Rocky Flats Closure Unit Cost Data

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ABSTRACT

The Rocky Flats Closure Project has completed the process of stabilizing residual nuclear materials, decommissioning nuclear facilities, remediating environmental media and closing the Rocky Flats Site (Site). The project cost approximately $4.1B and included the decommissioning of over 700 structures including 5 major plutonium facilities and 5 major uranium facilities, shipping over 14,600 cubic meters of transuranic and 565,000 cubic meters of low level radioactive waste, and remediating a 385-acre industrial area and the surrounding land. Actual costs were collected for a large variety of closure activities. These costs can be correlated with metrics associated with the facilities and environmental media to capture cost factors from the project that could be applicable to a variety of other closure projects both within and outside of the Department of Energy's weapons complex.

The paper covers four general topics: the process to correlate the actual costs and metrics, an example of the correlated data for one large subproject, a discussion of the results, and the additional activities that are planned to correlate and make this data available to the public. The process to collect and arrange the project control data of the Closure Project relied on the actual Closure Project cost information. It was used to correlate these actual costs with the metrics for the physical work, such as building area or waste generated, to support the development of parametric cost factors. The example provides cost factors for the Industrial Sites Project. The discussion addresses the strengths and weaknesses of the data, followed by a section identifying future activities to improve and extend the analyses and integrate it within the Department's Environmental Cost Analysis System.

INTRODUCTION

As of December 2005 the Rocky Flats Closure Project completed all physical work and paid all project costs (except minor incidental closeout costs), including the cost to decontaminate and decommission (D&D) facilities, remediate environmental media, and dispose of the waste. Records also exist of "metrics," or scope-defining parameters. The Department of Energy is collecting these costs and metrics in a form that can be used to assist in estimating or evaluating estimates for the decommissioning, environmental restoration, and waste management of future closure sites. This document discusses a portion of this effort.

The ultimate goal of the data collection process is to make the Rocky Flats Closure data available to the public through the Environmental Cost Analysis System (ECAS). The ECAS is a WEB-based computer system built to store and retrieve actual costs for completed and in-process DOE EM projects. It is organized based on the Environmental Cost Element Structure (ECES), a WBS-like hierarchical list of elements that may be present in D&D and environmental projects. ECES is further described in Reference 1. ECES elements include project management, compliance documentation, engineering support, site work, treatment technologies, decommissioning, and waste disposition. For a complete

description and listing of ECES elements see http://web.em.doe.gov/cost/eces.html. When complete, the Rocky Flats cost and metric data will be available on ECAS.

This paper is divided into four sections following the introduction. The following section discusses the process to collect, analyze, and segregate the Rocky Flats cost and metric data. The next section provides an example developing the factors for a limited portion of the overall Rocky Flats Closure Project – the Industrial Sites Project. This is followed by sections discussing the analysis and future work anticipated for the data collection project.

COST FACTOR DEVELOPMENT PROCESS

Conceptually the process of developing "cost factors" in the format of $/metric unit (e.g., $/sq. ft.) was straightforward – segregate the project into elements of scope, identify the cost and metric values associated with each element, and divide the cost by the metric to produce the "cost factor." The goal was for these cost factors to be suitable for use in a parametric estimate. Implementing the concept proved, as usual, to be more difficult. The key element of the effort was correlating the scope of a specific work element, as described by certain parameters or "metrics," with the funds expended to get that work done. There were a variety of work elements at different levels in the Closure Project Work Breakdown Structure (WBS). All the Closure Project costs and work hours were recorded in the Rocky Flats PIRS accounting database, broken out by WBS elements, charge numbers, department, worker skill type, contract, etc. Although there were some constraints based on the quality of the cost data on which WBS or charge number could be used (as discussed later), a cost was defined in PIRS for each of these scope elements.

Determining the "metric" data was more difficult in that it was first necessary to identify what parameters were both available and would be useful to future users, and then to segregate the metric data in a fashion that could be correlated with the cost data. We decided to focus on metrics that a future estimator would be able to identify from walkdowns and drawing takeoffs at a closure site. These included both quantitative metrics like areas of buildings (or sections of buildings), volume of waste, and area of caps; and qualitative (or discrete) metrics like general contamination level of buildings or type of construction. No metrics were universal, i.e., applied to all types of work. However, groups of metrics could generally be associated with certain types of activities such as facility dismantlement, demolition, and soil excavation for environmental remediation. Various spreadsheets and databases at Rocky Flats had information that could be "mined" for data that could be correlated to specific WBS elements, such as "Sets" of work in plutonium buildings or individual buildings in the Industrial Sites Project.

