D&D WASTE PROJECTIONS: EXPERIENCE FROM THE ROCKY FLATS SITE

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ABSTRACT

The Rocky Flats Site is in the midst of an multi-year decommissioning project (1995-2006) to dismantle and demolish six major plutonium facilities, four major uranium facilities, and over 400 additional facilities of different types. The project will generate large quantities of transuranic, low-level, mixed, hazardous, and sanitary wastes – determining how much of each is the subject of this paper. The paper describes the initial conceptual estimates and methods, the evolution of these methods as the initial "pilot" facilities were decommissioned, and how the lessons learned were incorporated into the Site "2006 Baseline" estimates.

When the Site completed the decommissioning of its first major plutonium facility, the estimates that had evolved from the earlier projects proved inadequate, and bottoms-up waste estimates using actual waste generation data were implemented. This current approach is described in detail, including which of the collected data proved relevant, actual container densities and build-up factors, sources of error, and examples of changes to decommissioning methods which impacted waste generation. The paper concludes with the discussion of approaches for waste baseline management, overall lessons learned, and future actions planned.

INTRODUCTION

The Rocky Flats Closure Project (Site) is the first major DOE plutonium-processing weapons site to be decommissioned and closed as a site, as opposed to decommissioning of individual facilities at sites that will remain in operation. The fact that the entire Site is being decommissioned over a relatively short time causes the management of decommissioning waste, normally a collateral activity for a site, to be critical to the success of Site closure. Successful waste management requires accurate projections of waste quantities, particularly those resulting from decommissioning, which vary in quantity and type as the building progresses through closure.

In addition to the quantities of equipment and facility structure to be decommissioned, there are a number of decisions and conditions (estimate inputs) that impact the quantity and categories of waste, which are very different during decommissioning from those that apply during Site operations. These inputs include disposal economics, economies of scale, ease of disposition, approach to worker safety, ability to dispose of waste on site, offsite shipping rate, and technologies available. Most of these can only be guessed at in the early project planning. As the sub-projects that comprise Site closure demonstrate consistent work methods, comparable results, and improved planning information, the uncertainties in these inputs continue to be reduced. At Rocky Flats we have collected and are continuing to collect information to track our decommissioning experience in waste generation, with the intent of providing data that can be reliably used to make decisions in the future for the management of our waste. The purpose of this paper is to provide some of the results of this experience, both in the approach and in the quantities and factors developed, so that other sites may more quickly and reliably estimate their waste to support policy and planning decisions.

The closure of Rocky Flats has been proceeding for a number of years and is currently projected to be complete in 2006. Closure encompasses a number of activities, including plutonium stabilization and disposition, plutonium residue processing and shipment, deactivation and hazards reduction, decommissioning, and environmental restoration. Kaiser-Hill and DOE recognized early in the process that not all of these activities could be accomplished simultaneously, and that it was necessary to focus on the higher-risk problems which also corresponded to a disproportionate share of the Site infrastructure (including security and health and safety) costs. Thus, upgrading the site safety posture, hazards reduction, plutonium stabilization, residue processing, and deactivation were emphasized at the expense of decommissioning and environmental restoration to reduce overall risk and cost. This was also physically necessary, since some of the higher-risk problems had to be resolved before critical-path buildings could be decommissioned.

The lesser emphasis on decommissioning over the first half of Site closure has had the benefit of allowing a more efficient growth curve; i.e. reducing startup inefficiencies inherent in large projects. The decommissioning program over the period of 1995 through 1999 consisted of a series of progressively more complicated demonstration projects, including Building 889, Buildings 980, Building 123, Building 788 and, the first plutonium processing facility, Building 779. The intent of this series of projects was to develop the programmatic infrastructure, worker skills, and technical approaches to support the increased emphasis on decommissioning during the 2000 through 2005 timeframe.

The approach for estimating decommissioning waste proceeded in parallel with the decommissioning program. Initial estimates were performed in 1994 and 1995, shortly after the Site's closure mission was established, as part of the "Systems Engineering Analysis" to provide answers to a variety of long-term planning questions. This analysis eventually formed the underlying basis for decommissioning wastes included in the "Rainbow Chart"* baseline. As information was collected from the demonstration projects, this baseline was modified to reflect the actual practice at that time. This approach appeared reasonable well into the Building 779 project.

During the final phase of the Building 779 project, after most of the highly contaminated equipment (e.g. gloveboxes and duct) had been removed, the project began generating waste at a considerably greater rate than expected. Since much of the remaining Site decommissioning will be more like the Building 779 project than previous projects, a new estimating approach was developed to reflect this experience and apply it to the rest of the Site.

This paper is organized into five sections following the Introduction. The first describes the initial scoping and project-specific waste estimates, the second covers the recent application of this experience to Site-wide waste projections, the third expands on the current approaches, and the forth provides lessons learned, and the fifth identifies ongoing and future work. An attachment gives an example of an estimate summary for a single building.

HISTORIC ROCKY FLATS WASTE PROJECTIONS

Systems Engineering Analysis [SEA] (1994-1996)

The SEA was developed as part of an overall effort to understand the problems in closing the Rocky Flats Site. It investigated 14 problems areas, including contaminated soils and groundwater, uncontrolled emissions, chemical, residue, and Special Nuclear Material (SNM) inventory, and legacy waste, as well as the equipment and structural materials expected to be removed during deactivation and decommissioning. The intent was to quantify the magnitude of the conditions (e.g. tons of waste to be dispositioned) to support the longer-term planning necessary to resolve the problem.

