

DESIGNING AND IMPLEMENTING A LIFE-CYCLE COST MODEL FOR FIRST-OF-A-KIND BUILDING DECOMMISSIONING

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ABSTRACT

Over the past year, an intensive effort has been undertaken to improve the basis and accuracy of the out year decommissioning cost estimates for the closure of the U.S. Department of Energy's (DOE) Rocky Flats Environmental Technology Site (RFETS or Rocky Flats). Decommissioning activities represent a substantial share of the total estimated life-cycle cost for closing the facility. In addition, decommissioning of many of the buildings at Rocky Flats, particularly the plutonium production and recovery facilities, are first-of-a-kind projects. The uniqueness of these projects pose substantial challenges in terms of estimating the costs, duration, and technical outcomes. The Facility Disposition Cost Model (FDCM) has been developed to generate an order-of-magnitude, life cycle cost estimate for decommissioning all facilities at the RFETS. A standard work breakdown structure (WBS) for decommissioning activities provides the organizing framework for the estimate. The FDCM relies primarily upon actual, early cost experience from decommissioning facilities at Rocky Flats. When actual Rocky Flats experience is not available, the model uses actual cost experience or bottom up estimates from comparable government and commercial facilities. The quantities included in the model are primarily based on DOE's Facility Information Management System (FIMS). Given the expected complexity and duration of the decommissioning effort, the FDCM includes a detailed cost uncertainty analysis to identify the necessary amount of contingency. The Basis of Estimate Software Tool (BEST) provides the electronic framework for organizing, summarizing, and reporting the estimate.

INTRODUCTION

The Rocky Flats Environmental Technology Site (RFETS) is a former nuclear weapons facility located approximately 16 miles northwest of Denver, Colorado. The site is comprised of approximately 700 facilities and buildings. These facilities/buildings range in size from small, freestanding tanks to massive process buildings. There are five primary types of structures at Rocky Flats: buildings, trailers, tents, tanks, and other facilities. Currently, there are 264 buildings, 119 trailers, 11 tents, 257 freestanding or underground tanks, and 40 other facilities. The other facilities include towers, pads, slabs, stacks, and pipelines. All of the facilities/buildings at Rocky Flats can also be classified according to their building type per the Rocky Flats Cleanup Agreement (RFCA). Type 1 facilities/buildings are those with no contamination, i.e., clean facilities. Type 2 facilities/buildings have no significant contamination but require some decontamination. Type 3 facilities/buildings have significant contamination, especially plutonium, and require large-scale decontamination, dismantlement, and demolition. Currently, there are 554 Type 1 facilities, 130 Type 2 facilities, and 7 Type 3 facilities.

The Department of Energy is currently participating in discussions with the community to determine when it will be appropriate to make long-term stewardship decisions and what the

future use of the site should be. However, for planning purposes, the current assumption is that all of the facilities will be decontaminated (where necessary), dismantled, and demolished over the next decade. This massive undertaking requires exceptional planning, including the development of accurate and reliable life cycle cost estimates. The Facility Disposition Cost Model (FDCM) has been developed to assist site planners in developing, organizing, and tracking life-cycle decommissioning cost estimates.

The architecture of the Facility Disposition Cost Model addresses the breadth and magnitude of facilities/buildings at RFETS. A standard work breakdown structure (WBS) for decommissioning activities provides the organizing framework for the estimate. The FDCM relies primarily upon actual cost experience from decommissioning facilities at Rocky Flats. These actual costs are converted into unit costs and form the basis for estimating the costs of the other facilities/buildings. When actual Rocky Flats experience is not available, the model uses actual cost experience or bottom up estimates from comparable government and commercial facilities. The quantities included in the model are primarily derived from the Facility Information Management System (FIMS).

The purpose of this paper is to describe the architecture of the FDCM and discuss design and implementation issues. The first section outlines the framework of the model, the second section describes the key features of the model, the third section discusses model verification and validation issues, and the final section proposes future improvements to the model.

MODEL FRAMEWORK

The FDCM estimates the costs associated with the decommissioning of buildings and facilities at the Rocky Flats Environmental Technology Site (RFETS). The FDCM is a parametric model based upon empirical data. In a parametric model, all of the buildings and facilities are classified into different types. Each building is assumed to be typical, with all requirements and characteristics common to all other buildings of that type. Since all buildings are atypical in some sense, some adjustments are made to incorporate special features or characteristics (such as gloveboxes, tanks, and type of construction). The model relies upon the best currently available information on the physical dimensions of the facilities/buildings at RFETS and, to the extent possible, actual RFETS decommissioning cost experience.