There were numerous activities associated with closure that did not correlate well with metric data that could be readily obtained by an estimator (i.e., the estimator would not be able to derive the relevant input from facility walkdowns or drawing takeoffs) and were more associated with how the work was planned and executed. These included activities such as project management for decommissioning projects or the overall Closure Site, engineering or nuclear safety support, security forces, general site maintenance, contractor fee, etc. These activities represented the majority of the $4.1 billion Closure cost, and to ignore them and evaluate just the costs that could be coupled with metrics would limit the usefulness of the overall data and make it difficult to arrive at an overall estimate at a different closure site.

The overall approach we used was to correlate all of the Rocky Flats Closure scope performed under the closure contract (February, 2000 through December, 2005) against all of the funds expended during that time. The costs and scope were reasonably definable at the highest levels of the WBS; the effort was to extend the correlation as far down the WBS as possible to develop more specific cost factors. Costs that could be associated with metrics were defined as "direct costs" for this analysis. Costs that could not be

directly associated with metrics were defined as "indirect costs." Using the overall cost versus the overall scope ensured that all costs would be captured in some way.

To display costs for which there is no direct metric, the indirect costs were associated with the direct costs at a given WBS level, such as at the "subproject," "project," or "overall site" level. For example, for the Building 371 Project, direct D&D costs for the "Sets" of gloveboxes and tanks to be dismantled were associated with metrics. Indirect costs for D&D waste inspection would be associated with the 371 Project D&D elements, and no other direct costs. Costs for overall project management would be associated with the Building 371 Project (the next higher level) which included the direct costs of processing of special nuclear material and plutonium residues as well as D&D. Costs for liquid radioactive waste treatment, an activity that the Building 371 Project provided as support to all other Projects, was associated with the overall site costs, i.e., equally distributed across all direct closure costs. The Rocky Flats Closure WBS is discussed in more detail below.

After the constraints imposed by the availability and applicability of metrics had been used to identify prospective scope elements, the costs that had been charged to those elements were examined. The cost collection data quality was found to vary between elements of scope. Although charge numbers were established based on WBS elements of scope, the costs charged to those numbers did not always appear consistent with the actual scope. As an example, the D&D costs for the eleven buildings associate with Building 444, which varied in size from a few hundred to 160,000 sq. ft., had been budgeted by building. The Industrial Sites Project found it impractical to collect costs this way, as workers or materials were often used in different buildings on the same day and were all managed under a single subcontract. Therefore the actual costs showed no charges for the demolition or characterization of some of the smaller buildings, scope that had to have occurred. For the analysis we used the total costs of the Building 444 complex as a single scope element, summing the metrics and costs for all of the individual buildings within their given categories. Thus there was an uncertainty associated with the cost of a given element of scope, as there is with any measured quantity. However, since all of the costs and scopes were rolled up in the WBS, the collective values (such as average characterization cost/sq. ft. for all industrial buildings) was less distorted than the values for lower level WBS elements (such as the characterization cost for a single small building); the data variance indicated the uncertainty.

The Rocky Flats WBS was divided into several major (WBS Level 2) elements identified alphabetically in the PIRS system and shown in Table I. The first four WBS elements (designated A-D) were major plutonium facilities that required stabilization and removal of plutonium special nuclear material, residues, and wastes, dismantlement of gloveboxes and process systems, and demolition of the building and associated structures. The Industrial Sites Project (WBS designation E) included decommissioning and removal of all of the remaining facilities and structures as well as management of a number of Site services such as the fire department and warehouse. The Material Stewardship Project (WBS designation F) included all waste management and disposition, and Site security and related activities. Environmental Restoration costs were collected under WBS designation G. The Site Support Project (WBS designation H) included the engineering and safety support activities, overall site management and project control, regulatory support, etc. Project-specific health, safety, and regulatory activities were part of the scope of the execution projects, WBS designation A-G. WBS designations J, T, and X included the Kaiser-Hill President's office and other Site administration, general overheads and contract fees, work for others, and closeout costs.

The effort to capture the Rocky Flats data applies different metrics and cost breakdowns based on the different projects. Projects A-D were originally planned based on "Sets" of work, with each Set representing an area and its associated process equipment to be size reduced, removed, and packaged as waste, and made available for shipment. The metrics for this "direct" work include room area, glovebox and tank volume, non-process equipment weight, piping length, waste volumes (low-level, transuranic,

etc.), and a "work complexity" factor. Most of the remaining project costs are "indirect" costs that are applied proportionately against the direct costs.