The Kaiser-Hill Planning and Integration organization developed the SEA, since at the time there was no specific Site organization responsible for decommissioning. This meant that there was little guidance as to what techniques would be used for size reduction, packaging, treatment – all of the activities related to taking the in-place material and converting it into a shippable form. The scope was therefore limited to estimating the in-place weight of the materials. The estimators walked down twenty buildings, including most of the larger buildings to estimate the equipment weight that would have to be removed. They used engineering drawings to estimate the weight of structural materials, and noted the areas that were identified as contaminated during the walkdowns. As a result of this work, they classified the in-place equipment and building materials into six categories of waste: transuranic (TRU), transuranic-hazardous mixed (TRUM), low-level (LLW), low-level hazardous mixed (LLM), Hazardous, and Solid. Once the weights of these categories were estimated for the twenty buildings, the numbers were averaged for a given type of building per square foot of floor area, and applied to the remaining Site buildings to yield total Site quantities.

The SEA was a useful scoping activity in that it established the order of magnitude of the waste expected to be produced over the Site decommissioning life cycle. In retrospect, a number of enhancements would have been useful. First, the important unit of as-disposed radioactive waste is the volume of shipping containers, not the net weight. While weight turned out to be a very useful parameter (some later volume-to-volume conversions proved less accurate), it provided only an intermediate result, and could not be used directly for waste management. To convert weight to volume requires an estimate of the container distribution and average weight per container for a given waste stream. Second, the methods for treatment and/or size reduction are relevant to categorizing the wastes. For example, the glovebox external lead shielding is removed at Rocky Flats before the glovebox is size reduced; this results in a modest quantity of LLM (lead) and a much lower quantity of TRUM waste than estimated in the SEA. Finally, the database was not kept up, and not used by the execution organizations. This resulted in some reinventing of methodologies and difficulty in identifying and changing estimate assumptions as the projects began supplying actual data.

Building 889 Decommissioning Project (1996)

The Building 889 Decommissioning Project was the first large-scale decommissioning project of a radiologically contaminated facility completed at Rocky Flats. Building 889 was a 5,800 square foot facility constructed in the late 1960's, and used as an equipment decontamination and repackaging facility supporting the uranium and beryllium manufacturing operations. The scope of the project consisted of the removal of all equipment and utility systems from the interior of the building, decontamination on interior building surfaces, and the demolition of the facility to ground level.

The Building 889 Project estimate was initiated by gathering and reviewing existing documentation of the building's previous mission, any past occurrence reports, and the construction drawings of the facility and the equipment layout to gain familiarity with the processes involved. Discussions with operational personnel provided the history for determining the possible contaminants and the location for a biased sampling strategy. Characterization walk-downs of the facility then identified uranium, beryllium, lead-based paint, and the asbestos as the high-risk contaminants or materials of concern. This approach was the basis for identifying the volumes of LLW and LLM. Volume estimates were derived by simple calculations, estimating the in-place volume and then applying a "fluff factor," i.e. an increase in the waste volume due to packing inefficiency, of 20% for density loss due to the material being packaged.

Building 889 project established the viability of structural decontamination by scabbling to unconditional release, and identified the efficiency limitations of several scabbling tools. For instance, the PenTek VAC-PAC Model 9 system was very effective on the horizontal surfaces but very slow on the vertical surfaces. Also, the "fluff" factor of 20% proved to be too low as the waste generated actually filled 25% more waste containers than was estimated. Several times the waste containers were ½ to 2/3 full but had reached the maximum weight allowed per container.

Since this project was the first activity of this type at the Site and some of the planning occurred over the replacement of the O&M Contractor, a number changes to the waste estimating methods occurred based more on management preference than improved experience or insight. These changes resulted in minimal increase in accuracy and added little value. The project would have benefited by staying with a consistent approach and not changing methods in midstream unless significant advantages can be gained.

Building 980 Cluster Decommissioning Project (1997)

The Scope of the Building 980 Project was to remove Buildings 965, 968, and 980, a total of approximately 28,000 square feet of shop and storage area located adjacent to the Solar Evaporation Ponds. Other items included in the project were the dispositioning of some 100 tons of excess equipment and materials contained within the buildings and surrounding lay-down yards.

The Building 980 Project developed a specific waste management plan based upon site walk-downs, historical information, Waste Stream Residue Identification and Characterization (WSRIC) records of the buildings, as well as site interviews of previous building occupants. A Reconnaissance Level Characterization Report (RLCR) was generated which established a definitive baseline of information for the generation of the waste estimates. The RLCR provided information to the project team for use during decommissioning activities assisting in determining in process waste streams. After the initial characterization, it was determined that no hazardous wastes would be encountered, but that some sampling should be performed to support the initial conclusion. The RLCR summarized the waste streams detected. The project team then calculated the volumes that would be generated during D&D. The report indicated that very little if any radiological (LLW) would be generated.

Initially, project waste minimization effort was poor. Waste disposal began using large equipment to pack the large cargo containers without much size reduction due to the thickness of the steel. Several shipments were made of cargo containers that were nominally full, but weighed1/3 of the maximum weight allowed. The project was paying for disposal by container volume, so changes needed to be made to improve the density of each waste shipment.

A larger shear was contracted to better size reduce the metal, allowing the cargo containers to be loaded to within 85-90% of maximum weight allowed. A cost overrun for cargo containers was averted and the extra cost of rental and size reduction were minimal compared to the savings resulting from the reduced number of shipments.

