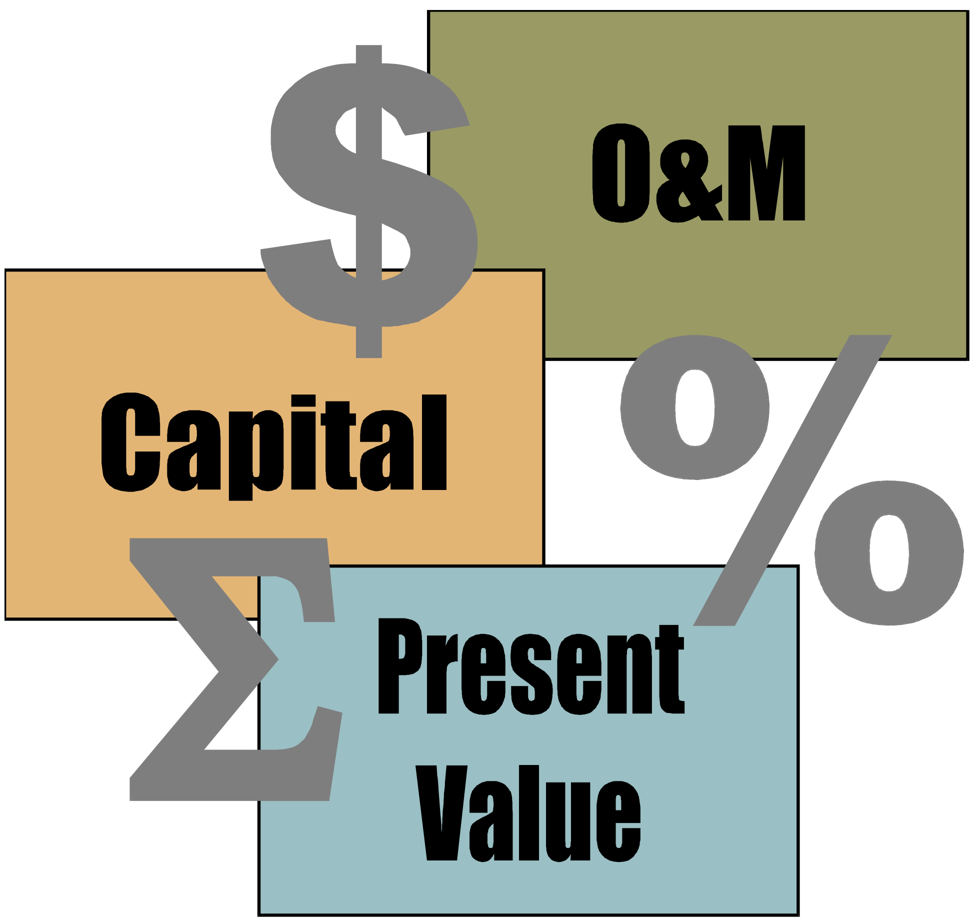
US Army Corps
of Engineers

US Environmental
Protection Agency

EPA 540-R-00-002
OSWER 9355.0-75
www.epa.gov/superfund
July 2000

A Guide to Developing and Documenting Cost Estimates During the Feasibility Study



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A Guide to Developing and Documenting Cost Estimates During the Feasibility Study

U.S. Army Corps of Engineers
Hazardous, Toxic, and Radioactive Waste
Center of Expertise
Omaha, Nebraska

U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Washington, D.C.

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ABSTRACT

This guidance document addresses cost estimates of remedial alternatives developed during the remedial investigation/feasibility study. The goals of this guidance are to improve the consistency, completeness, and accuracy of cost estimates developed to support the Superfund remedy selection process. To help achieve these goals, the document presents clear procedures and expectations, a checklist of cost elements, and example formats. It also identifies resources for estimating costs during the feasibility study. This guide is designed to help those with varying levels of cost estimating expertise, including cost estimators, design engineers, technical support contractors, remedial project managers, and program managers.

This document updates and clarifies previous USEPA guidance for developing and documenting remedial alternative cost estimates during the feasibility study. Previous guidance superceded by this document are Chapter 3 of *Remedial Action Costing Procedures Manual, October 1987 (EPA/600/8-87/049),* and Section 6.2.3.7 of *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA - Interim Final, October 1988 (EPA/540/G-89/004).*

ACKNOWLEDGEMENTS

This document was produced through a joint effort of the United States Environmental Protection Agency (USEPA) Office of Emergency and Remedial Response (OERR) and the United States Army Corps of Engineers (USACE) Hazardous, Toxic, and Radioactive Waste (HTRW) Center of Expertise (CX). Technical assistance was provided under USACE Contract No. DACA45-97-D-0019 by URS Greiner Woodward Clyde Federal Services (URS).

The project management team consisted of Mike Goldstein, USEPA OERR; Stan Hanson, USACE HTRW CX; and Jon Ritterling, URS. Active members of the project workgroup were John Abraham, USEPA Office of Research and Development, National Risk Management Research Laboratory; Keith Hemmer, Project Time & Cost, Inc.; Miguel Jumilla, USACE Headquarters Cost Engineering Branch; Leslie Voss, URS; and Sid Wolf, Environmental Management Support, Inc. In addition, numerous others provided careful review and constructive comments, contributing to the overall quality of the document.

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Acronyms

AACE	Association for the Advancement of Cost Engineering
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
EC2	Environmental Cost Engineering Committee
FR	Federal Register
FRTR	Federal Remediation Technologies Roundtable
FS	Feasibility Study
G&A	General and Administrative
HCAS	Historical Cost Analysis System
HTRW	Hazardous, Toxic, or Radioactive Waste
ICEG	Interagency Cost Estimating Group
MCACES	Micro Computer Aided Cost Engineering System
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRRB	National Remedy Review Board
O&M	Operation and Maintenance
OMB	Office of Management and Budget
OSWER	Office of Solid Waste and Emergency Response
PRP	Potentially Responsible Party
PV	Present Value
QA/QC	Quality Assurance/Quality Control
RA	Remedial Action
RACER	Remedial Action Cost Engineering and Requirements
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
USACE	United States Army Corps of Engineers
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
UPB	Unit Price Book
WBS	Work Breakdown Structure

Chapter One
Introduction

In the Superfund program,[1] the remedial investigation/feasibility study (RI/FS) process is used to characterize the nature and extent of risks posed by hazardous waste sites and to evaluate potential remedial options. During the feasibility study (FS) phase of this process, cost estimates are developed for each remedial action alternative being evaluated.