Table I – Rocky Flats Work Breakdown Structure (WBS) at Level 2 ($000)

WBS Letter Designation	Title	Direct Cost	Indirect-Subproj.	Indirect-Project	Indirect-Site	Total Cost
A	Building 371 Project	95,241	127,673	132,042	169,598	524,553
B	Building 707 Project	85,461	57,484	82,695	14,328	239,967
C	Building 771 Project	80,619	23,513	125,855	25,951	255,938
D	Building 776 Project	100,540	55,040	76,825	0	232,406
E	Industrial Sites Project	159,080	108,880	53,248	235,980	557,189
F	Material Stewardship Proj.	364,818	196,749	76,009	242,792	880,368
G	Env. Restoration Proj.	139,788	14,129	0	0	153,916
H	Site Support Project	0	0	0	182,776	182,776
J, T, X	Other Site Costs	0	0	0	1,104,230	1,104,230
Total		1,025,773	583,243	546,674	1,975,654	4,131,344

The Material Stewardship Project direct costs consist of the volumes of waste disposed of and indirect costs associated with waste management and the Site operations. The Environmental Restoration Project had specific metrics of Cap area, IHSS area, volume of waste removed, length of pipe removed and overall area, depending on the scope element. The Site Support Project scope is completely indirect costs at the Site level since there is no way to unambiguously correlate these costs to specific projects or activities. The next section discusses the effort as it relates to the Industrial Sites Project.

INDUSTRIAL SITES PROJECT DATA

The section on Industrial Sites Project Data is divided into three subsections. The first breaks out the costs at a higher level, the second describes in detail the source data and methodology used in correlating the data, and the third provides the data in tabular form along with some explanation of terms.

Industrial Sites Project Data Overview

The Industrial Sites Project scope contained two major components. The first component was those activities necessary to operate and maintain the Site, such as providing utilities (e.g., electricity, water, and sewage treatment), infrastructure (e.g., fire department, emergency preparedness), property (e.g., warehouse, intra-Site transport, and mail), maintenance (e.g., general maintenance, snow removal) and miscellaneous construction. The second component was the decommissioning and removal of all Site buildings and structures not part of the plutonium building project scope. This included the plutonium analytical laboratory (Building 559) with gloveboxes and filter plenums, five large uranium processing buildings substantially contaminated with uranium and beryllium, over 400 smaller facilities, fences, telephone poles, steam piping, road and sidewalks, and some earthwork and grading. The smaller facilities ranged from uncontaminated trailers to facilities that were substantially contaminated with uranium, beryllium, asbestos, and RCRA chemicals. Site facilities were grouped by contamination, with Type 1 facilities essentially uncontaminated (i.e., they could be surveyed and released for commercial-type demolition) and Type 2 facilities that required substantial decontamination or contaminated demolition. Type 3 facilities were "plutonium facilities. The Industrial Sites Project D&D was divided into five "Areas" for management. The overall costs are given in Table II with an additional breakout in Table III that shows the costs of different types of facilities (e.g., trailers, tanks, tents, buildings) and contamination types.

Table II provides some insight into the Industrial Sites Project. Most of the project cost is "indirect" in that it cannot be linked to closure metrics. Even in the D&D portion the indirect costs (WBS Elements EHA-EHF) for a given area vary. The Table II columns on indirect levels and multipliers illustrate the approach to applying indirect to direct costs. Direct costs from Area 1 work elements, for example, would be multiplied by the factor for Area 1 indirect costs (1.665) and also by the Facilities Disposition Project Management (1.02) to account for the total D&D work. A similar approach will eventually be applied to higher levels of indirect costs such as those contributed by the Industrial Site Project and the Overall Site activities. Most of the indirect costs for the Areas were associated with Landlord (i.e., keeping the buildings open, HVAC systems working, etc.) and pre-D&D stabilization of materials (e.g., removal of previously stored waste).

Table II – Industrial Site Project Actual Cost

WBS Level 4	Descriptor	Actual Cost	Indirect Level	Indirect Multiplier
IS Non-D&D				
EAA	Project Management	53,247,944	IS Proj.	
EBA	Site Services Project Mgmt	8,822,667	Site	
EBB	Utilities	51,716,378	Site	
EBC	Infrastructure	38,800,975	Site	
EBD	Property & Logistics	32,392,529	Site	
EBE	Facilities Maintenance and Services	46,322,928	Site	
ECA	Construction Project Mgmt	9,055,069	Site	
ECB	Misc. Construction Projects	2,261,195	Site	
	IS Non-D&D Total	242,619,686		
IS D&D				
EHA	Facilities Disposition Project Mgmt.	7,039,527	IS D&D	1.027
EHB	Area 1 Indirect Costs	47,591,832	Area 1 D&D	1.665
EHB	Area 1 Direct Cost	71,576,208		
EHC	Area 2 Indirect Costs	726,196	Area 2 D&D	1.119
EHC	Area 2 Direct Cost	6,092,030		
EHD	Area 3 Indirect Costs	27,872,092	Area 3 D&D	1.568
EHD	Area 3 Direct Cost	49,055,279		
EHE	Area 4 Indirect Costs	46,607,912	Site	
EHE	Area 4 Indirect Costs	12,389,799	Area 4 D&D	1.666
EHE	Area 4 Direct Cost	18,604,267		
EHF	Area 5 Indirect Costs	13,261,508	Area 5 D&D	1.964
EHF	Area 5 Direct Cost	13,752,699		
	IS D&D Total	314,569,349		
IS Total		557,189,034		