Building 123 Decommissioning Project (1998)

Building 123 was a 19,000 square foot 1950's vintage building, most recently used for bioassay and other low-activity radiological laboratory work. The scope of the Building 123 Project included the complete removal of all internal process waste piping, process hoods and ductwork, laboratory cabinets, radioactively-contaminated materials, polychlorinated biphenyl (PCBs), and all asbestos-containing materials. Waste was generated during each of the following phases of the project: (1) Building Deactivation and Strip-out, (2) Asbestos Abatement, (3) Demolition, and (4) remediation of the Individual Hazardous Substance Sites (IHSS).

Hazardous chemicals and laboratory equipment were removed during the building deactivation phase. Process waste lines and ventilation removed during strip-out had low levels of internal contamination caused by processing bioassay and environmental samples. Localized areas of contamination within the building were isolated and decontaminated to limit the amount of low-level and hazardous waste that was generated. Building 123 was then demolished and materials removed down to the base slab. Despite the structural decontamination, the demolition activities generated LLW in the form of soil, piping, and debris, and a quantity of asbestos building materials and insulation. The large quantity of asbestos contaminated waste, both during strip-out and especially during demolition, was significantly greater than anticipated. Asbestos removal was subcontracted to a commercial vendor who is licensed to remove and handle this type of waste. A subcontractor handled transportation and disposal of non-contaminated asbestos waste. Minor quantities of hazardous and mixed wastes also were generated.

The Building 123 Project was the first project on Site to fully utilize the Site D&D WSRIC, process knowledge and RLCR to characterize these wastes and excess materials, integrating D&D-generated waste into the Site waste characterization system. This information was used to properly characterize and prepare radioactive or hazardous waste for packaging and certification. Characterization and sampling requirements were defined in the Building 123 RLCR and the Characterization Plan.

Despite the RLCR, the Building 123 Project suffered from not performing a sufficient and complete characterization of the facility. The project was not allowed sufficient time and budget to perform the needed surveying and sampling to identify building hazards and contamination. Also, the building was occupied and operating during much of the time the facility characterization was being performed, further complicating characterization data collection. This resulted in waste estimates inaccurately predicting waste volumes and waste types, causing a negative cost variance.

Building 788 and Clarifier Tank Decommissioning Project (1998)

Building 778 and its associated systems were used to solidify LLM sludge from the Solar Evaporation Ponds, and the facility to stage and package the waste. The scope of the Building 788 and Clarifier Tank Project was to remove Buildings 788, 788A, 308A, the Clarifier Tank and surrounding plywood structure, and to relocate trailer T788A from the project site.

Various methods were evaluated to dispose of the largely metal equipment and Butler-type buildings that had been exposed to the pond spray and sludge. An analysis found it to be prohibitively expensive to unconditionally release the materials, so the project decided to recycle the metal as radioactive scrap metal, shipping it to GTS Duratek in Oak Ridge, Tennessee to become shielding for the nuclear industry. The fiberglass insulation between the wall was surveyed and determined to be unconditionally releasable. The project determined that the insulation from the ceiling could be unconditionally released following the segregation of the backing materials from the bulk insulation. The plywood found in the roof of the north side of Building 788A was separated from the rubberized membrane roofing material, to reduce Low Level Waste generated. The plywood was packaged and disposed of as Sanitary Waste.

The Building 788 and Clarifier Tank Project developed a specific waste management plan based upon a detailed Reconnaissance Level Characterization Report. After the initial site inspection, the review team developed a Site Hazard Assessment Plan (SHAP). The SHAP implemented the technical requirements of the Site's D&D protocols. The SHAP ensured that the sampling performed identifies the type, approximate quantity, condition, and sources of hazardous and radioactive substances present at the site. The Site Hazard Assessment Report (SHAR) summarized the data into concise, usable formats and provided interpretation of the data for use in estimating waste types and volumes.

The project encountered numerous unforeseen site conditions and changed the decommissioning approach to respond to those conditions during the demolition activities. The appropriate project team members investigated the situation, changes were made to the Waste Management Plan, and updated the waste volume estimates. One of the issues resulting from the project changes were a number of misinterpretations made in reviewing the waste estimates between the waste inspector and the waste generators. The misinterpretations were due to the estimating team and the procurement team not reviewing the estimates together, and resulted in the wrong waste containers being procured for the waste disposal option selected.

Building 779 Decommissioning Project (1998-2000)

The Building 779 project dismantled, decontaminated, and removed to slab-on-grade a plutonium laboratory and production building, two filter plenum buildings, and various ancillary structures totaling approximately 80,000 square feet. The building contained over 300 cubic meters of gloveboxes, approximately half of which were TRU waste, extensive ductwork, and additional contaminated mechanical systems.

The Building 779 project developed a project-specific waste management plan based on a room-by-room walk-down of the building. The approach was to visually estimate the in-place volume, determine whether it was in a contaminated or non-contaminated area (and hence TRU/LLW or excess property) and, if LLW, multiply by 125% to account for packaging inefficiencies. There was limited methodology development and reliance on previous data, and the minimal records were kept. Glovebox TRU waste as packaged was estimated to be equal to the in-place volume of gloveboxes. The waste management staff, not experienced cost estimators, did the original waste estimate. These individuals had little experience or guidance in estimating, management did not emphasize the product, and insufficient time or effort was invested. As a result several items were missed, intentionally deferred (such as ductwork), or omitted.

The Building 779 project also developed the initial "Economic Disposition Plan" to justify disposition of contaminated items as waste based on their residual value and the cost to decontaminate and certify them for free release. It was through this analysis that the determination was made to dispose of a larger portion of the equipment and strip-out waste as LLW instead of excess property. This was never reconciled with the original waste estimates.

