Paper

DEVELOPMENT OF SITE PROFILES FOR DOSE RECONSTRUCTION USED IN WORKER COMPENSATION CLAIMS

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Abstract—**For the purpose of dose reconstruction, personal dosimeter data and measured intakes through bioassay analysis (i.e., in-vivo and in-vitro measurements) should be used whenever possible and given precedence over area monitoring data, survey data, or source term data. However, this is not always possible. A worker's exposure record may be incomplete or missing, or, based on directives and guidelines at the time, a worker may not have been monitored during his or her time of employment. In an effort to recognize, analyze, and incorporate all possible considerations of potential exposures, the National Institute for Occupational Safety and Health Radiation Dose Reconstruction Program developed "site profiles" for all of the major U.S. Department of Energy sites and Atomic Weapons Employer sites. Site profiles are technical documents that (1) provide a brief, general overview of the site; (2) identify the facilities on site with a brief description of the processes and radionuclides used in these processes; (3) contain detailed information on the historical detection limits for film, thermoluminescent dosimeter, and bioassay measurements that are used by the dose reconstructor to interpret a worker's available monitoring records; and (4) provide important supporting information for the dose reconstructor to use if the monitoring data are inadequate or unavailable. When a complete set of monitoring data for an individual is unavailable, it is the parameters in the site profile that are of the most use to the dose reconstructor. These parameters include facility monitoring data (by radionuclide, mechanism of intake, year of exposure, location within a facility); occupational medical x rays and techniques used; environmental measurements (by area on site, radiation type, energy range); minimum detectable activities of the types and kinds of instruments used to detect the different radionuclides; specific source terms (quantities of material and their molecular form) within each facility or process; and specifics of the overall dosimetry programs as they evolved over time. An additional benefit of having a site profile for a site is that it promotes consistency among the numerous health physicists that are working on the project. Resources used in the development of site profiles include technical basis documents for external and internal dosimetry programs, facility descriptions, environmental reports, safety analysis reports, input from past and present site workers, and other reports that have been written to describe the workplace environments within the facilities.**

Health Phys. 95(1):47–54; 2008

Key words: dose reconstruction; exposure, occupational; environmental assessment; nuclear workers

INTRODUCTION

THE PREFERRED approach in reconstructing doses for nuclear weapons-related workers who have developed cancer and submitted claims for compensation under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) is to base the estimates on their personal dosimeter data, in the case of external exposures, and on measured intakes (e.g., through bioassay analysis, and in-vivo and in-vitro measurements) in the case of internal exposures. However, because this level of detailed individual data may not always be available, other sources of information must be used. One alternative is to use data based on the records of coworkers (ORAUT 2005a and b). Another is to use "site profiles" (SPs), which the National Institute for Occupational Safety and Health (NIOSH) has developed for all major U.S. Department of Energy (DOE) facilities and Atomic Weapons Employer (AWE) sites. The SPs also contain information on the historical detection limits for film, thermoluminescent dosimeters, and bioassay measurements and other useful facts related to a site's radiation protection program that are used by the dose reconstructors to interpret the worker's available monitoring records.

In essence, an SP provides dose reconstructors with detailed supporting information and assumptions about a specific site and its facilities based on the review and analysis of data from area monitors or surveys, and extrapolations from information on the source terms that were present. SPs help dose reconstructors interpret

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(*Manuscript accepted* 14 *December* 2007)
0017-9078/08/0

workers' dosimetry and monitoring data; they also document what is known about a site and provide assumptions for what is not known. These documents are valuable tools, and, without them and the information they provide, most dose reconstructions (especially for the larger sites) could not be completed. The purpose of this paper is to provide a description of an SP's structure, identify its content, and outline the process used in its preparation. Also discussed are the challenges faced during the document development process.

Examples of SPs used on the NIOSH radiation dose reconstruction project can be found on the NIOSH Office of Compensation and Analysis Support Web site (http://www.cdc.gov/niosh/ocas). After connecting to this Web site, the SPs can be accessed by going to "Technical Documents Used in Dose Reconstruction," then to the "List of Work Sites for which NIOSH has Developed Technical Documents." SPs are listed alphabetically.