Table III provides a lower level of detail for the Industrial Sites Project D&D costs. The direct costs for each D&D Area were apportioned among the general types of facilities. "Tents" were large fully-enclosed sprung structures used to provide inexpensive climate control or weather protection for waste

Table III – Industrial Sites Project - Direct Cost Breakout

WBS Level 4	Descriptor	Type 1 Facilities	Type 2 Facilities	Type 3 Facilities	Total
EHB	General Building D&D	1,449,625	69,316,371		70,765,996
EHB	Tent D&D		400,075		400,075
EHB	Trailer D&D	410,137			410,137
EHC	General Building D&D	841,078	3,842,625		4,683,703
EHC	Tank D&D		1,371,764		1,371,764
EHC	Trailer D&D	36,563			36,563
EHD	General Building D&D	7,607,109	41,084,596		48,691,705
EHD	Tank D&D		123,727		123,727
EHD	Trailer D&D	239,847			239,847
EHE	559 D&D			15,593,902	15,593,902
EHE	General Building D&D	2,891,028			2,891,028
EHE	Tank D&D				
EHE	Trailer D&D	119,337			119,337
EHF	General Building D&D	9,518,787	1,199,291		10,718,078
EHF	Tank D&D	327,655	1,019,333		1,346,988
EHF	Tent D&D		531,722		531,722
EHF	Trailer D&D	1,155,911			1,155,911
Direct Total		24,823,204	118,889,505	15,593,902	159,080,483

storage or operations. "Trailers" referred to uncontaminated office trailers or pre-engineered buildings. "Tanks" were free-standing tanks, typically for water or process waste. "General Buildings" were free-standing structures large enough to have their own WBS element. A "Building" could be envisioned as nominally greater than 1,000 sq. ft., although a "Building" would often include smaller adjacent structures physically or historically associated with it.

Details of Industrial Sites Data Analysis

The development of the costs shown in all of the tables required the manipulation of large amounts of data to provide unique correlations of costs and metrics and allow appropriate data rollups. The Industrial Sites Project cost data in PIRS consisted of over 64,000 records (managed as lines of data on Excel spreadsheets) with unique actual cost charges in the format shown in the top portion of Table IV. Approximately 45,000 charges were associated with D&D (WBS Elements EHA-EHF). After initial processing to segregate indirect costs and remove charge numbers which contained no actual charges over 18,000 records of cost data remained to be correlated.

The cost data was correlated using Microsoft Access with a database containing building metric data to provide information on the buildings such as gross square feet, building contamination type, and other information to allow for additional analysis if necessary (see the data in Table IV identified as FM Data from the Facility Management Database). The final data development activity involved grouping data and assigning "Direct/Indirect," "Building Category," and "Work Category" designations. This involved manually evaluating each of the approximately 18,000 D&D records, determining whether it was a Direct (i.e., whether it had relevant metrics) or an Indirect cost, what kind of building it was (i.e., Tent, Tank, Trailer, or General Building), and what type of work it was. The work categories – Planning, Characterization, Dismantlement, Decontamination, Pre-Demolition Survey, and Demolition – were usually identifiable from the WBS or Charge Number fields but used inconsistent nomenclature which

Table IV – PIRS Data Format and Example

Field Description	Example Data	Source
Cost Account	EHD	PIRS
Cost Account Description	Area3 Facilities Disposition	PIRS
WBS	EHD152015A3	PIRS
WBS Description	B-444 Dismantlement(Manufacturing)	PIRS
Activity ID	EDD5013	PIRS
Title	B444 Decommissioning Dismantlement	PIRS
Charge Number	EDD54DV3	PIRS
Charge Number Description	444 Dismantlement VIA 3	PIRS
CE	755	PIRS
CE Name	FRINGEBENEFITS	PIRS
Dept	CE11S	PIRS
Dept Title	Health & Safety	PIRS
To Date ACWP Dollars	9,733	PIRS
Building	444	FM Data
FG	20	FM Data
Property Name	Manufacturing Building Depleted Uranium Ops	FM Data
Facility Type	2	FM Data
Bldg Type	Admin-Industrial	FM Data
Building Sq Ft	161,980	FM Data
Footings	Yes	FM Data
Columns-Caissons	No	FM Data
Basement	Yes	FM Data
Floors	3	FM Data
Year Acquired	1953	FM Data
Construction Type	Reinforced Concrete	FM Data
Direct/Indirect	Direct	Assigned
Building Category	General Building	Assigned
Work Category	Dismantlement	Assigned

required manual assessment. In some cases project knowledge was solicited to make specific assignments.

Industrial Site Project Cost and Waste Factors

Table V through Table VIII show specific information on the Industrial Sites Project General Building D&D. The results for Trailers and Tents are shown in Table IX and Table X respectively. Only a few Tanks were decommissioned and the cost per volume varied so dramatically between them that they have not been included in this analysis. The analysis for Building 559, the Plutonium Analytical Laboratory that was a Type 3 building with gloveboxes, was analyzed with the other plutonium buildings and not discussed in this paper.