The Building 779 project demonstrated the disadvantages of not having a waste estimate based on specific work elements consistent with the execution methods and a rigorous estimate based on takeoffs. As the project progressed it was impossible to identify which work had been done and compare estimates with actual generation. This made it impossible to predict the significant increase in LLW that occurred at the beginning of the strip-out of the miscellaneous equipment (i.e. after the glovebox work was complete). Fortunately the project had a separate cost estimate (developed independently, subsequent to the original waste estimate) with reliable takeoffs of pipe, duct, and additional materials that allowed some after-the-fact correlation of data.

There were a number of improvements in decommissioning methods that occurred during the project that impacted the waste generation. The biggest was the use of the Surface Contaminated Object (SCO) determination of activity, which permitted LLW to be packaged in cargo containers instead of 4'X4'X8' crates. Although this proved to be a significant improvement in worker productivity, it resulted in a 20% reduction in the overall density of the waste (i.e. pounds net weight per cubic meter). This density is now identified as a parameter that is tracked by activity. The determination to waste the miscellaneous items instead of disposition them as excess property also should have resulted in a revision to the estimate; however, the data was such that it would have been difficult to make those changes.

APPLICATION OF ACTUAL D&D PROJECT EXPERIENCE TO SITE ESTIMATES

“Rainbow Chart” Approach (1998-1999)

In 1998 the D&D Program was asked to develop updated estimates for the wastes to be generated during the Site life-cycle decommissioning activities. The estimate was to be by quarter for the first two years and yearly thereafter. The purpose was to provide a long-term estimate of decommissioning waste projections which, when combined with other Site waste projections, could be used to properly plan and budget Waste Management projects and activities to support Site closure in 2006.

Since the goal was to develop a waste estimate for the whole Site, the SEA was chosen as the basis, with the quantities adjusted based on the actual results of Building 123 and the estimate for Building 779. This Building 779 estimate data was thought to be of higher quality than the SEA walk-down data for the building. Additionally, since the data was to be for off-site shipment, the weights provided by the SEA were converted to volumes, with the numbers of specific containers (e.g. drum, waste crate) to be determined at a later time. Finally, since the SEA provided quantities by building, the generation could be spread over the period of time each building was scheduled for decommissioning to yield a building-specific generation rate that could be combined to provide an overall Site waste generation rate. To make the data more manageable, and given the lack of precision of the input data, the Site was divided into the ten major contaminated buildings and a combined “Rest of Site” group. The waste types were limited to a combined TRU/TRUM, LLW, LLM, and Sanitary based on the off-site disposition pathway.

The “Rainbow Chart” approach evolved over time to account for some of the actual data being generated by the Building 779 project. It was modified to reflect near-term project estimates such as Building 788 and track actual values throughout FY 98 and FY 99. For instance, when the Site decided to recycle clean concrete, the estimate was changed to reflect a reduction in sanitary waste. The estimate values identified under "Rest of Site" were extrapolated across the minor buildings, and the data, originally just cubic meters, was extrapolated among the different container types to yield an approximation of the different containers to support additional analyses. Throughout this period the generation rates predicted by the estimate appeared to track reasonably well with actual data. However, during the final six months of the Building 779 project, approximately the time period that strip-out of less contaminated equipment and debris was occurring, actual generation rates were much greater than that predicted by the estimate. This led to the development of a fundamental change to the estimating approach.

The “Rainbow Chart” established the first real time-phased waste baseline for the Site. By breaking the waste generation into discrete units (i.e. generation activities and buildings) it allowed the estimates to be compared against actual data. It also served to identify requirements and goals for a more precise approach. The estimate was deficient in that the top-down approach, which basically used building floor area as the only “metric”, did not account for the difference in building conditions. The most detailed element of the waste estimate was at the building level, with no way to compare smaller elements of a building estimate against equivalent actual generation, and identify if the actual generation was trending away from the estimate. Although this was partly an estimate problem, it also requires coordination between waste estimate elements and the waste reporting elements. Finally, the biggest problem was the differences observed in container “waste density,” i.e. net weight of waste per volume unit. The original assumptions were much higher than the actual as-packed densities.

Equipment Metric Approach (2000+)

At the beginning of FY 00, as a result of the discrepancies between the Building 779 estimated and actual generation, and concerns about the impact of this on future decommissioning activities, a new waste estimate was developed. By this time the four biggest remaining plutonium processing buildings on Site, Building 771/774, Building 776/777, Building 707, and Building 371/374, had more detailed cost estimates based on physical walkdowns and takeoffs. Equivalent cost estimate data was also available for Building 779, along with the actual waste generated. The objective of the new estimate was therefore to better extrapolate the experience from Building 779 based on the different kinds of equipment and media to the remaining buildings.

The general estimating approach was straightforward: use the data from the Building 779 actual data to develop a volume of waste (both TRU and LLW) generated in-container per a given "metric" (e.g. cubic feet of glovebox, linear feet of pipe), and apply it to the equivalent metrics in remaining buildings. The metric data for the remaining buildings already had been subdivided into "Sets." These Sets are groupings of adjacent or logically connected gloveboxes, tanks, contaminated areas, or other decommissioning scope that will be managed as a major project activity. From a project management and control perspective, Sets are the principal elements of work that sum to the overall building scope, and are used for routine cost and schedule reporting. Thus, the resulting waste generation would also be grouped by Set. The methodology allowed us to quantitatively account for the differences in the equipment between the future buildings and Building 779. Finally, the sanitary waste and recycle concrete numbers were revised based on new takeoffs from structural drawings and application of Building 779 actual generation from analogous materials. This was applicable because all internal equipment was removed during stripout, leaving only the structure and roof. The "building shell" was then surveyed, decontaminated, and unconditionally released prior to demolition. After unconditional release the demolition debris was by definition sanitary waste or recycle material.