The model generates an order-of-magnitude estimate given the level of detail incorporated in the model. At this stage in the estimating process, only conceptual, summary data are available on the quantities associated with the decommissioning effort. In addition, unit costs are uniformly applied at a summary level. While some adjustments are made for specific facilities, preliminary scopes of work have not been developed and design of the decommissioning effort has not started on most of the facilities. The American Association of Cost Engineers (AACE) assumes that the actual cost of a project will fall within +50% and -30% of an order-of-magnitude estimate.

MAJOR FEATURES OF THE MODEL

The model development effort followed a traditional process. The major steps in this process included:

- Identify Key Assumptions
- Establish the Work Breakdown Structure
- Classify the Facilities and Buildings

- Collect Physical Information on the Facilities/Buildings
- Identify Unit Costs and Resources
- Schedule the Projects
- Identify and Quantify Project Uncertainties
- Load Information into an Automated Software Package
- Continue to collect additional, actual cost data and revise model

This section of the paper describes each of these steps in more detail. Issues related to the validity of the model are discussed in the next section.

Assumptions

Important assumptions were identified early in the model development process to bound the model. Other assumptions were established during the course of developing the model. The model was built using the following major assumptions.

- All costs are in unburdened (direct), constant 1999 dollars. No escalation has been applied to the estimate. Escalation is applied when the estimates are incorporated into the site baseline.
- The period of performance is from FY99 to completion of site decommissioning activities.
- No learning curve unit cost reductions are incorporated in this version of the model. A proposed approach for incorporating learning has been developed and will be incorporated in a future version of the model. Minor adjustments were made to actual unit costs to account for one-of-a-kind or unusual activities not likely to occur in the future.
- All decommissioning activities are conducted in accordance with existing RFETS practices and Site labor agreements.
- The required Site infrastructure will be in place to support all decommissioning activities. No funding constraints are assumed in developing the schedule.
- Current technologies will be sufficient for completing all decommissioning activities.
- The Facility Information Management System (FIMS) database is used as the source for the universe of facilities/buildings at RFETS and basic facility/building parameters, e.g., location, area, etc. The following facilities, which were included in the FIMS, were excluded from this model:
 - Slabs, tunnels, valve vaults, and pads are not included and are the responsibility of the environmental restoration program.
 - Stacks, tanks foamed in place, cooling towers, and clarifiers were excluded from the model.
- The Contaminated Area (CA) data were determined by the Radiological Engineering group and presented to DOE in an RFETS Radiological Areas Site-Wide report. The areas reported in this report are used as the official source for defining the CA areas.
- The proposed acquisition strategy assumes that when work is subcontracted, a lump sum (fixed price) contract will be let to the subcontractor. The site integration contractor team will complete all decommissioning planning and engineering, project management, and support services. All characterization, site preparation, and demolition/disposal work will be subcontracted. For decontamination, all asbestos work will be subcontracted. The site integration contractor team will perform all other decontamination work. In non-contaminated areas, all dismantlement activities will be subcontracted. In contaminated areas, the site integration contractor team will complete all dismantlement work.
- Adjustments are included to account for economies of scale for multistoried buildings. These economies are based on the assumption that increasing the area of a building by adding a second floor does not double the cost of most of the decommissioning elements

- A distinction is made between trailers install before and after 1989. Since the site ceased production in 1989, trailers installed after 1988 have not been exposed to the same levels of contamination as trailers installed prior to 1989. The costs for decommissioning trailers have been adjusted accordingly.

Work Breakdown Structure

A standard work breakdown structure (WBS) was developed to organize the estimate. The decommissioning WBS is a component of the RFETS sitewide WBS. The FDCM uses a standard work breakdown structure (WBS) to organize the cost estimate (see Table 1 below). All decommissioning projects are planned in compliance with applicable and relevant internal and external requirements in recognition of end state and at a commensurate level of detail using a graded approach. A graded approach to planning recognizes such factors as the importance to safety, environmental/regulatory compliance, current level of knowledge, safeguards and security, programmatic importance, magnitude of the hazard, financial impact, and other facility or project specific requirements. The generic WBS is adjusted, as appropriate, to recognize the graded approach and project specific needs and interests.