Table V provides the cost factors from all Type 1 "General Buildings" subdivided by building construction type - masonry, steel frame with masonry exterior, prefabricated (but not "trailers"), reinforced concrete, and steel frame with steel or other siding. The costs are also subdivided by work categories, or task elements involved in D&D – planning, initial characterization, dismantlement, decontamination, pre-demolition survey, and demolition. These categories represented the general

sequence of work, with the dismantlement activity removing as much of the interior equipment as possible to allow the facility surface to be cleaned for unconditional release ("decontamination") and surveyed. Decontamination referred to cleaning of the building surfaces – decontamination of equipment for free release was not cost effective. Although Type 1 buildings have little if any radioactive contamination on building surfaces, the asbestos remediation costs were also considered decontamination, and it is these costs that account for the majority of the decontamination charges for Type 1 buildings. The Subproject Indirect costs reflect the D&D-direct project management costs as well as costs for landlord activities, stabilization of materials, and other pre-D&D activities. Several Building Construction Types were not reported due to insufficient examples or suspect cost information, including concrete pads, wooden structures, freestanding equipment (e.g., large transformers), and unfinished shells. The number of buildings in each of the Building Construction Types listed in Table V and Table VI ranged from three (Masonry Exterior Walls/Steel Frame and Prefabricated/modular) to about forty (Masonry Exterior Walls and Steel Frame).

Table V – Type 1 Building Analysis – Cost Factors

Building Construction Type	Plan-ning	Charact-erization	Dismant-lement	Decon-tamin-ation	Pre-Demo Survey	Demo-lition	Subproject Indirect	Total
Masonry Exterior Walls								
Actual Cost ($)	490,206	1,096,700	2,393,064	3,483,083	253,069	4,683,049	9,485,242	21,884,413
Building Area (Sq. Ft.)	502,715	502,715	502,715	502,715	502,715	502,715	502,715	502,715
Cost/Sq Ft	0.98	2.18	4.76	6.93	0.50	9.32	18.87	43.53
Masonry Exterior Walls /Steel Frame								
Actual Cost ($)	78,893	93,240	364,741	780,342	-	533,657	1,080,524	2,931,398
Building Area (Sq. Ft.)	27,132	27,132	27,132	27,132	27,132	27,132	27,132	27,132
Cost/Sq Ft	2.91	3.44	13.44	28.76	-	19.67	39.82	108.04
Prefabricated/modular								
Actual Cost ($)	1,754	-	126,649	-	9,582	171,521	252,573	562,079
Building Area (Sq. Ft.)	24,944	24,944	24,944	24,944	24,944	24,944	24,944	24,944
Cost/Sq Ft	0.07	-	5.08	-	0.38	6.88	10.13	22.53
Reinforced Concrete								
Actual Cost ($)	232,830	235,424	881,668	53,583	15,961	1,691,252	2,637,157	5,747,875
Building Area (Sq. Ft.)	76,925	76,925	76,925	76,925	76,925	76,925	76,925	76,925
Cost/Sq Ft	3.03	3.06	11.46	0.70	0.21	21.99	34.28	74.72
Steel Frame								
Actual Cost ($)	191,113	835,749	1,038,874	87,400	9,093	2,326,847	3,401,190	7,890,266
Building Area (Sq. Ft.)	253,356	253,356	253,356	253,356	253,356	253,356	253,356	253,356
Cost/Sq Ft	0.75	3.30	4.10	0.34	0.04	9.18	13.42	31.14
Total								
Actual Cost ($)	994,796	2,261,114	4,804,996	4,404,409	287,705	9,406,326	16,856,685	39,016,030
Building Area (Sq. Ft.)	885,072	885,072	885,072	885,072	885,072	885,072	885,072	885,072
Cost/Sq Ft	1.12	2.55	5.43	4.98	0.33	10.63	19.05	44.08

The unusually high cost factors for the Masonry Exterior Walls/Steel Frame type was due to the group having only three buildings and being dominated by one – the Site Steam Plant, which included dispositioning of boilers, external equipment, and substantial asbestos remediation.

Table VI provides the total D&D waste data by Building Construction Type for Type 1 buildings. The waste data, compiled from the Waste and Environmental Management System (WEMS) and the Sanitary Waste databases, identified all waste generated and shipped from the Site. Since the Type 1 buildings are nominally uncontaminated some of the radioactive waste is due to waste stored at the locations that was removed during decommissioning. The biggest individual contributor was the sewage treatment plant, which needed to dispose of treatment sludge as radioactive waste. The unusually large sanitary waste from the Masonry Exterior Walls/Steel Frame group was again due to the dominance of the Steam Plant.