SP COMPONENTS

SPs for the larger sites consist of an introduction and five technical basis documents (TBDs). An understanding of each TBD is essential in order to understand an SP. SPs for smaller sites have the same types of information, but the material is contained in one document. Examples of smaller sites would be Allied Chemical Corporation, Medina Facility, and Stanford Linear Accelerator Center.

Each TBD focuses on a specific technical area at a site in relation to an aspect of the worker radiation protection program, the environmental surveillance program, or the equipment or techniques used to conduct occupationally related medical x-ray examinations. Table 1 provides an overview of the titles and scopes of the TBDs that comprise an SP; additional details are provided in the sections that follow.

Table 1. Title and scope of the TBDs that comprise a SP.

Title of TBD	Scope
Site description	Location, types of facilities; operational history, processes involved; identities and quantities of radionuclides used
Occupational medical dose	Historical information to assign dose from medical x-ray examinations that were performed for screening as a condition of employment
Occupational environmental dose	Information on external doses due to the deposition of radionuclides on the ground from operations and on-site releases, and internal doses from resuspension into the air and subsequent inhalation. These radionuclides include radon and its decay products resulting from on-site processing of depleted uranium and radium sources
Occupational internal dose	Potential airborne radionuclides within the workplace and their dosimetric properties, such as aerosol size, solubility, and estimated durations of exposure
Occupational external dose	History of personal external monitoring program; sources of external dose, surface contamination levels within the workplace; types of monitoring instruments used; and potential maximum external doses

Site description TBD

The site description TBD provides the dose reconstructor with general information on the site's facilities, processes used, radionuclides of concern, and major incidents. This section provides the dose reconstructor with information to become familiar with the site. This is particularly important because, in order to avoid any potential or perceived conflict of interest, one of the criteria established for the dose reconstructors was that no person who had worked at a specific site could reconstruct doses for workers from that site. This TBD helps in acquainting them with the details and history of a site at which they could not have worked.

Occupational medical dose TBD

This TBD lists medical x-ray dose information by year, type of machine and/or technique used, and organ. Uncertainties in the x-ray measurements also are estimated for input into the Interactive RadioEpidemiological Program (IREP) (NIOSH 2002a; Kocher et al. 2008). Details of the specific x-ray parameters included in the SP are covered elsewhere in this issue (Shockley et al. 2008).

Occupational environmental dose TBD

This TBD focuses on the internal and external doses that workers could have received from the on-site ambient environment, including exposures to radon sources that were present because of specific site operations. Internal environmental doses are based on estimated airborne concentrations due to on-site releases and the resuspension of radionuclides previously deposited on the ground. Internal dosimetry considerations also include inhalation and ingestion routes, with information listed by radionuclide, year, material type or solubility class, particle size (if readily available), area on the site, and job category (if possible). External environmental exposures are listed by area on the site, radiation type (photon, beta, neutron), and energy range. The maximum external environmental dose by year also is listed, and releases of noble gases are considered if they are applicable. This section of the SP also documents estimated uncertainties for the environmental dose parameters (NIOSH 2002b, 2006a). A detailed example of the environmental dose parameters, based on data from the

Savannah River Site, is provided elsewhere in this issue (Rollins 2008).

Occupational internal dose TBD

For assessing the internal dose of monitored workers, this TBD includes units of measurement (i.e., activity, mass, volume and/or period of collection used for the bioassay data used) and any special interpretation codes or instructions that the dose reconstructor might need to understand and/or evaluate the data in the worker's record. Methods of analysis over the operational period of the site are included, as are Minimum Detectable Activities (MDA), radionuclide, analysis type, date, and any consideration for cross-contamination issues. Source term information by facility or process is included by radionuclide and ratios (if available), by material type or solubility class, and by particle size. Internal dosimetry parameters are covered in greater detail elsewhere in this issue (Brackett et al. 2008). Uncertainties for the internal dose parameters are provided in this TBD (NIOSH 2002b).