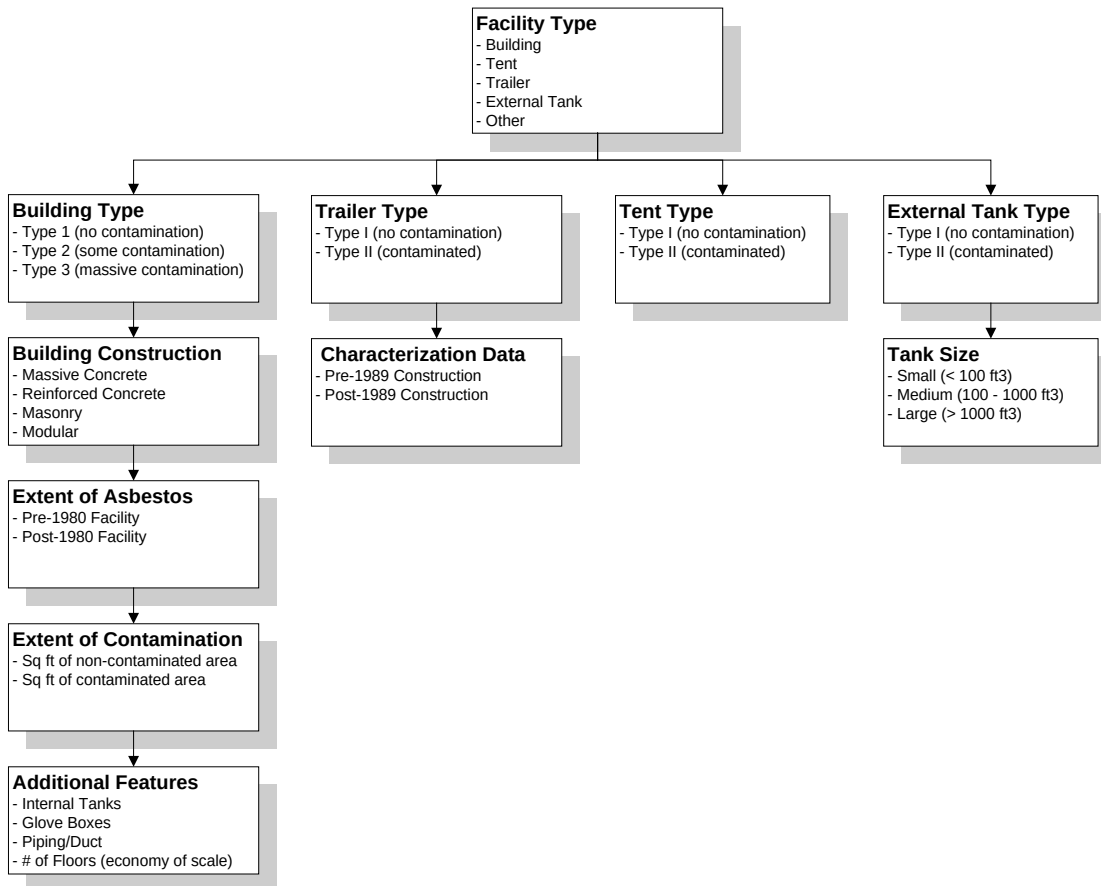
Table 1
Work Breakdown Structure

WBS Element	Description
1.0	Decommissioning Planning and Engineering
2.0	Characterization
3.0	Site Preparation
4.0	Decontamination
5.0	Dismantlement
6.0	Demolition and Disposal
7.0	Project Management
8.0	Support Services

Classification of Facilities and Buildings

The facilities and buildings were classified into different types to standardize the estimating process. The Rocky Flats Environmental Technology Site (RFETS) is comprised of approximately 700 facilities/buildings. These facilities/buildings range from small tanks to massive process buildings. A classification scheme, which is shown in Figure 1, provides the basic framework for organizing and describing all of the facilities/buildings at RFETS. First, all facilities/buildings are classified according to structure. There are five different types of structures: buildings, trailers, tents, tanks, and other facilities. Currently, there are 264 buildings, 119 trailers, 11 tents, 257 tanks (not in buildings), and 40 other facilities. The other facilities, which have been excluded from this version of the model, include towers, pads, slabs, stacks, and pipelines.

FIGURE 1
Facility/Building Classification Scheme



Second, all of the facilities/buildings are classified according to their building type per the Rocky Flats Cleanup Agreement (RFCA). Type 1 facilities/buildings are those with no significant contamination, i.e., clean facilities. Type 2 facilities/buildings have no significant contamination but require some decontamination. Type 3 facilities/buildings have significant contamination, especially plutonium, and require large-scale decontamination, dismantlement, and demolition. Currently, there are 554 Type 1 facilities, 130 Type 2 facilities, and 7 Type 3 facilities. Table 2 summarizes the estimated total area (in square feet) of the facilities by structure and type.