This approach was well suited for the remaining plutonium processing buildings; however, other buildings on Site had not yet been through the cost estimating walk-down and take-off process, and had no "metrics" to which factors could be applied. For these buildings the data from the SEA estimate for Building 779 was compared against the actual data on a weight-to-weight basis, and then the actual density for the LLW and LLM waste from Building 779 was applied. The distribution of waste between the individual buildings was done based on the floor area of the contaminated and non-contaminated buildings. This provides only an incremental improvement to the previous top-down estimate, and will be upgraded as the cost estimates and metric data are developed. While it would be advantageous to have a higher quality for the waste estimates of the other buildings, it is not a priority at this time. The plutonium processing buildings represent the Site's principal decommissioning scope over the next four years and will generate all of the TRU waste from decommissioning. Also, we believe that it is important that the data used for waste estimates be generated integral to the planning of the rest of the project.

The development of this new waste estimate was occurring in parallel with the larger rebaselining effort, which Kaiser-Hill initiated after the negotiation of the new Rocky Flats Site Closure contract with the DOE. The structure of the new contract places a premium on identifying and controlling costs. The waste management and disposal cost constitute a significant portion of the total project cost, and were made a more visible component of the new Site baseline by including a waste generation value in each of the project activities. The new waste estimate was integrated with this effort and the waste estimate was designed to provide waste generation data for every decommissioning activity. In this way the waste estimates, via the baseline activities, can be spread across the project lifecycle consistent with the Site working schedule to provide projections by baseline activity by quarter. The time-phased waste projection will automatically move forward or backward as the schedule changes.

DETAILS OF THE CURRENT WASTE ESTIMATE APPROACH

This section provides the details of how we developed the metric data and the actual waste data from the Building 779 cost estimate and waste records, respectively, applying that information to the different plutonium buildings, and evaluating potential uncertainties.

Development of Metric Data from Building 779 Experience

In order to capture and quantify the differences between the various buildings, specific metrics were identified and evaluated. These metrics were based upon our ability to collect the data from the building take-off cost estimates, and what specific data could be separated from the Building 779 actual waste generation. Since the equipment and building were essentially gone by the time this effort was started, the data from these sources could not be checked for accuracy or parsed into different metric groupings. This limited our choices of metrics. Both TRU and Low Level Waste LLW data were gathered for each metric. The metrics specific to the data desired are shown in Table I below and described in the following paragraphs.

The glovebox dimension data was used to calculate both the glovebox volume in-place and the surface area. Initially, all the gloveboxes were assumed to be TRU waste; however, this was modified to account for training, lab, and other gloveboxes, which were predicted prior to strip-out to be LLW. Both the glovebox in-place volume and the in-place surface area were evaluated to determine the waste in-crate and the secondary waste. The linear feet and square feet of contact area of the ductwork were estimated from the engineering drawings and grouped into three categories – less than 4-inch, 4 to 10-inch, and greater than 10-inch diameter. The duct surface area for each duct size grouping was summed to get a total duct surface area. It was assumed that no size reduction of ductwork would be performed, and that all Zone 1 and 1A (i.e. glovebox exhaust ventilation) duct would be TRU and all Zone 2 (operating spaces adjacent to gloveboxes) duct would be LLW. The linear feet of piping were estimated from the engineering drawings, grouped into 2-inch, 6-inch, and 10-inch diameter pipe. Using the cross-sectional area of each grouping, the pipe volume in-place was calculated. It was assumed that all process piping would be TRU and all non-process piping would be LLW. The linear feet of pipe for each pipe grouping were summed to get the total linear feet of pipe.

Table I – Metric Types

Metric	**Data to be Calculated**
Glovebox – in-place(standing) volume, m^3	Glovebox – waste in-crate, m^3 Glovebox – secondary waste, m^3
Glovebox – in-place surface area, m^2	Glovebox – waste in-crate, m^3 Glovebox - secondary waste, m^3
Duct – ft^2 (estimated like sheet metal)	Duct – Waste in-crate, m^3
Piping – linear feet (independent of size)	Piping – Waste in-crate, m^3
Tanks – volume in-place, m^3	Tanks – Waste in-crate, m^3 Tanks – Raschig Rings, m^3 Tanks – Secondary Waste, m^3
Miscellaneous items (surface area, ft^2)	Strip-out Waste, m^3 Debris Waste, m^3

The approach above is only one of many that could be used to determine define metrics, consistent with standard cost estimating techniques. Its principle advantage for us was that we had the data available and that rigorous take-offs and walk downs supported it. The final step in determining the metrics was to assume that once all the gloveboxes, duct, pipe, and tanks were removed from a building, the buildings would contain similar quantities of miscellaneous items per square foot of building area, making that the last metric. We recognized the potential for error in using this "catch-all" metric, but had no better data for these miscellaneous materials. Also, by removing the bulk of the materials that could be counted this reduced the building area metric to a much smaller percentage of the total, and an almost insignificant portion of the TRU waste, our highest cost-to-disposition waste.

The data reflecting the actual waste generation for Building 779 was principally that available in the Site-wide Waste and Environmental Monitoring System (WEMS). This database provided waste data for each container, including the waste type, the container type and volume, the net weight, the date waste was initially placed in the container, the date the container was full, the Item Description Code (IDC, i.e. waste code), and the process or process type from which the waste originated. The room location was indicated, but given the way work was performed this was not useful data for the analysis. Additional data was available on the Waste Travelers indicating generally what was in the containers (pipe, glovebox numbers, duct, etc.). Finally, property control documentation, indicating items of accountable property that were present in waste containers, was useful in tracking glovebox disposition.