Occupational external dose TBD

The SPs categorize occupational external dose data (for monitored workers) by radiation energy ranges for photons and neutrons (by percentage of dose received in each energy range), by labor category and location (if possible), and by exposure geometries for photon and neutron exposures by percent time for each geometry. The energy ranges for photons were established at <30 keV, 30–250 keV, and >250 keV; the energy ranges for neutrons are <10 keV, 10–100 keV, 100–2,000 keV, 2–20 MeV, and >20 MeV (NIOSH 2006a). The percentage of photons or neutrons in these energy ranges, respectively, are identified in each SP and those are directly input into IREP spreadsheets (NIOSH 2002a). Correction factors for reported photon, neutron, and beta exposures are provided, and missed doses for photons, neutrons, and betas are also listed by year, by facility and/or location, by type of dosimeter, and by energy range when possible. In the absence of detailed individual data, the SP provides dosimeter correction factors based on energy and geometry for each type of dosimeter. External dosimetry parameters are discussed elsewhere in this issue (Merwin et al. 2008). Uncertainties for the external dose parameters are provided in this TBD for input into the IREP spreadsheets (NIOSH 2006a).

Technical information bulletin

An important supporting document that is closely associated with an SP and is used by the dose reconstructors is a technical information bulletin (TIB). A TIB is designed to clarify how specific data should be used to complete a dose reconstruction, or how the information in a TBD or SP should be used to meet a specific need in the dose reconstruction process. It also may provide specific technical information that supports or justifies the tables or information included in a TBD. For example, TIBs have been developed for assigning lung dose from thoron (NIOSH 2006b), for characterizing occupational exposure to radium and radon progeny during specific uranium recovery operations (ORAUT 2006), and for estimating doses for plutonium strongly retained in the lung (ORAUT 2007).

INFORMATION ACQUISITION

In the beginning of the NIOSH dose reconstruction program, before SP development could even begin, a significant effort was required to identify, locate, and retrieve a wide variety of information based on resources such as:

- External dosimetry site-specific reports;
- Internal dosimetry site-specific reports;
- Safety analysis reports;
- Workplace environmental reports;
- Facility data (e.g., activity concentrations, contamination and dose rate surveys, effluent data);
- Memoranda exchanged between site personnel (e.g., documentation of process descriptions, start dates, and purchase orders);
- Peer-reviewed publications;
- The technical library at the Cincinnati Operations Center;
- Completed dose reconstruction reports on specific DOE sites;
- Information in workers' claim files and from DOE sites that had been submitted to NIOSH;
- Other DOE site reports (e.g., environmental reports, quarterly reports, progress reports, medical reports);
- Records of computer-assisted telephone interviews with claimants;
- Site-related Web sites;
- Conference calls (among SP Team members and external resources);
- Site contacts (e.g., via emails, interviews, verbal discussions);
- Site visits; and
- Input received from worker outreach efforts.

As can be expected, this was a difficult process, and the SP Team faced a number of issues, including:

- Some site representatives initially thought that the team was requesting additional or previously-sent worker dosimetry records; instead, the team needed facility information;

- Many earlier DOE site files and records, including some deemed sensitive in nature, had been destroyed, discarded, or not retained;
- Depending on the site and the time period of interest, on-site environmental exposures were either not monitored or the records were not retained;
- Younger on-site personnel had limited historical knowledge of the early processes, and the people that did have that knowledge had retired or were deceased; and
- At some sites, unclassified records had been stored with classified records, and security clearances were required to retrieve and review them.

Worker outreach

Information received from direct interaction with workers at a site proved to be some of the more useful data acquired. Several site visits were made during SP development to solicit comments from workers to determine if all radioactive sources had been identified accurately and to find out if other references were available that the team had not located. When the SPs were completed, copies were sent to the site labor representatives and a follow-up site visit was conducted to discuss it and address worker feedback. At times, additional information was obtained during those sessions; if the information was determined to enhance the document, the SP was revised to incorporate it.