Table 2
Estimated Area (sq. ft.) of Facilities/Buildings by Structure and Type

Facility	Facility Type			Total
	Type 1	Type 2	Type 3	
Buildings				
Modular	156,949	55,035	0	211,984
Masonry	664,181	809,060	139,610	1,612,851
Reinforced	29,125	80,610	857,462	967,197
Massive	0	60,275	0	60,275
Subtotal	850,255	1,004,980	997,072	2,852,307
Trailers	373,344	3,200	0	376,544
Tents	0	159,900	0	159,900
Tanks	7,303	0	0	7,303
Other	74,381	4,000	0	78,381
Total	1,305,283	1,172,080	997,072	3,474,435

Physical Information on the Facilities/Buildings

The best available, current facility and building data were collected from several sources. The list of facilities and associated basic data (footprint, total area, etc.) is from the Facility Information Management System (FIMS). FIMS serves as the official repository of building and facility information at RFETS. Existing Kaiser-Hill databases are the source of additional information on the number and quantity of gloveboxes, piping/duct, tanks, and other ancillary components.

Unit Costs and Resources

Actual RFETS decommissioning costs were collected and normalized for use in the model. The FDCM team gathered cost information from various completed projects or activities at RFETS. When actual RFETS costs were not available, the model uses costs based on detailed bottom up estimates or on actual costs from comparable government or commercial decommissioning projects. In some cases, the FDCM uses factors of actual cost information to account for differences in types of facilities. These factors are based on actual experience or on detailed analyses. The major sources of information by type of building are listed below.

- Buildings: Actual costs were gathered from on going work in Building 371 and Building 865 and the decommissioning of Buildings 123 and 889. Factors were developed to address various levels of contamination and the type of building construction.
- Gloveboxes: Costs are based on actual cost experience from dismantling 42 gloveboxes in Building 779.
- Piping and Ducts: Costs for the removal of contaminated process piping and duct are based on a detailed, bottom up estimate developed for the Automated Remedial Action Model (ARAM) developed by Pacific Northwest National Laboratory.
- Tanks (external): The cost basis for tank decommissioning is actual data from decommissioning Tank 221, Tank 224, and a small acid tank.
- Trailers: The basis of the cost estimate for trailers is the actual cost data collected for decommissioning the T690 trailers.
- Tents: The D&D of tents are estimated based on the bids that have been received for a recent tent decommissioning project.

Scheduling the Projects

A schedule for sequencing the projects was completed. Overall, the schedule is based upon risk reduction at the site. More emphasis was placed on the removal of plutonium from the site and the disposition of buildings containing plutonium. The schedule is logic driven and constrained by available annual funding in the initial years of the project. The work logic identifies the need for some of the nuclear facilities to remain in use for stabilizing and repackaging special nuclear materials and plutonium contaminated residues (stored byproducts of the plutonium production era). Additionally, some infrastructure buildings (e.g., steam plant) are required to remain in service to support the nuclear facilities.

Uncertainty Analysis

Cost, schedule, and technical uncertainty represent a large component of the FDCM estimate. This uncertainty is driven by a number of important factors that traditionally contribute to cost growth, schedule slip, and poor technical performance in large-scale projects.

- Complexity: The decommissioning program will address almost 700 facilities/buildings over a ten year period.
- First-of-a-Kind: The decommissioning of the Type 3 buildings will be the first large-scale decommissioning of plutonium contaminated facilities in the United States
- Poor Project Definition: Little characterization has been completed on the majority of the site's facilities. Consequently, significant portions of the overall scope of work for decommissioning is not well defined.

Because of the large degree of uncertainty surrounding these activities, two uncertainty estimating approaches were evaluated. The first approach uses the contingency analysis method currently utilized for other projects in the site baseline. This method uses a parametric approach for ranking the technical, cost, and schedule uncertainty of each project. Each rating is assigned an expected contingency percentage based on historical experience. The second approach uses range estimating. This method assigns an uncertainty range around the unit costs. In this case, these ranges were determined by a panel of decommissioning specialists for each major decommissioning activity for each building type. A specialized software package applied Monte Carlo to sample across these ranges and summarized the results.

Use of the Basis of Estimate Software Tool (BEST)

All of the data developed for the FDCM were loaded into the Basis of Estimate Software Tool (BEST). BEST serves as the primary repository for the FDCM data and assists site planners in collecting, storing, and retrieving Facility Disposition Cost Model information. BEST is built in Microsoft Access and is comparable to a number of off-the-shelf activity resource estimating packages. Kaiser Hill, the site integration contractor, uses BEST extensively to support project planning at RFETS. BEST was introduced to the site in 1996 and serves as the primary cost estimating tool for Kaiser Hill.