In determining the categories of the actual waste generated from Building 779, the total amount of waste generated, as accounted for in WEMS, remained constant; only the way it was divided between the equipment categories changed. Based on the work performed in the building, all TRU/M waste generated from October 1, 1997 to May 10, 1999, excluding waste, which was clearly not from gloveboxes, was counted as TRU/M glovebox waste. The actual LLW from gloveboxes was obtained from the number of standard waste boxes which returned from assay as LLW, as well as the number of LLW boxes containing glovebox pieces, as indicated from the property inventory and waste traveler logs. The actual secondary waste generated from glovebox removal was assumed to include all drums of TRU and TRUM combustibles and plastics, and all drums and crates of LLW and LLM combustibles and plastics generated from October 1, 1997 through May 10, 1999.

The actual quantity of TRU, TRUM, LLW and LLM pipe and duct were obtained by reviewing all of the waste travelers and assigning assumed portions of the box to pipe or duct depending on the description of the waste in the container and the relative size of equipment. For instance, if a waste traveler indicated that a waste box contained duct and transformers, the box was assumed to be ½ duct. If a box contained duct, conduit and pipe, the box was assumed to be ½ duct and ¼ pipe.

The amount of debris was obtained by taking only the IDC 374 (i.e. building debris and soil) for all containers from the WEMS data and separating it into TRU/TRUM and LLW/LLM. The Miscellaneous strip-out was obtained by taking the total amount of waste (TRU/TRUM and LLW/LLM) as reported in WEMS and subtracting all the other identified waste, e.g. glovebox, glovebox secondary, duct, pipe and debris. In this way the total amount of actual waste as reported in WEMS was accounted for, and the only assumption errors would be in how the waste was divided between the various equipment groups. Again, sanitary waste was calculated separately.

Application of Metric Data to Future Buildings

Once the Building 779 metric data and actual generation quantities that resulted from the metric categories were compiled, we could develop the waste estimates for the other buildings. Metric data was obtained from each of the other plutonium buildings. The waste estimate for each equipment type and waste type was calculated using the method shown in Equation 1. The application of this approach for a whole building (Building 771) is provided in Appendix 1. Using Building 771 duct as an example:

$$\frac{\left(B779\ DuctActualWaste, m^3\right)}{\left(B779\ Est.DuctSurfaceArea, m^2\right)}\left(B771\ Est.DuctSurfaceArea, m^2\right) = \left(B771\ DuctEst.Waste, m^3\right) \qquad \text{(Eq. 1)}$$

Two of the buildings, Building 771 and Building 776/777, already had bottoms-up waste estimates. In the process of validating and developing project acceptance, the waste estimate methodology using Building 779 metrics was compared with the bottoms-up waste estimate from those buildings. The metrics chosen were evaluated by comparing the results of each equipment-type estimate with the original waste estimate generated by building personnel. This required some manipulation of the data in the item-by-item estimates. It was from this comparison that it was decided that the quantity of glovebox waste would be estimated from the in-place volume of the glovebox, and the quantity of glovebox secondary waste would be estimated from the glovebox surface area. This comparison was possible for all equipment except for tanks and related tank waste, as the Building 779 project only had a single deluge tank in Building 782. Based on the thoroughness of the Building 771 tank estimate, the tank waste data from Building 771 was incorporated into the model for subsequent tank estimates.

The comparison between the bottoms-up waste estimates and the estimates using the Building 779 metrics was reasonably close in most areas that had been the greatest focus of the bottoms-up estimates, particularly in the area of TRU waste from gloveboxes. Areas where the approaches tended to diverge were the areas where the bottoms-up estimates had placed less emphasis. For instance, the original estimate of strip-out LLW from the Building 771 waste estimate was less than half of the actual strip-out LLW from Building 779, a much smaller and less contaminated building. The culmination of this comparison was the building's general acceptance of the metrics approach, with specific estimate elements modified by the buildings to reflect unique features (e.g. contaminated equipment buried under floors). The overall impact of the building-specific adjustments for the two buildings for comparable items was about an 8% difference in the TRU volume and less than 5% difference in LLW volume. Again, these buildings had their take-off data broken out by Set, allowing the waste estimate data to be grouped by Set, even though the Building 779 metrics had been averaged across the whole building.

The remaining two plutonium buildings, Building 707 and Building 371, were developing their detailed cost estimates using the "POWERTool" estimating system. POWERTool is a proprietary Microsoft Access database in which walk-down-generated physical equipment data is combined with cost and resource data to generate equipment and labor costs, man-hours by craft, and other planning and support costs. Although the general system is used at a number of locations for decommissioning estimates, the version used for these buildings was modified significantly to meet Site-specific requirements.

With the Access database available, we developed the necessary queries to extract the relevant data into the metrics needed to apply the model. The data allowed us to go back and identify individual tanks and gloveboxes, and assess their likely condition and resulting waste type, instead of being limited to Set-level data. The ability to track data at this level will allow more detailed analysis in the future.

The question of why the original Building 779 estimate and actual waste data were so different was investigated. Comparison showed that most of the difference was the result of two factors: some of the items in the building had not been included in the waste estimate, and the actual packing density was much less than estimated. To better understand the packing density, and to allow it to be tracked for analysis of variances between the estimate and actual volumes, we determined the average weight for the various container types for various IDCs. In general, as the container size increased, the packing density (pounds per cubic meter) decreased. This was most evident in the packing density for Surface Contaminated Objects (SCO – IDC 5001) in waste crates and cargo containers, where the packing density decreased from 600 to 444 pounds per cubic meter.