SP DEVELOPMENT

The preparation and development of an SP is a major undertaking. Although SPs for all major DOE and AWE sites have been completed, they will continue to be updated as new data and information are acquired, and new SPs may be developed for additional sites as the need arises. The primary aspects of SP development, conducted in accordance with a formal set of procedures, are described below.

Documentation of need

The decision to prepare an SP for a specific DOE or AWE site is based on a documented need for the establishment of a foundation of information in order to perform dose reconstructions for workers who were or are employed at a specific site. The large effort to develop an SP will not be expended for sites with zero or just a few claims (e.g., AC Sparkplug, Chupadera Mesa, Crane Co.). The claims for sites such as these will be processed on a one-to-one basis by the dose reconstructors. The types of work and/or the radioactive source terms or processes at these sites may be comparable to other sites that already have an SP or that have been processed using specific documented assumptions that can apply to these smaller sites also. The priority for initiating the preparation of an SP could be based on the number of claims received from site workers (or their beneficiaries); the known availability of site information; the knowledge that there could be weaknesses in the existing dosimetry data; and a confirmed belief that the information in the SP will be adequate to fill a large portion of these voids.

Team selection

Once the previous decision is made, the next step is to select an SP development team. In so doing, a number of factors need to be considered. These include the size and complexity of the site; the availability of the team members over the specific period of time that they will be needed; their experience specific to the processes in which the exposed workers were involved; and the range of topics to be covered. Document Owners are chosen based on their level of project and personnel management and health physics experience. However, care must be exercised to avoid selecting a Document Owner—or any other team member—who has worked at the specific site in the past; otherwise he or she will be considered by third-party reviewers as having a potential conflict of interest. Team members may be from one company or from several; the key is the technical background of each person contributing to the SP. Each team member may be responsible for gathering information for a different topical area (e.g., x rays, internal dosimetry, environmental). The overall effort of the team will take several months to complete the final document, so the members need to be available (not necessarily full-time) or accessible during that period. Dose reconstructions are normally performed by personnel focused just on that task. Staff members become familiar with one site and focus on processing claims submitted by workers from that site. Very few project staff have dual roles in writing TBDs and performing dose reconstructions.

Role of the Document Owner. As would be anticipated, the roles and responsibilities of the Document Owner cover a wide range. One of the most important relates to the selection of the members of the team. The Document Owner must ensure that he or she has appropriate knowledge and experience to research site information, but also that he or she can be objective and bias-free in his or her analysis. Any potential conflicts of interest must be avoided. The Document Owner can obtain information from site experts, but the information must be carefully reviewed, annotated, and attributed in the document. The Document Owner has the final decision-making responsibility over the information and conclusions contained in the SP.

Another important requirement for the Document Owner is that he or she has the capability to communicate effectively with the DOE point of contact and identify site personnel who could provide technical information.

Most important of all, the Document Owner must have leadership capabilities. This is critical to the resolution of conflicting comments that reviewers may provide during the review process to ensure that the bases for the decisions are documented. The Document Owner must be capable of coordinating the work of the team members who develop the five TBDs of the site profile to ensure that (1) both the individual TBDs and the SP, itself, are completed on time, and (2) the individual TBDs within the SP are consistent in style and quality.

Lastly, the Document Owner must be an effective administrator. Records of email messages, minutes of conference calls, and records of related interactions and decisions must be properly prepared and, when necessary, submitted to records management. The same is true for the documentation of the validation and verification (V&V) of various processes for handling analytical data, and documentation of calculations resulting from the use of computer programs and related computational models.

Experience has shown that it is often best for the Document Owner to personally select most of the team members. Nonetheless, he or she should consult as necessary with the manager on the project responsible for the overall development of site profiles before confirming the appointments. For the larger DOE sites, teams were selected to meet a level of approximately six full-time employees for at least four months. These factors were adjusted depending on the complexity of the site and the availability of the necessary information.