Table VI – Type 1 Building Analysis – Waste Factors

Building Construction Type	Low-Level Waste (CM)	Low-Level Mixed (CM)	RCRA Hazardous (CM)	TSCA-Regulated Waste (CM)	Regulated Non-Hazardous (CM)	Sanitary (Tons)
Masonry Exterior Walls						
Sum of Waste Volume (Weight)	1,202	20	29	1	43	67,461
Building Area (Sq. Ft.)	502,715	502,715	502,715	502,715	502,715	502,715
Volume (Weight)/Sq. Ft.	0.00239	0.00004	0.00006	0.00000	0.00009	0.13419
Masonry Exterior Walls / Steel Frame						
Sum of Waste Volume (Weight)	102	5	-	-	-	19,343
Building Area (Sq. Ft.)	27,132	27,132	27,132	27,132	27,132	27,132
Volume (Weight)/Sq. Ft.	0.00374	0.00019	-	-	-	0.71291
Prefabricated/modular						
Sum of Waste Volume (Weight)	1	-	-	-	-	5,314
Building Area (Sq. Ft.)	24,944	24,944	24,944	24,944	24,944	24,944
Volume (Weight)/Sq. Ft.	0.00002	-	-	-	-	0.21303
Reinforced Concrete						
Sum of Waste Volume (Weight)	119	93	1	23	-	21,824
Building Area (Sq. Ft.)	76,925	76,925	76,925	76,925	76,925	76,925
Volume (Weight)/Sq. Ft.	0.00155	0.00121	0.00001	0.00030	-	0.28371
Steel Framed						
Sum of Waste Volume (Weight)	1,060	118	56	1	1	34,390
Building Area (Sq. Ft.)	253,356	253,356	253,356	253,356	253,356	253,356
Volume (Weight)/Sq. Ft.	0.00418	0.00046	0.00022	0.00000	0.00000	0.13574
Total						
Sum of Waste Volume (Weight)	2,483	236	86	25	44	148,331
Building Area (Sq. Ft.)	885,072	885,072	885,072	885,072	885,072	885,072
Volume (Weight)/Sq. Ft.	0.00281	0.00027	0.00010	0.00003	0.00005	0.16759

Table VII provides an analysis similar to that shown in Table V but for Type 2 buildings. It provides the cost factors from all Type 2 "General Buildings" subdivided by Building Construction Type and work category. There were between 10 and 18 buildings represented in each Building Construction Type; one additional category, Wood Frame, was not included since there was only one example.

Table VII – Type 2 Building Analysis – Cost Factors

Building Construction Type	Planning	Charact-erization	Dismant-lement	Decon-tamin-ation	Pre-Demo Survey	Demo-lition	Subproj. Indirect	Total
Masonry Exterior Walls								
Actual Cost ($)	1,411,451	447,654	12,037,255	8,540,453	393,436	4,877,663	18,194,674	45,902,586
Building Area (Sq. Ft.)	187,125	187,125	187,125	187,125	187,125	187,125	187,125	187,125
Cost/Sq Ft	7.54	2.39	64.33	45.64	2.10	26.07	97.23	245.30
Reinforced Concrete								
Actual Cost ($)	2,487,291	998,026	34,162,251	34,648,936	1,588,427	12,692,225	53,983,085	140,560,241
Building Area (Sq. Ft.)	514,540	514,540	514,540	514,540	514,540	514,540	514,540	514,540
Cost/Sq Ft	4.83	1.94	66.39	67.34	3.09	24.67	104.92	273.18
Steel Framed								
Actual Cost ($)	4,660	112,502	405,515	128	13,966	620,546	886,237	2,215,682
Building Area (Sq. Ft.)	34,474	34,474	34,474	34,474	34,474	34,474	37,346	37,346
Cost/Sq Ft	0.14	3.26	11.76	0.00	0.41	18.00	23.73	59.33
Total								
Actual Cost ($)	3,903,402	1,558,182	46,605,022	43,189,517	1,995,829	18,190,435	73,063,995	188,678,509
Building Area (Sq. Ft.)	736,139	736,139	736,139	736,139	736,139	736,139	739,011	739,011
Cost/Sq Ft	5.30	2.12	63.31	58.67	2.71	24.71	98.87	255.31

Table VIII provides the total D&D waste data by building construction category for Type 2 buildings. The waste values identified in Table VIII for the Steel Frame buildings underreport the waste quantities that were generated during their D&D because many of these buildings were filter plenums associated with larger Reinforced Concrete buildings. The WEMS system data did not reliably distinguish between which waste was generated from the D&D of the main buildings and the associate buildings. The lower sanitary waste for the Reinforced Concrete Building Construction Type is due to one of the larger buildings being imploded with the rubble remaining in place in the building basement and not requiring disposal as sanitary waste.