Key Issues for Cost Estimates in Feasibility Study Reports

Cost estimates of remedial alternatives provided in feasibility study reports should clearly present the following information:

- Expected accuracy range of the cost estimate (e.g., –30 to +50 percent for detailed analysis of alternatives)
- Source references for quantity and unit cost information
- Contingency to account for possible cost overruns
- Basis for applied contingency
- Costs for professional and technical services
- Period of present value analysis (e.g., 50 years)
- Basis for period of present value analysis (e.g., time required to achieve remedial action objectives)
- Discount rate used in present value analysis (e.g., 7 percent)
- Basis for discount rate used in present value analysis (e.g., per USEPA policy)
- Major assumptions and sources of uncertainty in the overall estimate
- Analysis of sensitivity of cost estimate to uncertain factors
- Logical and organized presentation of cost estimate summaries and detailed backup information

The U.S. Environmental Protection Agency (USEPA) first published guidance for developing and documenting remedial alternative cost estimates during the FS as part of the *Remedial Action Costing Procedures Manual* (USEPA 1987). That document provided the basis for the discussion of cost estimating in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988). Since these documents were published, remedial alternative cost estimates prepared during feasibility studies generally have followed this basic guidance, but have typically varied in approach and content. Additionally, the number of available cost estimating resources has increased during this time. To take advantage of lessons learned and help improve the consistency, completeness, and accuracy of remedy cost estimates during the FS, this guide was prepared to update and clarify previous USEPA guidance in this policy area. Specific guidance superceded by this guide are Chapter 3 of *Remedial Action Costing Procedures Manual* (USEPA 1987) and Section 6.2.3.7 of *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988).

[1] As used by this guide, "Superfund" refers to the program operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and the Superfund Amendments and Reauthorization Act (SARA) of 1986.

1.1 Purpose of Guide

The purpose of this guide is to provide a current reference for developing and documenting cost estimates of remedial action alternatives during the FS. The goals of this guide include improving the consistency, completeness, and accuracy of cost estimates prepared during the FS. To help achieve these goals, the guide presents clear procedures and expectations, presents a checklist of cost elements and example formats, and points out resources for cost estimating.

This guide is designed to help those with varying levels of cost estimating expertise, including cost estimators, design engineers, technical support contractors, remedial project managers, and program managers.

1.2 Scope of Guide

This guide addresses cost estimates of remedial alternatives developed during the FS in support of the Superfund remedy selection process. Therefore, Superfund terms are primarily used to describe the concepts presented. However, many of these cost engineering concepts are universal in nature and could be applied to other environmental cleanup projects or programs.[2]

While cost estimates are developed at different stages of the Superfund process (Chapter 2), this guide specifically addresses the FS phase. Cost estimates are developed during the FS primarily for the purpose of comparing remedial alternatives during the remedy selection process, not for establishing project budgets or negotiating Superfund enforcement settlements.[3] During remedy selection, the cost estimate of the preferred alternative is typically carried over from the FS to the proposed plan for public comment. The subsequent cost estimate included in the record of decision (ROD) reflects any changes to the remedial alternative that occurs during the remedy selection process as a result of new information or public comment.

Finally, this guide does not address how to use cost estimates in making a remedy selection decision or how to make a cost-effectiveness determination in the Superfund program. USEPA guidance that addresses this issue can be found in *The Role of Cost in the Superfund Remedy Selection Process* (USEPA 1996).

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[2] Examples include Superfund removal actions, Superfund enforcement settlements, Resource Conservation and Recovery Act (RCRA) corrective actions, Federal facilities cleanups, brownfields cleanups, underground storage tank remediation, installation restoration program, base realignment and closure, formerly used defense sites, and cleanup programs under State authorities.

[3] The FS remedial alternative cost estimate can be used as starting point for budgeting purposes, but adjustments may be needed based on individual agency requirements. For example, estimates may need to be revised based on project scope requirements, escalation factors may need to be added, or discount factors may need to be removed.

1.3 How to Use the Guide

This guide is intended to provide the user with the basic information necessary to develop and document cost estimates for remedial action alternatives during the FS. This guide is not meant to contain all of the information necessary to complete the cost estimate, but to be a primary reference, pointing to other resources as necessary. The objectives of each chapter and appendix are listed below:

- Chapter 1: Introduce the guide, including its purpose, scope, and use.
- Chapter 2: Provide background information on applicable regulatory and cost engineering concepts, including the Superfund process, role of project definition in cost estimates, cost estimating within Superfund, and cost estimating during the FS.
- Chapter 3: Provide a cost element checklist to help identify capital, annual operation and maintenance (O&M), and periodic costs to include in the cost estimate for a remedial action alternative.
- Chapter 4: Provide guidelines for conducting a present value analysis, including period of analysis and discount rate.
- Chapter 5: Provide steps to develop the basic cost estimate for a remedial action alternative, including alternative description, identification of cost element structure, estimation of cost elements, application of contingency, present value analysis, sensitivity analysis, and review of estimate.
- Chapter 6: Provide information on how to document the cost estimates of remedial action alternatives developed during the FS, including an example cost summary.
- Chapter 7: Provide a list of references used in the document.
- Appendix A: Provide a list of government and non-government resources on the Internet that can be used to help develop remedial alternative cost estimates during the FS.
- Appendix B: Provide information on how to adjust costs for geographic location, escalation, and for impacts of health and safety requirements on productivity.
- Appendix C: Provide example templates for cost estimate summaries and backup information.
- Appendix D: Provide a glossary of key terms used in the document.

Rules of thumb for cost estimating during the FS, identified by the 👍 symbol, are highlighted periodically within the document text. These rules of thumb, many of which provide typical cost percentages, are based on engineering judgement and not on detailed analysis of historical cost data. Also, highlight boxes throughout the document provide information on topics that are important, but not necessarily central to the discussion at hand. Web site addresses cited in the document were current at the time of publication.

Chapter Two
Background

Estimating the cost of remedial action alternatives during the FS requires a basic understanding of applicable regulatory and cost engineering concepts. Therefore, this chapter provides background information on these subjects, including an overview of the Superfund process, discussion of the role of project definition in cost estimates, cost estimating within the Superfund process, and cost estimating during the FS.

2.1 Overview of Superfund Process

The Superfund "pipeline" (Exhibit 2-1) illustrates the major phases and decision points of the Superfund remedial response program.

The RI/FS process is used to gather the information necessary to select a remedy that will meet the statutory and regulatory requirements of the Superfund cleanup program. The remedial investigation (RI) includes sampling and analysis to characterize the nature and extent of contamination; baseline risk assessment to assess current and potential future risks to human health and the environment; and treatability studies, as appropriate, to evaluate the effectiveness of treatment or recovery technologies to reduce the toxicity, mobility, or volume of hazardous substances or contaminated media.

The FS consists of two main phases: (1) development and screening of remedial action alternatives; and (2) comparison of each alternative that passes screening in a detailed analysis. A range of remedial action alternatives is developed during the FS as data become available from the RI site characterization, with treatability studies helping to reduce uncertainties concerning cost and performance of treatment alternatives.