TBD development process

Typically, the development of a TBD includes a period of initial data collection, followed by evaluations and requests for more information. This process typically lasts a minimum of 8 wk, during which several team members are devoted to writing the TBD, interspersed with a series of internal reviews among team members and the dose reconstructors responsible for reconstructing the doses. Sometimes, the team requires additional time to interact with site technical representatives to fill in information gaps. They may interview retirees or other long-time site personnel to obtain information describing work performed on the site and details of the radiation protection program, particularly during the initial years of operation. Site visits to retrieve records are sometimes necessary. Additional details on the nature of these activities and the sequence in which they occur are outlined in Fig. 1. Fig. 1 represents the time to produce one TBD. There are five TBDs in each SP. The "typical" time shown for each activity is an estimate of the average time when all TBDs are considered. The technical sections of some TBDs (e.g., for the Site Description and Occupational Medical Dose) will take less time to write than the other TBDs. In most cases, the Internal Dosimetry TBD is the most challenging to complete quickly. It seems that much of the information describing early counting and analysis systems and procedures are difficult to find and document. The team members are working on their TBDs simultaneously with some TBDs being completed faster than others and with different TBDs going into review at different times. However, the SP itself cannot be used by a dose reconstructor until all five TBDs have been approved for use.

Document review and approval

Both informal and formal reviews are important components of the SP development process. The SP is always reviewed informally by authors, dose reconstructors, document control staff, and technical editors (who are all project staff) and may be reviewed by non-project staff such as Authorized Derivative Classifiers (ADC) or Classification Officers (CO). Depending on the nature of the information included in the TBDs, draft documents may need to be reviewed by site ADCs or COs to ensure that there is no possibility of including or creating classified information in the document. The formal portion of the review includes subject matter experts, NIOSH staff members, other TBD authors, the Document Owner, technical editors, quality assurance (QA) specialists, and document control staff. ADC or CO reviews may also be needed prior to final publication of the documents.

The Document Owner ensures documentation of all comments and their resolutions, which is then submitted to Document Control. This documentation may consist of official review forms, email messages, conference call minutes, or other material that identifies the commenter and subject matter.

During the V&V process, an unbiased third-party individual reviews any equations used for accuracy and appropriateness and performs a test to see if the same results as obtained by the author can be repeatedly achieved. The results of the V&V must be available for review by QA representatives and NIOSH before final approval of the document.

Another important step in the review process was introduced as the TBD development process was maturing. This step is to have dose reconstructors test the SP after all five TBDs had been completed and approved. The SP is tested using four or five different claims for the site to see if the information included in the SP was adequate to complete claims of different complexities.

