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COST ESTIMATING FOR CERCLA REMEDIAL ALTERNATIVES A UNIT COST METHODOLOGY

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Cost Estimating for CERCLA Remedial Alternatives: A Unit Cost Methodology

1. INTRODUCTION

The United States Environmental Protection Agency (EPA) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final*, dated October 1988 (EPA 1988) requires a detailed analysis be conducted of the most promising remedial alternatives against several evaluation criteria, including cost. To complete the detailed analysis, order-of-magnitude cost estimates (having an accuracy of +50 percent to -30 percent) must be developed for each remedial alternative. This paper presents a methodology for developing cost estimates of remedial alternatives comprised of various technology and process options with a wide range of estimated contaminated media quantities. In addition, the cost estimating methodology provides flexibility for incorporating revisions to remedial alternatives and achieves the desired range of accuracy.

It is important to note that the cost estimating methodology presented here was developed as a concurrent path to the development of contaminated media quantity estimates. This methodology can be initiated before contaminated media quantities are estimated. As a result, this methodology is useful in developing cost estimates for use in screening and evaluating remedial technologies and process options. However, remedial alternative cost estimates cannot be prepared without the contaminated media quantity estimates.

In the conduct of the feasibility study for Operable Unit 5 at the Fernald Environmental Management Project (FEMP), fourteen remedial alternatives were retained for detailed analysis. Each remedial alternative was composed of combinations of remedial technologies and processes which were earlier determined to be best suited for addressing the media-specific contaminants found at the FEMP site, and achieving desired remedial action objectives.

2. METHODOLOGY

To develop remedial alternative cost estimates, the methodology described in the following sections was developed. Figure 1 provides a graphical representation of the methodology.

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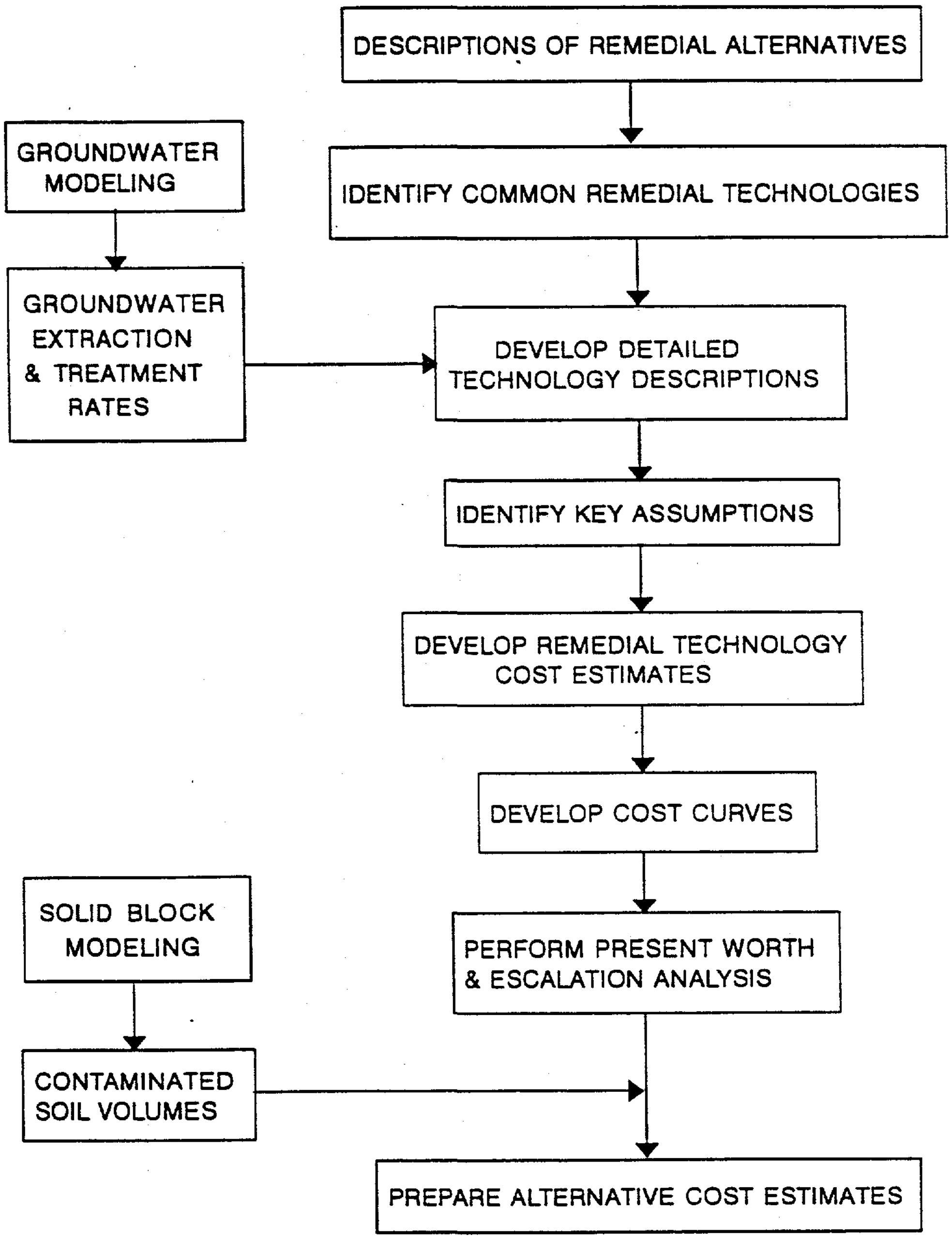