Table VIII – Type 2 Building Analysis – Waste Factors

Building Construction	Trans-uranic Waste (CM)	Low-Level Waste (CM)	Low-Level RCRA Mixed (CM)	Low-Level TSCA Mixed (CM)	RCRA Hazard-ous (CM)	TSCA-Regu-lated Waste (CM)	Regu-lated Non-Hazard-ous (CM)	Sanitary (Tons)
Masonry Exterior Walls								
Sum of Waste Volume (Weight)	4	31,244	97	170	5	24	51	25,932
Building Area (Sq. Ft.)	187,125	187,125	187,125	187,125	187,125	187,125	187,125	187,125
Volume (Weight)/Sq. Ft.	0.00002	0.16697	0.00052	0.00091	0.00003	0.00013	0.00027	0.13858
Reinforced Concrete								
Sum of Waste Volume (Weight)	0.4	68,689	781	21	126	3	34	48,033
Building Area (Sq. Ft.)	514,540	514,540	514,540	514,540	514,540	514,540	514,540	514,540
Volume (Weight)/Sq. Ft.	0.00000	0.13350	0.00152	0.00004	0.00024	0.00001	0.00007	0.09335
Steel Framed								
Sum of Waste Volume (Weight)	-	3	-	-	0	-	-	506
Building Area (Sq. Ft.)	34,474	34,474	34,474	34,474	34,474	34,474	34,474	34,474
Volume (Weight)/Sq. Ft.	-	0.00008	-	-	0.00001	-	-	0.01467
Total								
Sum of Waste Volume (Weight)	5	99,936	878	191	131	27	84	74,471
Building Area (Sq. Ft.)	736,139	736,139	736,139	736,139	736,139	736,139	736,139	736,139
Volume (Weight)/Sq. Ft.	0.00001	0.13576	0.00119	0.00026	0.00018	0.00004	0.00011	0.10116

Table IX shows the Site trailer decommissioning costs and areas. The actual costs charged to the individual trailer numbers varied significantly; for a group or cluster of trailers often all of the costs were charged to the charge number originally designated for one trailer. While satisfactory for purposes of project control the charging practices made it impossible to distinguish between costs by trailer. Also notable is that the indirect costs apportioned based on direct project cost and accounting for the project management and landlord charges totaled approximately the same as the direct costs. No dismantlement charges were incurred because there was no equipment in the trailers that required disassembly.

Table IX – Trailer Analysis Data – Cost Factors

Trailers	Planning	Character-ization	Dismantle-ment	Demolition	Subproject Indirects	Total
Actual Cost ($)	122,625	262,543		1,630,627	1,679,881	3,695,676
Building Area (Sq. Ft.)	354,468	354,468		354,468	354,468	354,468
Cost/Sq Ft	0.35	0.74		4.60	4.74	10.43

About 15, 200 tons of sanitary waste were generated during trailer D&D for a generation factor of about 0.043 Tons/Sq. Ft. About 46 cubic meters of non-radioactive regulated waste were attributed to trailer D&D. Note the absence of decontamination and pre-demolition survey costs in that no decontamination was required of the clean structures and that the initial characterization was of sufficient rigor to demonstrate that the trailers could be released unconditionally.

The most notable item from the data in Table X is the absence of planning charges indicating that the planning effort was performed in conjunction with other closure activities. Since the Tents were all used for waste storage and processing, and hence were Type 2 facilities, there was a substantial characterization cost.

Table X – Tent Analysis – Cost Factors

Tents	Planning	Character-ization	Dismantle-ment	Demolition	Subproject Indirects	Total
Actual Cost ($)		171,601	101,405	658,791	799,653	2,098,416
Building Area (Sq. Ft.)		155,622	155,622	155,622	155,622	155,622
Cost/Sq Ft		1.10	0.65	4.23	5.14	13.48

About 12,100 tons of sanitary waste were generated during the D&D of the tents and the pads on which they were located (of which less than 20% was due to the tent structures and associated equipment) for a generation factor of about 0.078 Tons/Sq. Ft. While it is likely that some small amount of radioactive waste was generated during the D&D of the tents it was not possible to distinguish the D&D radioactive waste from the much greater quantity of radioactive waste generated by the waste operations activities.

DISCUSSION

The tables in the section above provide average factors to estimate costs that would be incurred and waste that would be generated during the D&D of buildings similar to those of the Industrial Sites Project at the Rocky Flats Site. The building costs and wastes were segregated by their type of construction and by their level of contamination. The construction category is an indication of both a building's operational history and of its demolition difficulty. The designation of buildings as having either negligible radioactive contamination (Type 1) or significant non-plutonium radioactive contamination (Type 2), while somewhat an artifact of the Rocky Flats regulatory regime, also reflects the reality that even modest levels of contamination in buildings impose significant additional waste management and characterization costs. The three metric types, Building Construction Type, Building Type, and building area (in square feet), are all readily obtainable elements during an initial estimate or validation exercise. The provision of average waste quantities per area for the building types allows approximation of waste management throughput and costs. The cost factor data presented in this paper should be broadly applicable to other closure site estimates because the Industrial Sites Project had the largest variety of building of types to be decommissioned and many of these types will be similar to those at other closure sites.