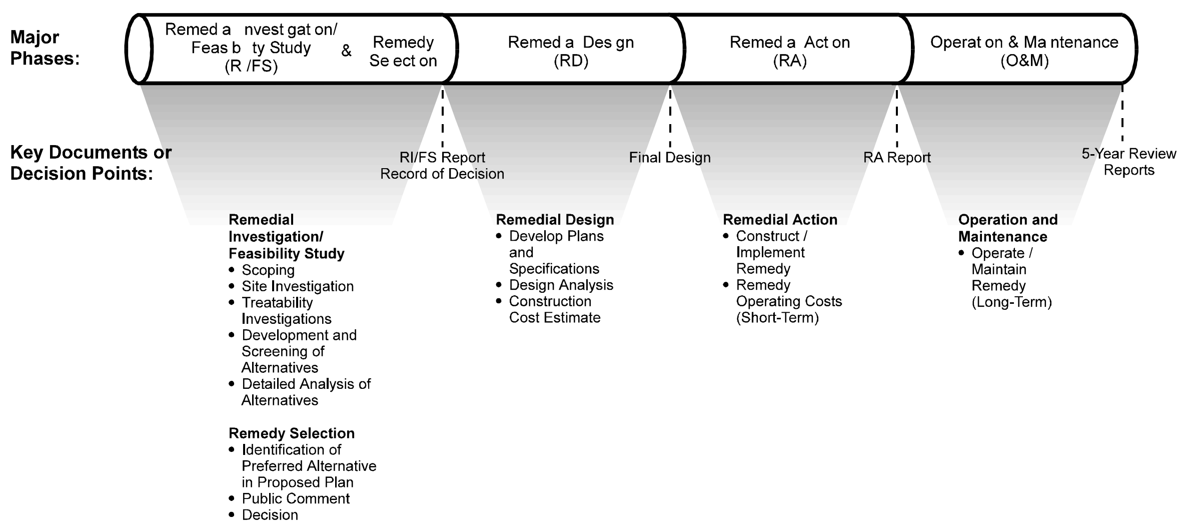
For Further Information

For further information on the Superfund remedy selection process, see the following publications:

- National Oil and Hazardous Substances Pollution Contingency Plan (NCP), Subpart E - Hazardous Substance Response, Section 300.430 – Remedial Investigation/ Feasibility Study and Selection of Remedy (40 CFR Part 300) (*http://www.epa.gov/docs/epacfr40/chapt-I.info/subch-J/*)
- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final (USEPA 1988)
- A Guide to Selecting Superfund Remedial Actions (USEPA 1990)
- The Role of Cost in the Superfund Remedy Selection Process (USEPA 1996) (*http://www.epa.gov/superfund/resources/cost_dir/index.htm*)
- Rules of Thumb for Superfund Remedy Selection (USEPA 1997) (*http://www.epa.gov/superfund/resources/rules/index.htm*)
- A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents (USEPA 1999) (*http://www.epa.gov/superfund/resources/remedy/rods/index.htm*)

During remedy selection, a preferred alternative is identified, presented in a proposed plan, and documented in a ROD following evaluation of public comment.[1] Plans, specifications, and other documents necessary to construct or implement the remedy are developed during remedial design (RD). Remedial action (RA) is the actual implementation of the remedy. Operation and maintenance (O&M) is used to maintain the effectiveness of the remedial action. More information on the differences between the RA and O&M phases and how they relate to estimating the cost of remedial action alternatives is provided in Chapter 3.

Exhibit 2-1
The Superfund Pipeline



2.2 Role of Project Definition in Cost Estimates

The Association for the Advancement of Cost Engineering (AACE) International defines a cost estimate as "an evaluation of all the costs of the elements of a project or effort as defined by an agreed-upon scope" (AACE 1990). The total estimated cost of a project is primarily dependent on how well, or to what degree, the project is defined (i.e., "scope" or completeness of design).

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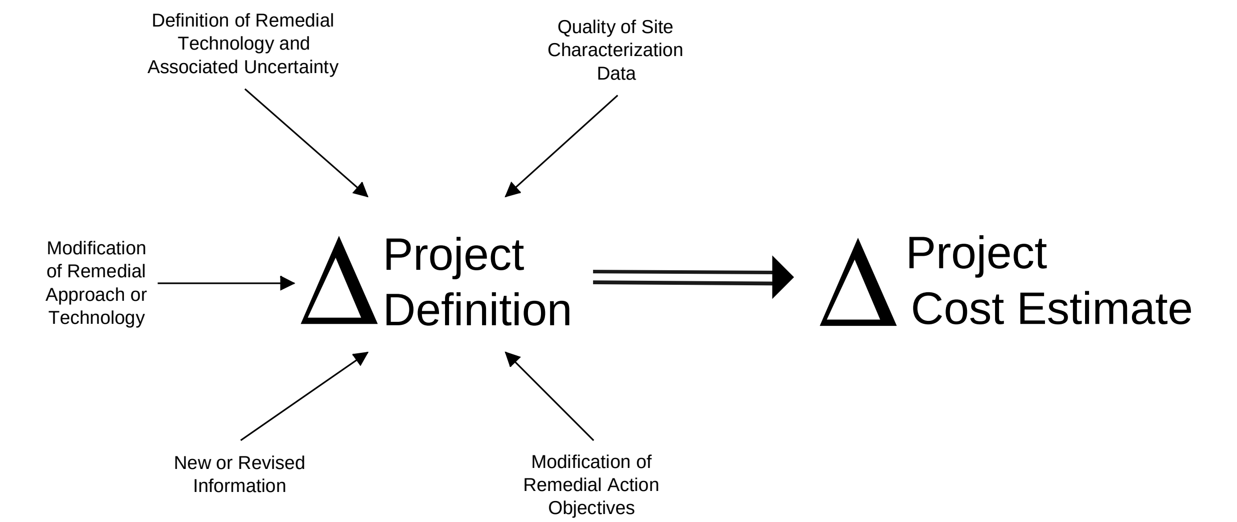
[1] Cost is one of nine criteria established by USEPA to guide remedy selection decision making and is a critical factor in the process of identifying a preferred remedy. In addition, CERCLA and the NCP require that every remedy selected must be cost-effective. See *The Role of Cost in the Superfund Remedy Selection Process* (USEPA 1996) for a more complete discussion.

A change (Δ) in project definition will result in a change (Δ) in the project cost estimate. This relationship, including factors that may affect a change in project definition and, therefore, a change in the cost estimate for a remedial action project, is illustrated in Exhibit 2-2.

Exhibit 2-2
Relationship of Project Definition to Cost Estimate for a Remedial Action Project



2.3 Cost Estimating During the Superfund Process

As a project moves from the planning stage into the design and implementation stage, the level of project definition increases, thus allowing for a more accurate cost estimate. An "early" estimate of the project's life cycle costs is made during the FS to make a remedy selection decision.[2]

At the FS stage, the design for the remedial action project is still conceptual, not detailed, and the cost estimate is considered to be "order-of-magnitude." The cost engineer must make assumptions about the detailed design in order to prepare the cost estimate. As a project progresses, the design becomes more complete and the cost estimate becomes more "definitive," thus increasing the accuracy of the cost estimate. This process is depicted in Exhibit 2-3 for remedial action projects in the Superfund program.[3]