FIGURE 1 - COST ESTIMATING METHODOLOGY FLOW DIAGRAM

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2.1 Identify Common Remedial Technologies

A review of the retained remedial alternatives revealed there were a number of remedial technologies which were common to two or more remedial alternatives. These remedial technologies comprise the building blocks of the remedial alternatives.

The following common remedial technologies were identified:

- Contaminated soil surveys
- Contaminated soil excavation
- Soil washing (physical separation/chemical extraction)
- Off-site disposal of contaminated soil and process wastes
- Stabilization of contaminated soil and process wastes
- Consolidation of contaminated soil in an on-property area
- On-property disposal of contaminated soil and process wastes
- Backfill of excavated areas
- Long-term environmental monitoring
- Groundwater extraction
- Groundwater and wastewater treatment
- Temporary storage of contaminated soil and process wastes

Technology boundaries were defined to prevent overlap and duplication of costs. As an example, the first remedial technology started with the verification of the extent of soil contamination and ended with the loading of contaminated soil into trucks or boxes for transportation.

2.2 Develop Detailed Technology Descriptions

Each remedial technology had to be better described in order to develop order-of-magnitude cost estimates. A detailed engineering description of each remedial technology was developed based upon the potential remedial action objectives for each contaminated media, assumed contaminated soil quantities, results of groundwater modeling, general information about FEMP activities, and general industry and engineering practices. As a minimum, each engineering description included preliminary calculations, process flow diagrams, equipment arrangements and sizes, site layouts, and operating philosophies. The detailed technology descriptions provided the engineering basis for developing the component cost estimates.

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2.3 Identify Key Assumptions

Key assumptions were made to establish a consistent approach to developing the technology cost estimates. The assumptions addressed such key issues as:

- Remediation start dates
- Operating periods
- Contract types
- Engineering costs
- Government-furnished equipment
- Annual cost distributions
- Contractor markups

2.4 Develop Remedial Technology Cost Estimates

Cost estimates were developed for each remedial technology based on the detailed descriptions of each technology and the key assumptions identified. All costs were estimated in 1995 constant dollars. The remedial technology estimated cost included construction costs, operations and maintenance costs, post-remediation costs, and risk budget and contingency. Life cycle construction, operation and maintenance, and post-remediation costs, less risk budget and contingency, were provided as constant-dollar cash flows for the planning horizon for each technology. Each of these costs is discussed in greater detail below.

Pricing was from vendor quotes, Means, Richardsons, USACOE, and Factory Quote, tempered by estimator experience. The labor rates applied against manhours in the estimate were the FEMP Craft Wage rates effective March 1, 1994.

Technology cost estimates did not include site overhead costs - the cost for typical daily operations (e.g., labor, utilities, supplies) not specifically for remedial activities.

Construction Costs

Construction costs include expenditures for the equipment, labor, materials, and indirect costs necessary to install remedial actions. Construction costs include engineering design cost plus direct and indirect field labor and materials to construct the facility. Indirect labor includes contractor supervision (field office overhead), equipment rental, temporary facilities, health physics, CERCLA training, payroll burden and benefits and overhead and profit. Other

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associated costs such as the site contractor's purchased equipments and material, waste characterization, transportation, direct burial of materials, sales tax on materials, project management and construction management, are also included.