Table II – Building 779 Waste Container Density

Container Description	Container Volume m^3	Number of Containers	Packing Density Lb/m^3
Drums – TRU/TRUM	0.209	371	374
Standard Waste Box – TRU/TRUM	1.90	167	548
Drums - LLW	0.209	103	1,288
Half Crate	1.586	50	716
Metal Crate	3.002	16	898
Full Crate	3.172	417	601
Cargo Container	33.3 to 36.6	96	444

The majority of the decommissioning waste from Building 779, because of the equipment and approach taken during decommissioning, was TRU, LLW, or Sanitary. We decided that the best approach was to use these categories as a basis for tracking, combining the relatively small quantity of TRUM and LLM into the larger category, then breaking the mixed category out on a percentage basis when needed based on the Building 779 experience. The percentages observed in Building 779 were then modified to reflect specific building conditions, if necessary. This information was also used to estimate decommissioning container requirements.

Table III – Percent of Building 779 Waste by Container

Waste Type	Quantity (m^3 or Tons)	% Volume in Drums	% Volume in Half Crates	% of Volume in Metal Crates	% Volume in Full Crates	% Volume in Cargo Containers
TRU	332 m^3	21.7	78.4	0.0	0.0	0.0
TRUM	63 m^3	9.6	90.4	0.0	0.0	0.0
LLW	3,343 m^3	7.4	3.6	1.4	87.6	0.0
LLW-SCO	4,795 m^3	0.5	0.0	1.7	28.6	69.3
LLM	47 m^3	63.6	36.4	0.0	0.0	0.0
Hazardous	12 m^3	100.0	0.0	0.0	0.0	0.0
Sanitary	1,419Tons	0.0	0.0	0.0	0.0	0.0

We decided not to apply a top-down or metric-based approach to a number of specialized waste forms that typically have smaller volumes but are harder to treat, such as PCBs or specific RCRA codes. For those cases where characterization data was available, we utilized building characterization and historical data, and incorporated that information into waste management plans, along with the disposition pathway for that waste.

Waste Estimate Uncertainty

A model that provides waste estimates based on previous decommissioning project experience will only be as good as the data collected in previous projects, the quality of metric data for the new work, and how closely the conditions and approach for the estimated work correspond to previous experience. The model uncertainties basically relate to those areas.

The quality of the data collected from the Building 779 project (the accuracy of the cost estimate data needed to establish metric values and the actual waste data from project and waste generation records) limited our ability to assign the decommissioning waste generated to specific project activities. While it would have been useful to categorize by Sets in the building, work crew, in-situ size reduction, etc., we had no ability to collect that data – in fact, much of the data, such as "secondary waste" is inferred from other information, not directly collected. There is therefore an uncertainty associated with applying these values to the metrics.

A second area of uncertainty is in the estimate data for the future buildings to be decommissioned. Waste estimates are often viewed as an after thought in project planning and cost estimating, particularly if the project is not responsible for the waste disposal cost, and need to be flexible in the data that they can accept. In developing the POWERTool estimates we had some control over the walk-down data, and could control it's quality. In other situations the data quality was less certain. Since one of the biggest sources of error is not identifying things that have to be removed, we have to assume that the estimates are approximately equal in that regard and that the "Miscellaneous" category is consistent. The error resulting from the estimating uncertainties and uncertainties inherent in the metrics will be evaluated based on the ongoing tracking of the projects.

A final area of uncertainty is in changes to method of doing business. One of the most noticeable changes in decommissioning at the Site to date is that resulting from the increased use of SCO. There are several ongoing efforts to improve decontamination of gloveboxes and tanks. If these succeed, then the SCO-LLW volumes will increase significantly and the TRU volumes will decrease. Other potential impacts will be thermal cutting of TRU materials, use of "Intermodals" (i.e. reusable containers to transport LLW), and the potential for contaminated demolition of buildings instead of decontamination of the facilities and subsequent clean demolition. Finally, there will be an increases in LLW volumes due to the Site's decision to dispose of beryllium contaminated waste that has the potential for radiological contamination as LLW.

LESSONS LEARNED

A consolidated list of lessons learned from our experience in estimating the decommissioning waste is given below:

Data Collection Requirements

- Use a combination of walkdowns supplemented by drawing takeoffs to obtain in-place metric data; coordinate waste estimating and cost estimating
- Use historical data on actual container net weights and container volume to define other metrics to improve both waste estimates and waste packaging performance
- Recognize that decommissioning operations personnel typically do not believe that it is their job to collect data
- Evaluate data quality, both in the walkdowns and takeoffs, and in the actual waste volumes and characteristics
- Track both actual net weights and container volumes of waste
- Use a consistent approach for data collection
- Prior to and during data collection critically evaluate the usefulness of the data to minimize the impacts to the project
- Use any existing waste data collection system already available to the greatest extent possible

Estimate Output Requirements

- Define what are the decisions to be made from the estimates. It may be useful to have different estimates for the Site-level and the building-level requirements, coordinated rather than combined

- Focus on the waste estimate accuracy of higher disposal-cost waste (e.g. TRU) at the expense of lower-cost waste (e.g. Sanitary)
- Group wastes by disposition path – e.g. asbestos waste and sanitary waste both go to a Subtitle D landfill
- Use the same parameter for estimating as is used for disposal (i.e. volume for TRU and LLW, weight for sanitary)
- Be able to track how much waste should have been generated against project completion; assuming an average waste generation rate per month allows schedule delays to mask waste overruns