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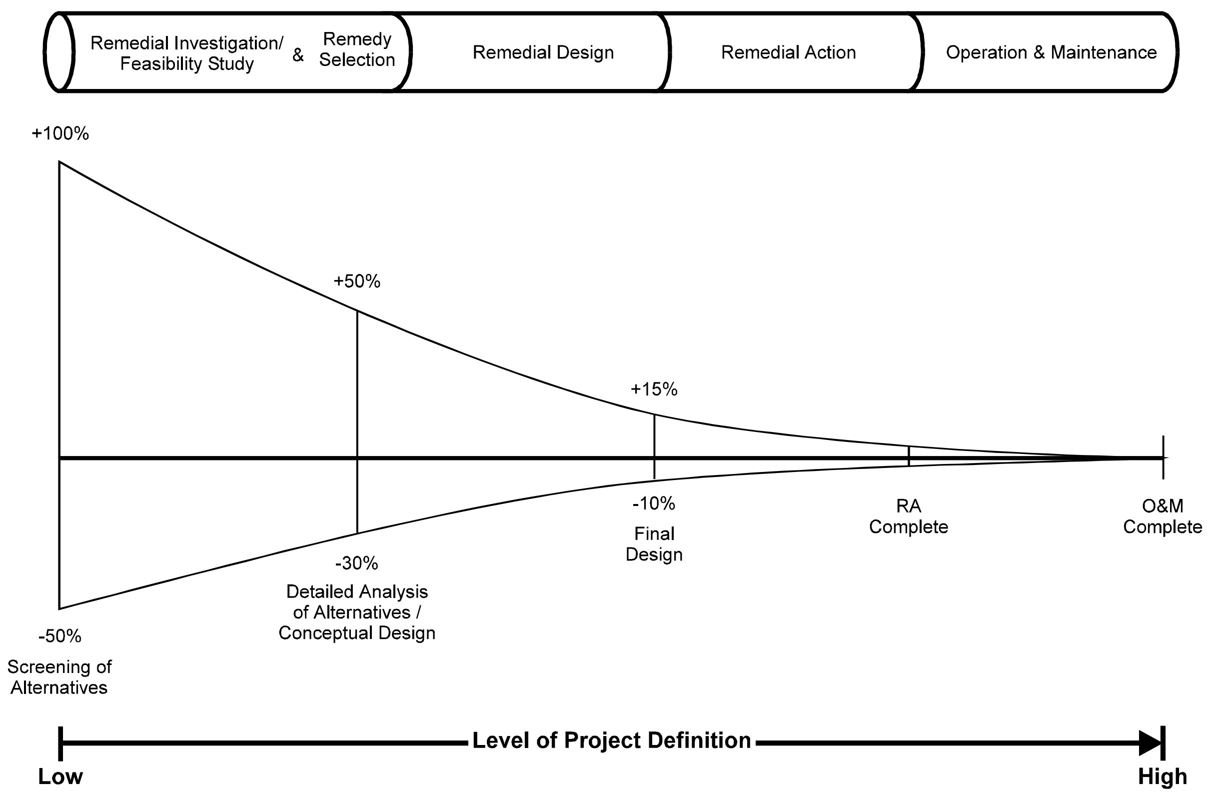
[2] The term "life cycle cost" refers to the total project cost across the life span of a project, including design, construction, operation and maintenance, and closeout activities. The cost estimate developed during the FS is a projection of the life cycle cost of a remedial action project, not including the RI/FS or earlier phases.

[3] The accuracy range curves shown in Exhibit 2-3, representing both construction and operation costs, are for illustrative purposes only. The specific percentages correlate with generally accepted rules of thumb for cost estimating accuracy and are not meant to imply that these goals will be precisely achieved.

Exhibit 2-3
Expected Cost Estimate Accuracy Along the Superfund Pipeline



2.4 Cost Estimating During the Feasibility Study

During the FS, cost estimates are developed for each remedial action alternative for comparison purposes. The accuracy of these estimates is linked to the quality of the RI data, which helps define the scope of each alternative. Because the RI/FS cannot remove all uncertainty no matter how good the data may be, the expected accuracy of cost estimates during the FS is less than that of estimates developed during later stages of the Superfund process.

Cost estimates are developed at both the "screening of alternatives" and "detailed analysis of alternatives" phases of the FS, with expected accuracy ranges of –50 to +100 percent and –30 to +50 percent, respectively, as shown in Exhibit 2-3.[4] Cost estimates developed during these two phases are further described in the following paragraphs.

[4] If the number of viable alternatives developed during the FS process is limited, the "screening of alternatives" step is not always performed, nor is it required (Section 4.1.2.1 of RI/FS guidance [USEPA 1988]). However, the "detailed analysis of alternatives" is performed regardless to evaluate each alternative against the NCP evaluation criteria.

Screening of Alternatives

Screening-level cost estimates are used to screen out disproportionately expensive alternatives in determining what alternatives should be retained for detailed analysis. The National Oil and Hazardous Substances Contingency Plan (NCP) includes the following language in its description of the cost criterion for screening of alternatives:

> "The costs of construction and any long-term costs to operate and maintain the alternatives shall be considered." (40 CFR 300.430(e)(7)(iii))

Screening-level cost estimates should focus on relative accuracy in order to make comparative estimates so that decisions between alternatives can be appropriately considered as the accuracy of the cost estimates improves beyond the screening process. The procedures used to develop these estimates are similar to those used for the detailed analysis, except that alternatives are not as well refined and cost components are not as well developed. The screening-level accuracy range of –50 to +100 percent means that, for an estimate of $100,000, the actual cost of an alternative is expected to be between $50,000 and $200,000.

The basis for a screening-level cost estimate can include a variety of sources, including cost curves, generic unit costs, vendor information, standard cost estimating guides, historical cost data, and estimates for similar projects, as modified for the specific site. Both capital and O&M costs should be considered, where appropriate, at the screening level.

Detailed Analysis of Alternatives

Cost estimates developed during the detailed analysis phase are used to compare alternatives and support remedy selection. The NCP includes the following language in its description of the cost criterion for the detailed analysis and remedy selection:

Direct and Indirect Cost Terminology

There may be some variability in the use of the terms "direct cost" and "indirect cost." This is due to a difference in perspective. To the "owner" of the project (e.g., government or potentially responsible party [PRP]), the "direct costs" of cleanup are the equipment, labor, and material costs necessary to construct the remedial action (including contractor markups, such as overhead and profit). From this perspective, the "indirect costs" are all other costs not part of the actual construction project but necessary to implement the remedial action (e.g., engineering, legal, construction management, and other technical and professional services). However, to the "implementor" of the project (e.g., construction contractor), the "direct costs" of cleanup are those costs that can be attributed to a single task of construction work, while the "indirect costs" are those that cannot be assigned to a specific activity (e.g., contractor markups).

Due to the potential for confusion caused by these differences in perspective, the specific terms "direct cost" and "indirect cost" are not used in the remainder of this guide. Rather, a distinction is made between costs associated with specific construction or O&M activities and costs for professional/technical services necessary to support those activities. Contractor markups would be included along with the labor, equipment, and material costs for specific construction or O&M activities. This terminology should avoid confusion, while still addressing both aspects of cost that are identified in the NCP for the Superfund remedy selection process.