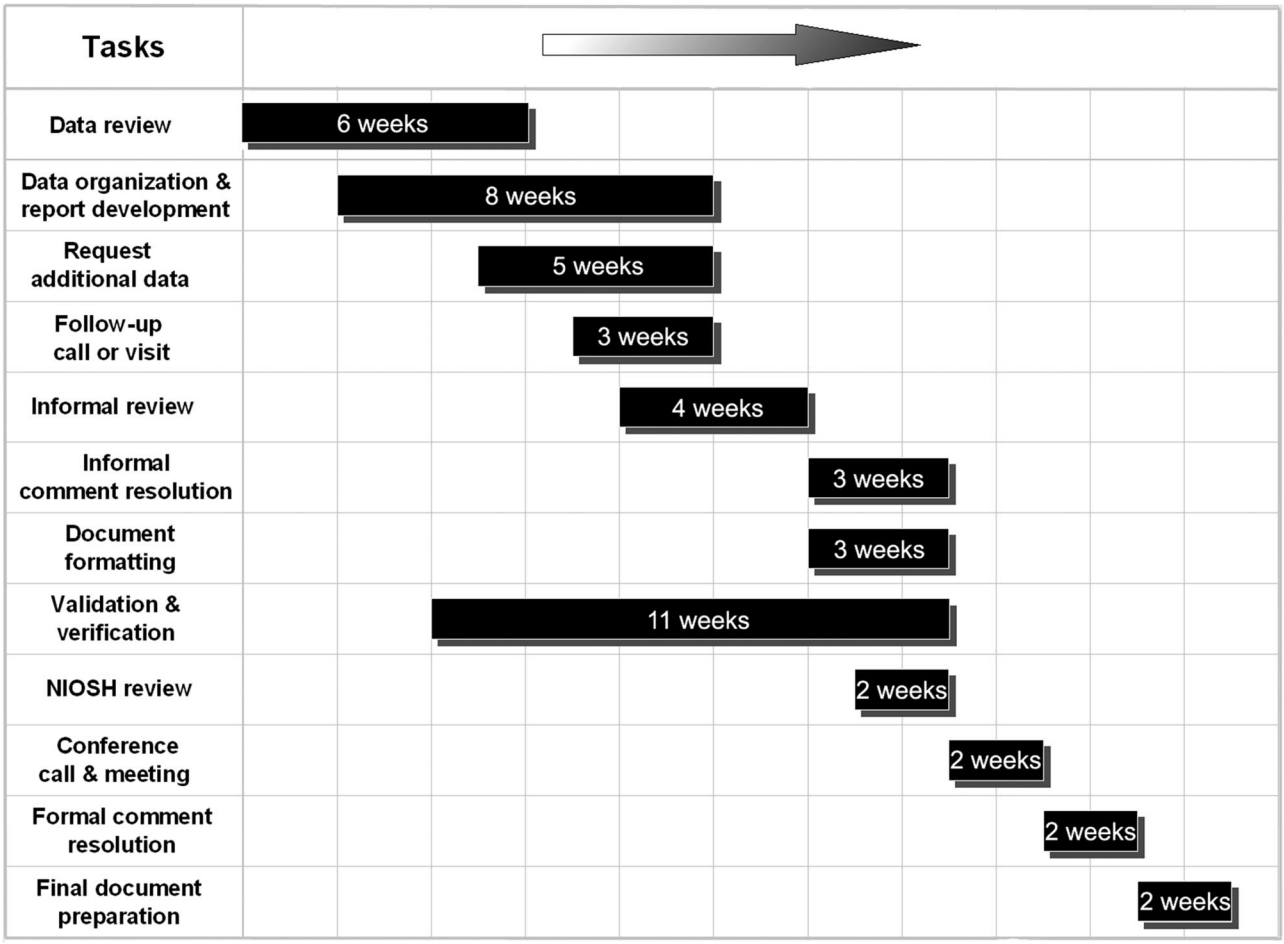

Fig. 1. Typical TBD timeline.

Positive results need to be obtained before the SP goes into the formal review process.

Playing important roles in these activities is a records storage/reference librarian who manages the acquisition and control of the references used in the development of the SP, and a control coordinator who ensures that the SP is formatted and reviewed, that all comments have been resolved, that a record of these actions is preserved, and that the SP is signed by the proper officials. Martin et al. (2008) explain the data management process in more detail elsewhere in this issue.

CHALLENGES

The SP development process required years to evolve and mature. SPs for the larger DOE sites and AWE sites that had a large number of claims were initiated first. The need to produce several SPs simultaneously challenged the resources of the health physics community. The key to success was the interaction among team members and the ability of the SP development teams to adapt to the changing needs of the dose reconstructors and the project.

As would be anticipated, there were many challenges and limitations associated with the development of the SPs. These included:

- Recruiting the necessary qualified staff;
- Identifying the technical site personnel with the necessary knowledge of the internal and external dosimetry programs;
- Locating and retrieving large quantities of data and records from multiple locations (additional details are provided in the earlier section on acquisition of information);
- Organizing records and making them readily accessible to team members;
- Locating and validating information describing the facilities, processes, and instrumentation used during the early years of operation;

- Ensuring the availability of security-cleared personnel to review potentially classified information; and
- Coping with extended time periods to resolve the continuing flow of document review comments.

Most of these challenges were identified as the TBDs were being developed for the first time. Additional resources or streamlined techniques were incorporated where needed to compensate for longer time periods than had been expected. The time periods shown in Fig. 1 take into account these challenges. However, one must realize that some activities could basically shut the development process down until resolution of a problem was achieved. Examples that have occurred include an ADC review that was delayed for weeks because the site did not have a person with a Q clearance or the experience necessary to perform the review of a document, and a team that had issues with access to files stored in an area where a clearance was required. These extreme issues are not reflected in Fig. 1.