Operations and Maintenance Costs

Operations and maintenance costs are post-construction costs necessary to remove, treat, and/or dispose of contaminated media. Operations costs include the cost of labor and staff required to operate the remediation facilities, utility costs such as electrical power and sewer, fuel costs, material handling costs, disposal costs, supplies, and sampling and analysis. Maintenance cost includes repair or replacement of equipment and structures, maintenance personnel, and spare parts.

Post-Remediation Costs

Post-remediation costs include decommissioning of remedial facilities and equipment after remediation goals have been met, and the associated long-term monitoring and maintenance of on-property disposal facilities.

Risk Budget and Contingency

A budget risk analysis was performed for each component using a computer program based on a Monte Carlo simulation. The program input was developed as follows:

1. Within each remedial technology, major cost elements related to construction, operations and maintenance, and post-remediation were identified.

2. Each cost element was then weighed against cost driver factors, such as Labor Efficiency, Material Pricing, Class (and extent) of Contamination, New Technology, New Laws and Regulations, Quantity Variation, and Project Definition. Low and high percentage ranges were assigned to each cost driver factor. The low and high cumulative totals were then used as input to the computer simulation.

The computer simulation output showed the following:

1. The Risk Budget and Overrun Analysis Output reflecting the

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chances of overrun percentage versus the percentage of risk budget of base estimate.

2. The frequency histogram of Project Cost Distribution for 2000 samples.

3. The Cumulative Overrun Curve representing the probability of cost overrun versus project cost.

Risk budget and overrun analysis were developed separately for each technology. The risk budget percentage was based on a 50 percent chance of overrun. The contingency was then derived from the difference between the 5 percent and 50 percent chance of overrun of the base estimate.

The risk budget and contingency percentages were then applied to the sum of component construction, operations and maintenance, and post-remediation costs.

2.5 Develop Cost Curves

Contaminated media quantities were expected to vary greatly depending upon the desired remedial action objective (residual risk and future land use). To address uncertainties involving contaminated media quantities, cost curves were developed for each soil-related technology. The curve represents a relative correlation between cost and a given soil volume.

A base cost estimate was prepared for soil-related technologies based on an assumed contaminated soil quantity and assumed remediation period. Since the remediation period was assumed to be fixed, equipment sizes and treatment capacities would change depending on the total volume of contaminated soil. To address the changes in equipment capacities and the impacts to construction costs, a six-tenths factor rule was applied to provide a multiplying factor for the variations in volume. The factor was applied to the technology construction costs only. Changes in annual operations and maintenance costs were increased or decreased proportionately.

A range of contaminated soil volumes was assumed and supplemental cost estimates were prepared to develop the appropriate number of points for the technology cost curves. Component construction and operational strategies were developed for costing purposes. The curve was then fitted to the points to present a smooth curve. Two curves were plotted for each

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technology; raw cost versus volume, and raw cost plus risk budget and contingency versus volume. Raw cost includes construction, operations and maintenance, and post-remediation costs as previously described. The area between each curve represents the cost range versus volume.

The costs for environmental monitoring required during construction of remediation technologies, in addition to long-term environmental monitoring required when leaving contaminated media on site, were included with the applicable remedial technologies. Site-wide environmental monitoring during- and post-remediation was developed and costed as a separate remedial technology.

Contamination surveys are required to determine the extent of soil contamination, guide soil excavation, and certify excavated areas meet clean-up goals. Contamination survey costs are based on the areal extent of contamination, not the contamination volume. Therefore, contamination surveys was developed and costed as a separate remedial technology.

Cost curves were not developed for groundwater-related components. Groundwater extraction and treatment rates were derived from computer modeling to achieve contaminant concentration levels in the Great Miami Aquifer. Detailed groundwater-related technology descriptions, and their associated cost estimates, were based upon providing the computer-derived extraction and treatment capacities and remediation periods.