> “The types of costs that shall be assessed include the following: (1) Capital costs, including both direct and indirect costs (2) Annual operations and maintenance costs; and (3) Net present value of capital and O&M costs.” (40 CFR 300.430 (e)(9)(iii)(G))

Remedial action alternative cost estimates for the detailed analysis are intended to provide a measure of total resource costs over time (i.e., “life cycle costs”) associated with any given alternative.[5] As such, these estimates generally are based on more detailed information and should achieve a greater level of accuracy than screening-level estimates. The detailed analysis level accuracy range of –30 to +50 percent means that, for an estimate of $100,000, the actual cost of an alternative is expected to be between $70,000 and $150,000.

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[5] These life cycle estimates should not include costs that would be incurred by the site owner or government independent of the remedial action (e.g., U.S. Department of Energy program management costs, unrelated facility or site maintenance costs). Nor should these estimates include other “external costs” not associated with the implementation of the remedial action (e.g., economic impacts to residents or businesses as a result of remediation activity).

Chapter Three
Capital and O&M Costs

The NCP states that the types of costs to be assessed in the FS include capital and annual O&M costs. This chapter provides definitions and checklists that can be used to identify capital and O&M costs for remedial action alternatives.

3.1 Definitions

Included under the general categories of capital and O&M costs identified in the NCP are capital, annual O&M, and periodic costs (capital or O&M), as defined below. These definitions are consistent with past USEPA guidance and do not change the intent of the NCP.

Capital Costs

Capital costs are those expenditures that are required to construct a remedial action. They are exclusive of costs required to operate or maintain the action throughout its lifetime. Capital costs consist primarily of expenditures initially incurred to build or install the remedial action (e.g., construction of a groundwater treatment system and related site work).

Capital costs include all labor, equipment, and material costs, including contractor markups such as overhead and profit, associated with activities such as mobilization/demobilization; monitoring; site work; installation of extraction, containment, or treatment systems; and disposal. Capital costs also include expenditures for professional/technical services that are necessary to support construction of the remedial action.

Annual O&M Costs

Operation and maintenance (O&M) costs are those post-construction costs necessary to ensure or verify the continued effectiveness of a remedial action. These costs are estimated mostly on an annual basis.

Annual O&M costs include all labor, equipment, and material costs, including contractor markups such as overhead and profit, associated with activities such as monitoring; operating and maintaining extraction, containment, or treatment systems; and disposal. Annual O&M costs also include expenditures for professional/technical services necessary to support O&M activities.

Periodic Costs

Periodic costs are those costs that occur only once every few years (e.g., five-year reviews, equipment replacement) or expenditures that occur only once during the entire O&M period or remedial timeframe (e.g., site closeout, remedy failure/replacement). These costs may be either capital or O&M costs, but because of their periodic nature, it is more practical to consider them separately from other capital or O&M costs in the estimating process.

3.2 Relationship of Capital and O&M Costs to Superfund Phases

A Superfund response action can occur in two phases: (1) remedial action and (2) O&M. In general, remedial action is defined by CERCLA to include activities required to prevent or mitigate the migration of contaminants into the environment. As such, a "remedial action" may not be complete when construction is complete, as in the case of a pump and treat remedy that may require many years of operation. In these cases, remedial action may include tasks that are traditionally considered to be O&M (see "Regulatory Definitions" to right for further explanation). Per CERCLA, O&M typically occurs after the remedial action has been completed and may include the tasks necessary to continue preventing or mitigating the migration of contaminants into the environment (e.g., long term surveillance and monitoring). Therefore, the RA phase of the Superfund pipeline can include both construction and short-term O&M activities, while the O&M phase consists primarily of long-term O&M (Exhibit 3-1).

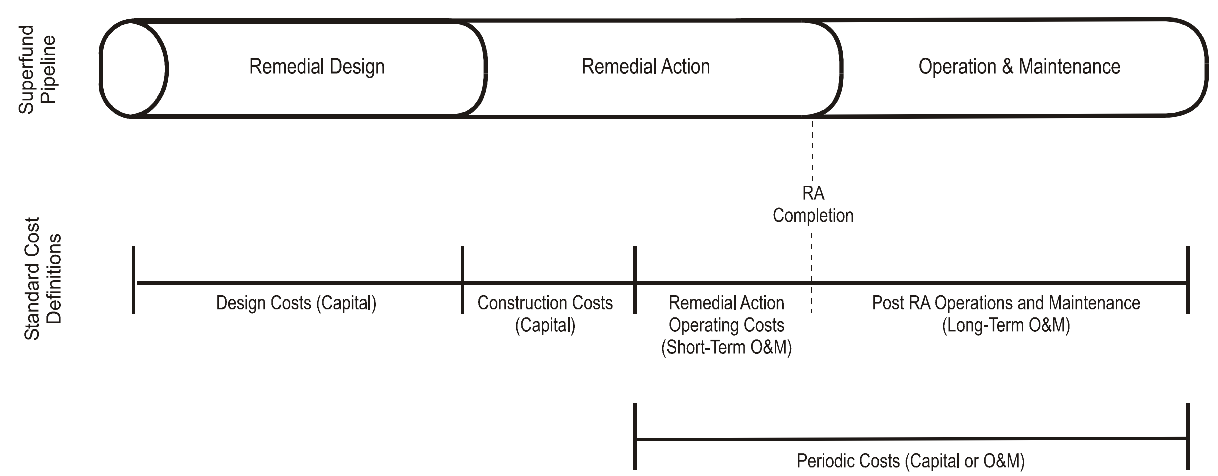
Regulatory Definitions for RA and O&M

Under the Superfund program, O&M typically begins only after the remedial action has achieved remedial action objectives and remediation goals stated in the ROD and is determined to be operational and functional (40 CFR 300.435(f)(1)). A remedy becomes "operational and functional" normally within one year after construction is completed.

For Fund-financed remedial actions to treat or restore groundwater or surface water quality to a level protective of human health and the environment, the operation of the remedy is considered part of the remedial action phase for a period of up to 10 years after the remedial action becomes operational and functional (40 CFR 300.435(f)(3)). Activities necessary to maintain the effectiveness of the remedy past this period are considered to be O&M, thereby shifting financial responsibility from the Federal government to the government of the State in which the site is located.

For remedial alternative cost estimates developed during the FS, the conventional distinctions between capital and O&M costs should be used. As shown in Exhibit 3-1 on the "standard cost definitions" line, capital costs considered during the FS include design and construction while O&M costs include both short-term and long-term O&M. Periodic costs (e.g., replacement or repair costs, five-year review costs) can occur at any time during the O&M period (both short-term and long-term).

Exhibit 3-1
Relationship of Capital and O&M Costs to Superfund Phases



3.3 Cost Element Checklists

Checklists can be used to help evaluate capital and O&M costs for each remedial action alternative and to reduce the possible exclusion of key cost elements. A cost estimate generally will be more "complete" if as many cost elements as possible are accounted for, even though uncertainty may remain about their quantity or unit cost. Checklists also promote consistency between estimates.

Checklists are provided in Exhibits 3-2, 3-3, and 3-4 for capital, annual O&M, and periodic cost elements, respectively. The checklists are designed to be flexible, and by design, do not follow any standard work breakdown structure (WBS) or numbering system. The checklists are not all-inclusive and, therefore, the listed cost elements should not be assumed to apply to every remedial action alternative. Rather, the checklists can be used to identify applicable cost elements, which can be added to or modified as needed. Exhibits 3-2, 3-3, and 3-4 provide descriptions of cost elements, as well as example sub-elements.