While the averaging process is necessary to distill the large quantities of data into useful information, of necessity it filters out information on the particular features of an individual building or activity that caused it to cost substantially more or less than the average. There was a considerable variance in the average costs and waste generation per area within the population of a Building Construction Type. Part of this variance is caused by charging discrepancies and project control practices, such as the lack of changes for planning for the Tent D&D activities – work packages and engineering were required and were done but not charged to those accounts. A larger part of the variance reflects the inability to capture all of the factors that contribute to the cost of executing the activity scope using just three metric types, and that more information is necessary. For specific cases where the costs per unit area were clearly inappropriate project participants were contacted and those cases corrected.

One way to address the problem is to provide more data. The ECAS system will allow documents to be inserted in its Oracle database that will provide additional definition of scope for selected activities. However, this can only partially remedy the problem since information to address these questions was never systematically compiled and there are limitations to the detail available to support cost factor

development after a project is complete. If there is an ongoing need to collect this type of information it will need to be part of the formal project documentation process that will specify causes of high and low cost and/or waste factors (in addition to the Project Management Review project control-type information) to avoid having to rely on anecdotal information or interpret between conflicting memories and speculations.

One of the factors that was not analyzed in this paper is the cost of waste management and disposal. The costs identified in the tables do not include these costs. While the cost of sanitary disposal is a non-trivial but not overwhelming factor in the overall D&D cost, the cost of regulated waste management and disposal, and particularly low-level waste for the Type 2 facilities, is very significant.

The cost of waste disposal is a particular issue in addressing the method of building demolition. A building could be decontaminated to unrestricted release, surveyed, demolished, and disposed of as sanitary waste or recycled concrete, which would result in a relatively low waste disposal cost. A variant of this approach was to decontaminate the building and implode it into its basement to use its concrete as fill. Alternatively the building could be less rigorously decontaminated, demolished, and the building rubble disposed of as radioactive waste to a licensed disposal facility, incurring a much greater disposal cost. Of the five major process buildings demolished by the Industrial Sites Project (not including Building 559), two were contaminated demolitions, two were decontaminated and disposed of as sanitary waste, and one was imploded. The analysis process essentially averaged together the three demolition approaches, which may be an advantage in a situation where the demolition method is undetermined but also eliminates potentially valuable information. The cost of waste disposal will be addressed in the ECAS database development.

The development of the indirect costs factors also results in a loss of information. In particular, it might be useful to be able to identify cost factors for Project Management, Landlord (e.g., surveillance and maintenance, operation of ventilation and liquid waste systems, etc.), and "Stabilization and Hazards Removal" – essentially deactivation, removal of stored wastes, etc. While the process would have been technically feasible it would have required identification and compilation of additional metrics, such as duration of the Landlord period and quantities of previously stored waste, and would have been additionally subject to the uncertainties associated with charging irregularities.

NEXT STEPS

The results described in this paper represent only a portion of the data being collected and consolidated in the Rocky Flats cost factor development effort. Cost data that addresses the individual buildings in the Industrial Sites Project is being collected and analyzed to provide a better level of resolution on costs per building and to identify additional potential metrics. Additional indirect costs are being analyzed to allow them to be used as factors for direct activities allowing the buildup to total project and site costs. The costs of waste management are being analyzed to identify the cost elements associated with staging, characterizing, shipping, and disposing of the Closure Project waste by waste type. The Plutonium facilities (WBS descriptors A-D) are being analyzed to provide detailed cost factors by Set area, waste volumes, and additional appropriate metrics.

Another major area of effort is the translation of this cost data into the ECES format to allow the most effective use of the ECAS database. Since the Rocky Flats WBS was not set up to be consistent with the ECES format it will not be possible to completely translate Rocky Flats actual costs unambiguously into the lowest ECES categories. However, since ECES is also a "tree" structure we are continuing to evaluate ways to correlate the Rocky Flats and ECES cost data at a level in which we have confidence.

Finally, the eventual goal of this overall effort is to have all of the actual Rocky Flats cost and metric data available in ECAS for public access. The ECAS will have most of the individual data-points developed for this paper, including some of the un-averaged building data. It will also include text from documents such as the plutonium building Decommissioning Operations Plans with detailed information on the Set scope. This would allow users to evaluate the scope of particular WBS elements for similarities to work that they were estimating and using the cost and metric data from those WBS elements in ways that best fit their needs.

REFERENCES

1. "Standardized Cost Structure for the Environmental Industry," Bryan Skokan, Dan Melamed, Karen Guevara, Pramod Mallick, George Bierman, Harold E. Marshall, WM'06 Proceedings.