2.6 Perform Present Worth and Escalation Analysis

Technology cost estimates were developed in constant 1995 dollars and anticipated annual costs over the study period for each technology were summarized. However, according to EPA guidance (EPA 1988), present worth costs should be used to evaluate remedial alternatives. Therefore, a Present Worth Analysis was conducted on the annual expenditures of each technology. The Present Worth Analysis used the "Real Discount" rates established by the Office of Management and Budget, which include the adjustments for varying interest rates on annual constant-dollar cash flows. A Discount Rate of 2.8 percent was used for the Present Worth Analysis for specific planning periods.

In addition to the Present Worth Analysis, the total annual constant-dollar expenditures for each technology were escalated to present the affects of inflation (real dollars) in the year the costs were actually incurred. An average escalation rate of 3.7 percent was used in the analysis. The rate is based on the August 1994 Economic Escalation Indices for DOE construction projects established by the Office of Infrastructure Acquisition.

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2.7 Contaminated Soil Volumes

Solid block modeling was used to establish contaminated soil volume estimates. The solid block model consists of a three-dimensional model of the FEMP and surrounding area down to 30.5-feet deep. The model was created using software developed by Integraph Corporation of Huntsville, Alabama. The model represented both the surface and subsurface features of the FEMP including buildings, utilities, roads, and other features. Moreover, the model represented environmental media, including subsurface soil, perched groundwater, and Great Miami Aquifer groundwater.

The total model volume was divided into discrete volumes, or solid blocks. Subsurface blocks represented a volume of soil which was 125 feet by 125 feet by 1 foot deep. Surface soil blocks are 6 inches deep to support a more refined estimate of contaminated soil at shallower depths where contamination is more prevalent.

The model contained the results of environmental media sampling data collected from various locations and depths on and around the FEMP site. These sampling results provided contaminant concentrations only at the point from which the samples were collected. A geostatistical analysis technique known as kriging was used to establish contaminant concentrations between sampling locations. The kriging model begins with a single block location in the three-dimensional model and then looks in both the vertical and horizontal directions (within established limits) to find other data points which it can use to support the process of establishing contaminant concentrations between data points. Contaminant concentrations between data points were established by interpolation.

2.8 Prepare Alternative Cost Estimates

Each remedial alternative was composed of a combination of remedial technologies intended to remediate a residual risk-derived contaminated media quantity. The cost of each remedial alternative was therefore composed of the costs of its remedial technologies. Similar to the remedial technology costs, remedial alternative costs consist of construction costs, operations and maintenance costs, post-remediation costs, and risk budget and contingency.

Using the cost curves developed for each soil-related remedial technology, and the estimated contaminated soil volumes described previously, a cost was determined for each soil-related technology of each alternative. The costs for construction, operations and maintenance, post-remediation, risk budget and contingency, present worth, and escalated costs were determined

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for each technology of each alternative using mathematical interpolation between curve data points.

The soil-related costs were added to the groundwater-related technologies' costs and site-wide environmental monitoring costs to determine the remedial alternative costs. Remedial alternative costs were thus derived for construction, operations and maintenance, post-remediation, risk budget and contingency, present worth, and escalated costs.

3. RESULTS

For the initial draft of the Operable Unit 5 Feasibility Study, a total of 40 remedial technology cost estimates and 42 remedial alternative cost estimates were prepared at a cost of 5,664 manhours - approximately 69 manhours per estimate. This cost includes the cost of preparing detailed technology descriptions; it does not include the cost of management and administrative support.

For the second draft of the Operable Unit 5 Feasibility Study, the remedial alternatives were significantly revised and minor revisions were made to the remedial technology descriptions. Twelve remedial technology cost estimates were revised and 29 new remedial alternative cost estimates were prepared at a cost of 2,000 manhours - approximately 49 manhours per estimate. This cost was approximately 29 percent less than for the initial draft.

For the final draft, a total of 20 remedial alternative cost estimates were revised at a cost of 503 manhours - approximately 25 manhours per revision.

4. CONCLUSIONS

The methodology presented here provides a timely approach to cost estimating remedial alternatives when contaminated media quantity estimates are not immediately available. By breaking down remedial alternatives into common remedial technologies, developing detailed descriptions of each remedial technology, and developing costs-versus-unit volume curves for each remedial technology, remedial alternatives can be costed when contaminated media quantity estimates do become available. This methodology provides great flexibility for accommodating multiple revisions to remedial alternatives and contaminated media volumes with minimal additional cost estimating effort. The desired level of cost estimating accuracy is achieved through the detailed descriptions of the remedial technology.

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