Work Breakdown Structures

Cost estimates for Federal hazardous, toxic, or radioactive waste (HTRW) cleanup projects typically use a work breakdown structure (WBS) to identify cost elements. The Environmental Cost Engineering Committee (EC2), formerly known as the Interagency Cost Estimating Group (ICEG), has played a key role in WBS development. EC2 is comprised of cost professionals from the USEPA, U.S. Department of Energy (USDOE), U.S. Army Corps of Engineers (USACE), U.S. Navy, and U.S. Air Force. Several work breakdown structures have been developed, each of which can be useful for identifying potential cost elements to include in a remedial alternative FS cost estimate. These include:

- HTRW Remedial Action (RA) / Operation & Maintenance (O&M) WBS, February 1996 (*http://www.frtr.gov/cost/ec2/wbs1.html*)
- Phased Based HTRW WBS, April 1998 (*http://www.frtr.gov/cost/ec2/wbs2.html*)
- Environmental Cost Element Structure (ECES), September 1999 (*http://www.em.doe.gov/aceteam/eces.html*)

While the 1996 HTRW WBS (required by USACE) focuses on the RA and O&M phases, the ECES is more comprehensive and covers cost elements from initial studies through long term monitoring.

Capital Cost Elements

Capital cost elements from the checklist in Exhibit 3-2 are listed below:

<u>Construction Activities</u>

- Mobilization / Demobilization
- Monitoring, Sampling, Testing, and Analysis
- Site Work
- Surface Water Collection or Containment
- Groundwater Extraction or Containment
- Gas/Vapor Collection or Control
- Soil Excavation
- Sediment/Sludge Removal or Containment
- Demolition and Removal
- Cap or Cover
- On-Site Treatment (specify treatment technology)
- Off-Site Treatment / Disposal
- Contingency

Professional/Technical Services

- Project Management
- Remedial Design
- Construction Management

Institutional Controls

The elements listed as construction activities would be incurred as part of the physical construction of the remedial action. Contingency covers unknowns or unanticipated conditions associated with construction activities. Project management, remedial design, and construction management are professional/technical services to support construction of the remedial action. Institutional controls, which are legal or administrative measures used to limit or restrict site access or human exposure to contamination, can be a major component of a remedial alternative and therefore warrant separate consideration.

The terminology for each cost element should be made as alternative-specific as possible (i.e., terminology from the checklist should not necessarily be used directly). For example, "Sediment/Sludge Removal or Containment" could simply be "Contaminated Sludge Removal" if only removal of sludge, not sediment, is to occur. For on-site treatment, the applicable treatment technology (e.g., "Soil Vapor Extraction") should be specified (see "Example" to right).

Costs of construction activities are typically estimated on an element-by-element basis. Contractor markups such as overhead and profit should generally be included in these cost elements, rather than listed separately in the capital cost summary. Contingency is typically added as a percentage to the total cost of construction activities. Professional/technical services are typically estimated as a percentage of the total cost of construction activities plus contingency. A more detailed discussion of contingency is provided in Chapter 5. Institutional controls are typically estimated on an element-by-element basis. The development and documentation of capital costs are further described in Chapters 5 and 6, respectively.

Example Capital Cost Element Structure

An example of how capital cost elements and sub-elements might be structured for a remedial alternative that uses air sparging (AS), soil vapor extraction (SVE), and a passive treatment wall (i.e., permeable reactive barrier) to treat contaminated soil and groundwater is as follows:

- Mobilization/Demobilization
  - Construction Equipment
  - Submittals/Implementation Plans
  - Temporary Facilities & Utilities
  - Post-Construction Submittals
- Monitoring, Sampling, Testing, and Analysis
  - SVE Monitoring Wells
  - Treatment Wall Monitoring Wells
- Site Work
  - Clearing and Grubbing
  - Seeding/Mulch/Fertilizer
- Air Sparging / Soil Vapor Extraction
  - Mobilize SVE System
  - AS Injection Wells
  - AS Blower
  - AS Piping
  - SVE System
  - SVE Extraction Wells
  - SVE Piping
  - Electrical Hookup
  - Startup and Testing
- Passive Treatment Wall
  - Construct Slurry Trench
  - Install Reactive Media
- Off-Site Treatment/Disposal
  - Off-Site Transport of Soil Cuttings
  - Off-Site Disposal of Soil Cuttings
  - Wastewater Discharge/Testing
- Project Management
- Remedial Design
- Construction Management
- Institutional Controls
  - Institutional Controls Plan
  - Groundwater Use Restriction
  - Site Information Database

Exhibit 3-2
Capital Cost Element Checklist

Cost Element	Description	Example Sub-Elements
<u>**Construction Activities**</u>		
Mobilization/ Demobilization	Bringing equipment and personnel to the site (mobilization) or removing equipment and personnel (demobilization) for purposes of constructing or installing the remedial action. Includes setup/construction and/or removal of temporary facilities and utilities. Does not include mobilization or demobilization specific to constructing or installing an on-site treatment facility.	☐ Construction Equipment ☐ Submittals/Implementation Plans __ Air Monitoring Plan __ Construction Quality Control Plan __ Construction Schedule __ Environmental Protection Plan __ Materials Handling/Transportation/Disposal Plan __ Permits __ Sampling and Analysis Plan __ Site Safety and Health Plan __ Site Security Plan __ Site Work Plan __ Storm Water Pollution Prevention Plan __ Training & Medical Certifications ☐ Temporary Facilities __ Office Trailers __ Storage Facilities __ Security Fencing & Signs __ Roads and Parking __ Decontamination Facilities ☐ Temporary Utilities ☐ Temporary Relocation of Roads/Structures/Utilities ☐ Post-Construction Submittals __ As-Built Drawings __ O&M Manuals __ QA/QC Documentation ☐ Site Security Personnel ☐ ____________________ ☐ ____________________

Exhibit 3-2 (cont.)
Capital Cost Element Checklist

Cost Element	Description	Example Sub-Elements
Construction Activities (cont.)		
Monitoring, Sampling, Testing, and Analysis	Sampling, testing, on- or off-site analysis, data management, and quality assurance/ quality control. Includes monitoring to evaluate remedy performance and/or compliance with regulations.	☐ Meteorological Monitoring ☐ Air Monitoring and Sampling ☐ Radiation Monitoring ☐ Health and Safety Monitoring ☐ Personal Protective Equipment ☐ Monitoring Wells ☐ Geotechnical Instrumentation ☐ Soil Sampling ☐ Sediment Sampling ☐ Surface Water Sampling ☐ Groundwater Sampling ☐ Radioactive Waste Sampling ☐ Asbestos Sampling ☐ Laboratory Chemical Analysis ☐ On-Site Chemical Analysis ☐ Radioactive Waste Analysis ☐ Geotechnical Testing ☐ Chemical Data Management ☐ ____________________ ☐ ____________________
Site Work	Activities to establish the infrastructure necessary for the project (i.e., site preparation). Also includes permanent site improvements and restoration of areas or site features disturbed during site remediation. Site work is generally assumed to be “clean work,” meaning that there is no contact with contaminated media or materials. Excludes all site work specific to constructing or installing an on-site treatment facility.	☐ Demolition ☐ Clearing and Grubbing ☐ Earthwork __ Stripping __ Stockpiling __ Excavation __ Borrow __ Grading __ Backfill __ Topsoil ☐ Roads/Parking/Curbs/Walks ☐ Vegetation and Planting __ Topsoil __ Seeding/Mulch/Fertilizer __ Sodding __ Erosion Control Fabric __ Shrubs/Trees/Ground Cover ☐ Fencing/Signs/Gates ☐ Utilities __ Electrical __ Telephone/Communications __ Water/Sewer/Gas ☐ Storm Drainage/Subdrainage ☐ Sediment Barriers ☐ ____________________ ☐ ____________________