COMMENTARY AND CONCLUSION

During the first four years of the NIOSH radiation dose reconstruction project, a total of 43 SPs were developed, approved, and are now in use for dose reconstruction (Table 2). A significant number have been revised at least once based on new information retrieved or additional needs identified by the dose reconstructors or the NIOSH staff. Many SPs have been updated based on discussions with workers at the sites or reviews of information provided in the original SPs. As part of the SP development process, 143 TBDs and 50 TIBs have been prepared, of which 50% have undergone at least one revision or page change.

The SP for each site is distinctive in that the information it contains is based on the radiation sources and processes being used, and the specific counting, survey, and measurement instrumentation that was in use over the years, as well as when it was put into use at that site. However, throughout the nearly 60 years characterized by various SPs, many of the sites shared the same technology for both internal and external dosimetry as well as field instrumentation. Perhaps the biggest reasons for these common characteristics are twofold: (1) in the beginning of the nuclear age, these were the very best operational techniques, instrumentation technology, and guidelines that were available in both the government and private sectors; and (2) as the operational nuances within facilities changed, each facility tended to modify or create its own instrumentation that best fit its working conditions. Even as a result of different configurations of dosimeters and instrumentation, there were no more than four or five different basic types of dosimeters used across the entire DOE complex because, simply, they were the very best technology available at the time. In a similar manner, all sites used similar medical diagnostic x-ray equipment over the years; nonetheless, some sites were able to acquire newer models earlier than the others. One of the major contributions of the SPs was to document the differences and similarities among the sites.

Also to be recognized is that the initial completion of an SP does not bring the matter to a close. As long as new data and information are located and acquired, the SPs will continue to be dynamic in nature and will be updated for two reasons: (1) new data and information affect outcomes of estimated dose reconstructions; and (2) to ensure that the SP is all-inclusive of data and information that provide the most comprehensive assessment of each site. In cases in which new information is

Table 2. List of the 43 SPs published to date.

Aliquippa Forge, PA
Allied Chemical Corporation Plant
Argonne National Laboratory—East
Argonne National Laboratory—West
Atomics International or Energy Technology Engineering Center
Bethlehem Steel
Blockson Chemical Company
Bridgeport Brass (Havens Laboratory and Adrian Plant)
Brookhaven National Laboratory
Chapman Valve Manufacturing Company, Indian Orchard, MA
Clarksville Base Weapons Storage Area and Modification Center (with Guidance for Medina Base)
Extrusion Plant Site
Fernald Site
Hanford
Huntington Pilot Plant
Idaho National Laboratory
K-25 Site
Kansas City Plant
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Linde Ceramics Plant (including Tonawanda Laboratory)
Los Alamos National Laboratory
Mallinckrodt Chemical Company
Mound Site
Nevada Test Site
Oak Ridge National Laboratory (X-10) Site
Pacific Northwest National Laboratory
Pacific Proving Ground
Paducah Gaseous Diffusion Plant
Pantex Plant
Pinellas Plant
Portsmouth Gaseous Diffusion Plant
Rocky Flats Plant
S-50 Liquid Thermal Diffusion Project
Sandia National Laboratories in Livermore, CA
Savannah River Site
Simonds Saw and Steel
Stanford Linear Accelerator Center
Superior Steel, Carnegie, PA
Tennessee Valley Authority, Muscle Shoals, AL
Weldon Spring Plant
W.R. Grace and Company (Erwin, TN)
Y-12 National Security Complex

incorporated into an SP, dose reconstructors re-evaluate dose to the worker to determine whether this could change the compensation decision on a claim that had previously been processed (i.e., a claim that had been completed and submitted).

Acknowledgments—The work described in this paper was supported by the National Institute for Occupational Safety and Health under contract no. 200-2002-0593. The authors would like to thank the reviewers of this document that were thorough and accurate with their comments.

Disclaimer: The findings and conclusions in this paper have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

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