Estimating Method

- Don't use visual assessment of physical in-place volume to estimate waste volume
- Differentiate between wastes generated by different programs (e.g. routine generation vs. deactivation vs. decommissioning), and use estimating methods appropriate to the program, taking into consideration the types of waste generated, quantities, and availability of input data
- Don't use "fluff factors" – for lighter items use historical in-container volumes data and for heavier items estimate weight and use historical container densities or maximum container weights

Interfaces

- Begin early to integrate estimating with on-site waste characterization and management processes
- Perform facility characterization based on waste estimate requirements – if most equipment that might be released goes a LLW, characterization must consider LLW acceptance criteria
- Work with the waste generating D&D teams so they can understand the importance of the data as well as learn project-specific difficulties in data collection
- Use project-specific waste management plans to define programmatic interfaces and responsibilities, particularly for one-time or initial projects

Follow-up

- Identify sources of error between estimates and actual data
- Bootstrap – use lessons learned and new data to improve later estimates
- Waste generation is based on decommissioning methods used; the estimate must be modified to keep current with project techniques; the estimate must be flexible to incorporate ongoing input of project data

ONGOING AND FUTURE EXTENSION OF THE WASTE ESTIMATES DEVELOPMENT ACTIVITY

The next steps for waste estimating at the Site fall into two basic areas. The most obviously, for the facilities which had no cost estimate takeoffs, and which are therefore dependent on top-down waste estimates, there will be an ongoing effort to collect the necessary walk-down and take-off data. As this data is collected, we will use the same methodology to update the waste estimates for those facilities.

Given the nature of the Kaiser-Hill contract, and concerns about achieving the baselines in terms of the waste estimates, we are attempting to implement a waste tracking system analogous to the project control system used to control costs and schedules. The general approach is to collect actual waste data by Set, and compare it with both the project waste baseline and the earned value measured by the project. This makes it possible to track and extrapolate upcoming deviations from the baseline in time to change project approach or expectations (probably quarterly reporting), but not to be constantly revising documents and estimates. Routine tracking of appropriate data should also allow us to collect the floor-level data and obtain the metrics needed to estimate the non-plutonium processing buildings. Changes in waste generation characteristics caused by changes in decommissioning methodology, such as the wider use of thermal cutting for TRU materials, can also be tracked (e.g. changes in waste density), and the impacts incorporated into the building waste projections.

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FOOTNOTES

* The "Rainbow Chart" was the colloquial name for the Waste Generation, Inventory, and Shipping Forecast used by Site Waste Management for planning purposes prior to the June, 2000 rebaselining.

APPENDIX 1

Building 771 Waste Estimate Summary

Item Description	Building 779			Building 771			Subjective Comparison Factor	Consensus B771 Estimate
	metric		B779 m^3 Actual	metric		B771 m^3 Estimate		
Gloveboxes - TRU/M	157	m^3	196	694	m^3	866	1.1	952
Gloveboxes - LL/M	159	m^3	198	5	m^3	6	1.1	6
GB Sec waste-TRU/M	682	m^2	53	2,793	m^2	219	1.2	263
GB Sec waste-LL/M from TRU GB	682	m^2	384	2,793	m^2	1,574	0.5	787
GB Sec waste - LL/M from LL GB	726	m^2	96	20	m^2	3	1.0	3
GB Sec waste - LL/M Total			480			1,577		790
Ductwork - TRU/M	15,288	ft^2	101	30,764	ft of cut*	607	1.1	667
Ductwork - LL/M	64,197	ft^2	987	44,227	ft of cut*	2,040	1.0	2,040
Piping - TRU/M	0	lin ft	15	28,970	lin ft	319	1.0	319
Piping - LL/M	36,775	lin ft	391	146,711	lin ft	1,558	1.0	1,558
Tank Raschig Rings - TRU/M	NA		NA	NA		NA	1.0	72
Tank Raschig Rings - LL/M	NA		NA	NA		NA	1.0	12
Tanks - TRU/M	NA		NA	NA		NA	1.0	198
Tanks - LL/M	NA		NA	NA		NA	1.0	3
Tanks Sec Waste - TRU/M	NA		NA	NA		NA	1.0	181
Tanks Sec Waste - LL/M	NA		NA	NA		NA	1.0	3
Stripout TRU/M	76,039	Bldg ft^2	30	181,143	Bldg ft^2	72	1.0	72
Stripout LL/M Misc during GB Rem	76,039	Bldg ft^2	1,051	181,143	Bldg ft^2	2,504	1.0	2,504
Stripout LL/M Misc after GB Rem	76,039	Bldg ft^2	3,925	181,143	Bldg ft^2	9,350	1.0	9,350
LL/M Debris	76,039	Bldg ft^2	1,303	181,143	Bldg ft^2	3,104	1.0	3,104
Total - TRU/M			**396**			**2,534**		**2,725**
Total - LL/M Stripout			7,032			17,053		16,266
Total - LL/M Debris			1,303			3,104		3,104
Total - LL/M			**8,335**			**20,157**		**19,370**

This table is an excerpt of the estimate summary for Building 771. In the left column are the metric groupings of waste. Successive columns are the building metric values (i.e. cubic meters, square feet), the actual volumes of as-generated waste from Building 779, the metric values for Building 771, and the corresponding estimated waste for Building 771. The final columns are the adjustments made for differences in conditions between Building 779 and Building 771.