Exhibit 3-2 (cont.)
Capital Cost Element Checklist

Cost Element	Description	Example Sub-Elements
Construction Activities (cont.)		
Surface Water Collection or Containment	Collection or containment of contaminated surface water. Excludes treatment, off-site transportation, or off-site treatment/ disposal of contaminated surface water.	☐ Pumping ☐ Draining ☐ Channel/Waterway ☐ Berm/Dike ☐ Lagoon/Basin/Tank ☐ ________ ☐ ________
Groundwater Extraction or Containment	Extraction or containment of contaminated groundwater. Excludes treatment, off-site transportation, or off-site treatment/disposal of contaminated groundwater.	☐ Extraction/Injection Well __ Vertical __ Horizontal ☐ Extraction Trench ☐ Pumps ☐ Piping ☐ Lagoon/Basin/Tank ☐ Subsurface Drains ☐ Subsurface Barrier __ Slurry Wall __ Grout Curtain __ Sheet Piling ☐ ________ ☐ ________
Gas/Vapor Collection / Control	Collection or control of off-gas or air emissions from contaminated sources.	☐ Collection Well System ☐ Collection Trench System ☐ Collection System at Lagoon Cover ☐ Fugitive Dust Control ☐ Vapor/Gas Emissions Control ☐ ________ ☐ ________
Soil Excavation	Excavation and handling of contaminated soil. Excludes treatment, off-site transportation, or off-site treatment/disposal of contaminated soil.	☐ Excavation ☐ Hauling ☐ Stockpiling ☐ ________ ☐ ________

Exhibit 3-2 (cont.)
Capital Cost Element Checklist

Cost Element	Description	Example Sub-Elements
Construction Activities (cont.)		
Sediment / Sludge Removal or Containment	Removal or containment of contaminated sediment or sludge. Excludes treatment, off-site transportation, or off-site treatment/disposal of contaminated sediment or sludge.	☐ Excavation ☐ Dredging ☐ Vacuuming ☐ Lagoon/Basin/Tank ☐ ____________ ☐ ____________
Demolition and Removal	Demolition/removal of contaminated or hazardous materials or structures. Excludes treatment, off-site transportation, or off-site disposal of contaminated or hazardous materials or structures.	☐ Drum Removal ☐ Tank Removal ☐ Piping Removal ☐ Structure Removal ☐ Asbestos Abatement ☐ Contaminated Paint Removal ☐ Ordnance Removal and Destruction ☐ ____________ ☐ ____________
Cap or Cover	Construction of a multi-layered cap or cover over contaminated materials or media (e.g., soil, sediment, sludge) to prevent or reduce exposure and minimize infiltration of surface water and production of leachate.	☐ Subgrade Preparation ☐ Gas Collection Layer ☐ Low Permeability Clay Layer ☐ Bentonite ☐ Geosynthetic Clay Layer ☐ Geotextile ☐ Geomembrane ☐ Granular Drainage Layer ☐ Geonet ☐ Waste Placement (Cut/Fill) ☐ Protective Soil Layer ☐ Asphalt/Concrete Pavement ☐ Topsoil ☐ Erosion Control Fabric ☐ Seeding/Mulch/Fertilizer ☐ ____________ ☐ ____________

Exhibit 3-2 (cont.)
Capital Cost Element Checklist

Cost Element	Description	Example Sub-Elements
Construction Activities (cont.)		
On-Site Treatment[1]	Construction or installation of a complete and usable on-site facility for treatment of contaminated media (e.g., soil, solids, sediment, sludge, surface water, groundwater), including in situ and ex situ techniques. Includes all mobilization and site work required for the treatment facility.	☐ Mobilization/Demobilization ☐ Site Work ☐ Structures ☐ Process Equipment and Appurtenances ☐ Non-Process Equipment ☐ Startup and Testing ☐ Equipment Upgrade/Replacement ☐ ____________ ☐ ____________
Off-Site Treatment / Disposal	Final placement of contaminated media, material, or treatment residuals at off-site commercial facilities, such as solid or hazardous waste landfills and incinerators, that charge fees to accept waste based on certain criteria.	☐ Material Handling/Loading ☐ Transportation to Off-Site Facility ☐ Treatment/Disposal Fees ☐ ____________ ☐ ____________
Contingency	Costs added to cover unknowns, unforeseen circumstances, or unanticipated conditions related to construction or installation of the remedial action.	☐ Scope Contingency ☐ Bid Contingency

[1] Specify treatment technology. Examples include solidification/stabilization, biopile, low temperature thermal desorption, soil vapor extraction, passive treatment wall, air stripping, carbon adsorption, constructed wetland, etc. More than one technology may be associated with an individual alternative, depending on approach and media to be treated.

Exhibit 3-2 (cont.)
Capital Cost Element Checklist

Cost Element	Description	Example Sub-Elements
Professional/Technical Services		
Project Management	Services to support construction or installation of remedial action not specific to remedial design or construction management.	☐ Planning ☐ Community Relations ☐ Bid/Contract Administration ☐ Cost and Performance Reporting ☐ Permitting ☐ Legal ☐ Construction Completion Report ☐ ____________ ☐ ____________
Remedial Design	Services to design the remedial action, including pre-design activities to collect the necessary data.	☐ Field Data Collection and Analysis ☐ Design Survey ☐ Treatability Study __ Bench-Scale __ Pilot-Scale __ Field-Scale ☐ Preliminary/Intermediate/Final Design __ Design Analysis __ Plans & Specifications __ Construction Cost Estimate __ Construction Schedule ☐ ____________ ☐ ____________
Construction Management	Services to manage construction or installation of remedial action, excluding any similar services provided as part of construction activities.	☐ Submittal Review ☐ Change Order Review ☐ Design Modifications ☐ Construction Observation ☐ Construction Survey ☐ Construction Schedule Tracking ☐ QA/QC Documentation ☐ O&M Manual ☐ Record Drawings ☐ ____________ ☐ ____________
Institutional Controls	Non-engineering (i.e., administrative or legal) measures to reduce or minimize potential for exposure to site contamination or hazards (i.e., limit site access or restrict site access).	☐ Institutional Controls Plan ☐ Restrictive Covenants ☐ Zoning ☐ Property Easements ☐ Deed Notice ☐ Advisories ☐ Groundwater Use Restrictions ☐ Site Information Database ☐ ____________ ☐ ____________

Annual O&M Cost Elements

Annual operation and maintenance cost elements from the checklist in Exhibit 3-3 are listed below:

O&M Activities

- Monitoring, Sampling, Testing, and Analysis
- Extraction, Containment, or Treatment Systems
- Off-Site Treatment / Disposal
- Contingency

Professional/Technical Services

- Project Management
- Technical Support

Institutional Controls

The elements listed as O&M activities are incurred as part of physical operation and maintenance activities. Contingency covers unknowns or unanticipated conditions. Project management and technical support are professional/technical services to support O&M activities. Institutional controls may require annual update or maintenance to ensure potential for exposure to site contamination or hazards is reduced or minimized.

