90}Y (318-012, -013)	±3.0%	Distance = 0.30 m; Flattening filter used for -013 only.
ANSI ^{90}Sr/^{90}Y (318-102, -103)	±3.0%	Distance = 0.35 m; No flattening filters used.
^{204}Tl (318-192)	±4.4%	Distance = 0.35 m; No flattening filters used.
Depleted Uranium (318-166)	±3.3%	Distance = 1.5 mm.
Well #1: attenuated (318-031)[a][b]	±1.1% to ±2.2%	Dependant on source position, total charge collected from the ion chamber and standard error of replicate readings
Well #1: unattenuated (318-031)[a][b]	±1.1% to ±3.6%	Dependant on source position, selection of ion chamber, total charge collected from the ion chamber and standard error of replicate readings
Well #2: attenuated (318-288)[a][b]	±1.1% to ±2.5%	
Well #2: unattenuated (318-288)[a][b]	±1.9% to ±3.0%	Dependant on source position, total charge collected from the ion chamber and standard error of replicate readings
Well #4: unattenuated (318-030)[a][b]	±1.9% to ±2.0%	Dependant on source position, total charge collected from the ion chamber and standard error of replicate readings

(a) Quoted values applicable to discrete measured points only. Range covers all points assessed. Dose rates associated with the use of the computer-controlled positioner are not covered within this quoted value because an uncertainty component for the applied equation has not been determined.

(b) Characteristics of the reference field(s) emitted by these sources within the well geometry may differ in energy spectra in comparison with an ideal beam geometry from which the reference chamber is established traceable to NIST. Use of this value to establish uncertainty for the calibration of dissimilar instruments must account for the potential differences in energy dependence.

7.4 Audits and Observations

Three audits/assessments were performed during 1998, all of which reviewed, in part, facets of the RS&CP. These included, in chronological order, a self assessment performed in accordance with the CR&A-specific procedure AP-0003, "CR&A Assessments and Problem Reporting;" an audit by one of PNNL's offsite DOE clients in reference to DOE/ID-12105, *Quality Assurance Manual for the Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems* (DOE 1997); and an onsite assessment by NIST on behalf of NVLAP. This latter assessment references the criteria of NIST Handbook 150, *National Voluntary Laboratory Accreditation Program – Procedures and General Requirements* (NIST 1994). This handbook reiterates the "General requirements for the competence of calibration and testing laboratories" section of ISO Guide 25 (ISO 1990) as well as NVLAP interpretations of ISO Guide 25 via ANSI/NCSL Z540-1-1994 draft (ANSI 1994).

Via these assessments, 14 items were identified for corrective action with the CR&A internal tracking system. Of these items, eight were rated as observations and six as non-compliance issues. None were classified as deficiencies, the most critical of the internal classifications. Table 7.5 identifies the general operational areas of these 14 items. All of the items identified in the table were entered into an Internal Observation Report tracking system and have been assigned recommended actions and expected completion dates, most of which will extend into 1999.

Table 7.5. Summary of 1998 Audit Items

General Performance Area		Observations	Non-Compliance	Deficiencies
Reference Field Calibration/Verification	Documentation	4		
	Practice			
Reference Field Characterization/Uncertainty	Documentation	1		
	Practice	1		
Software	Documentation	1		
	Practice			
Qualifications	Documentation			
	Practice	1		
Procedure/Technical Basis	Documentation		1	
	Practice		1	
General Quality System	Documentation		3	
	Practice		1	

7.5 Documentation

The Quality Manual for the CR&A subgroup's Calibration Laboratory for Ionizing Radiation operations was rewritten during 1998, replacing an outdated version written in 1993. This was done to clearly document that policies and operations are directed toward satisfying ISO Guide 25 (ISO 1990), a mandatory requirement for NVLAP-accredited calibration laboratories. This document is also necessary to replace prior quality basis documents (i.e., Quality Assurance Plans) that had been rendered obsolete by the elimination of Battelle's quality assurance procedure (PNL-MA-70) in favor of the new Standards Based Management System (SBMS). The new quality manual and its inclusive policies satisfy the requirements of the new SBMS system.

7.6 Project-Related Professional Activities

None.

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