BEST is part of a client/server system. A central database runs on a server while the client program (BEST) runs on the client's personal computer. BEST provides an easy-to-use interface to the server database. Multiple users can access the server data simultaneously. BEST provides a mechanism to create, modify, and retrieve activity cost estimates and related data. For each activity, any number of line items can be defined. (Line items are tasks within an activity. For each line item, any number of bases of estimates (BOEs) can be established.

Resources and factors, which are used to compute resource quantities, are easily identified. Costs for each line item of an activity are automatically rolled-up to the activity. BEST provides several types of activity reports.

MODEL VERIFICATION AND VALIDATION

The FDCM is currently undergoing verification and validation. The FDCM team is investigating actual decommissioning cost experience from other DOE sites and the commercial sector. These benchmarks will be used to improve the accuracy of the FDCM and to identify areas for improving the execution of decommissioning work at RFETS.

Unfortunately, direct cost comparisons between Rocky Flats and other sites are very difficult and potentially deceptive. Normalizing the costs such that an “apples-to-apples” comparison can be made requires a great deal of effort. From an accounting perspective, the costs must be adjusted for escalation/inflation, burdens/overhead, overtime, work stoppages, and any unexpected conditions. Technically, comparable scopes need to be benchmarked. From an execution perspective, costs can vary substantially due to contracting approach, health/safety requirements, environmental requirements, security requirements, and other special requirements.

A cursory benchmarking effort, which did not properly normalize the costs, shows that the unit cost estimates used in the FDCM are within a reasonable range of actual experience. These benchmarks are based on comparable actual and estimated decommissioning cost experience at other DOE sites. The results of this comparison are shown in Table 3.

Table 3
Summary Results of Benchmarking Analysis

Facility Basis	Type 1 (\$/ft ²)	Type 2 (\$/ft ²)	Type 3 (\$/ft ²)
DOE Benchmarks	\$32 - \$83	\$91 - \$637	\$217 - \$1,455
FDCM	\$85 - \$132	\$180 - \$325	\$243 - \$371

FUTURE ENHANCEMENT TO THE MODEL

A number of improvements to the model are underway. The next revision of the model is expected in March 1999. The new version will incorporate many of the improvements identified below.

- **Incorporate Learning into the Model:** Earlier iterations of the FDCM incorporated learning. Given the large number of buildings to be decommissioned and the time period over which this work will take place, some learning should be incorporated in the model.
- **Improve the Unit Cost Estimates for Different Building Types:** As RFETS decommissions additional facilities, actual cost information will be available to improve the basis of the unit cost estimates. However, in the short term, alternative approaches can be taken to improve the basis of these estimates:
- **Learn from Benchmarking Data from Other DOE Sites:** Notwithstanding the difficulties outlined above on normalizing benchmarking data, additional supporting data from other sites could greatly improve the basis and confidence in these unit cost estimates. Preliminary research suggests the unit cost estimate for Type 1 buildings may be high in comparison with other sites. A focused benchmarking effort with a small number of sites could greatly improve the basis of the estimates.

- **Establish “Typical” Bottom Up Estimates for Each Facility Type:** Another approach is to develop “typical” estimates for the different building types. These more detailed estimates should be built using expected resources and costs for RFETS. Current efforts to develop detailed estimates for buildings (e.g., Building 771) could serve as a takeoff for these “typical” estimates.
- **Improve the Quantity Estimates for Piping/Duct and Internal Tanks:** The results of the current model suggest a great deal of costs are driven by dismantling process piping and ducts in contaminated buildings. Furthermore, tanks located inside buildings, which were not included in this version of the model, could add a substantial amount of cost to the dismantling effort. The methods for estimating the quantities of both piping/duct and internal tanks should be improved. Walkdown data on the quantities of piping and duct may be available for all of the Type 3 facilities. A database of all tanks on site is also available and should be reviewed for use in future versions of the model.
- **Improve the Cost Estimating Method for External Tanks:** The current method for estimating the cost of external tanks relies upon three RFETS data points. Fortunately, a large number of tanks have been removed within the DOE complex and at other comparable industrial sites. One possibility is to establish three classes of tanks (small, medium, large) and build a conceptual estimate for each type. Data from other DOE sites or industrial sites could provide additional basis for the estimates.
- **Immediately Establish a Sitewide Process for Collecting Actual Decommissioning Cost Data:** Efforts are underway to establish a standard code of accounts (based on the WBS) for collecting actual cost information. A standard format for collecting cost is necessary for a number of reasons. First, the opportunity for learning is greater if projects can be compared on an equivalent basis. Second, the ability to incorporate actual cost information into the FDCM is greatly enhanced with a standard collection format. Third, estimates developed with recent, actual cost information are likely to be more accurate.