As with capital costs, the terminology for each element should be made alternative-specific, as applicable (see "Example" above).

Example Annual O&M Cost Element Structure

An example of how annual O&M cost elements and sub-elements might be structured for a remedial alternative that uses air sparging (AS), soil vapor extraction (SVE), and a passive treatment wall to treat contaminated soil and groundwater is as follows:

- Performance Monitoring
  - SVE Vapor Monitoring
  - SVE Emissions Monitoring
  - Treatment Wall – Groundwater Sampling
  - Treatment Wall – Groundwater Analysis
- Site Monitoring
  - Groundwater Sampling
  - Groundwater Laboratory Analysis
- Air Sparging / Soil Vapor Extraction
  - Operations Labor
  - Maintenance Labor
  - Equipment Repair
  - Utilities
- Off-Site Treatment/Disposal
  - Wastewater Discharge/Testing
- Project Management
- Technical Support
- Institutional Controls
  - Site Information Database

Annual O&M costs can vary and may be estimated for different time periods, depending on the operating conditions and requirements. For example, the first five years of a groundwater monitoring program may require semiannual sampling, while the next twenty years may only require annual sampling. Likewise, an installed cap or cover may require more frequent inspections during the first year of O&M than during subsequent years.

Costs of O&M activities are typically estimated on an element-by-element basis. Contractor markups such as overhead and profit should generally be included in these cost elements, rather than listed separately. Contingency (Chapter 5) is typically added as a percentage to the total cost of O&M activities. Professional/technical services are typically estimated as a percentage of the total cost of O&M activities plus contingency. Chapters 5 and 6 provide more information on development and documentation of annual O&M costs.

Exhibit 3-3
Annual O&M Cost Element Checklist

Cost Element	Description	Example Sub-Elements
<u>**O&M Activities**</u>		
Monitoring, Sampling, Testing, and Analysis[1]	Sampling, testing, on- or off-site analysis, data management, and quality assurance/quality control during the O&M period. Can include monitoring to evaluate remedy performance, compliance with regulations, or monitoring to track migration of contaminant plume.	☐ Meteorological Monitoring ☐ Air Monitoring and Sampling ☐ Radiation Monitoring ☐ Health and Safety Monitoring ☐ Personal Protective Equipment ☐ Monitoring Wells ☐ Soil Sampling ☐ Sediment Sampling ☐ Surface Water Sampling ☐ Groundwater Sampling ☐ Process Water Sampling ☐ Process Air Sampling ☐ Laboratory Chemical Analysis ☐ On-Site Chemical Analysis ☐ Chemical Data Management ☐ ____________________ ☐ ____________________
Extraction, Containment, or Treatment Systems[2]	Operation and maintenance of on-site systems to extract, contain, or treat contaminated media (e.g., soil, sediment, sludge, surface water, groundwater).	☐ Operations Labor ☐ Maintenance Labor ☐ Equipment Upgrade/Replacement/Repair ☐ Spare Parts ☐ Equipment Ownership/Rental/Lease ☐ Consumable Supplies ☐ Bulk Chemicals ☐ Raw/Process Materials ☐ Utilities ☐ ____________________ ☐ ____________________

[1] Site monitoring, performance monitoring, or compliance monitoring.

[2] Specify extraction, containment, or treatment system. Examples include groundwater extraction system, engineered cap or cover, soil vapor extraction system, groundwater treatment facility, etc. More than one system may be associated with an individual alternative.

Exhibit 3-3 (cont.)
Annual O&M Cost Element Checklist

Cost Element	Description	Example Sub-Elements
O&M Activities (cont.)		
Off-Site Treatment / Disposal	Treatment and/or disposal of wastes generated during operation and maintenance (e.g., on-site treatment residuals, monitoring wastes) at off-site commercial facilities, such as solid or hazardous waste landfills and incinerators.	☐ Material Handling/Loading ☐ Transportation to Off-Site Facility ☐ Treatment/Disposal Fees ☐ ____________ ☐ ____________
Contingency	Costs to cover unknowns, unforeseen circumstances, or unanticipated conditions associated with annual O&M of the remedial action.	☐ Scope Contingency ☐ Bid Contingency
Professional/Technical Services		
Project Management	Services to manage O&M activities not specific to technical support listed below.	☐ Planning ☐ Community Relations ☐ Cost and Performance Reporting ☐ Permitting ☐ Legal ☐ ____________ ☐ ____________
Technical Support	Services to monitor, evaluate, and report progress of remedial action.	☐ O&M Manual Updates ☐ O&M Oversight ☐ Progress Reports ☐ ____________ ☐ ____________
Institutional Controls	Annual update or maintenance of non-engineering measures to reduce or minimize potential for exposure to site contamination or hazards.	☐ Institutional Controls Plan ☐ Restrictive Covenants ☐ Zoning ☐ Property Easements ☐ Deed Notice ☐ Advisories ☐ Groundwater Use Restrictions ☐ Site Information Database ☐ ____________ ☐ ____________

Periodic Cost Elements

Periodic cost elements from the checklist in Exhibit 3-4 are listed below:

Construction / O&M Activities

- Remedy Failure or Replacement
- Demobilization of On-Site Extraction, Containment, or Treatment Systems
- Contingency

Professional/Technical Services

- Five Year Reviews
- Groundwater Performance and Optimization Study
- Remedial Action Report

Institutional Controls

Example Periodic Cost Element Structure

An example of periodic cost elements and sub-elements that might apply for a remedial alternative that uses air sparging (AS), soil vapor extraction (SVE), and a passive treatment wall is as follows:

- Five Year Reviews
- Demobilization of AS/SVE System
- Well Abandonment
- Remedial Action Report
- Update Institutional Controls Plan

Contingency is typically applied to the total of construction/O&M activities cost elements for the year in which they occur. Professional/technical services are typically estimated on an element-by-element basis, rather than as a percentage, for periodic costs. Chapters 5 and 6 provide more information on development and documentation of periodic costs.

Exhibit 3-4
Periodic Cost Element Checklist

Cost Element	Description	Example Sub-Elements
<u>Construction/O&M Activities</u>		
Remedy Failure or Replacement	Construction activity to replace an installed remedy or key components of the remedy.	☐ Mobilization/Demobilization ☐ Site Work ☐ Structures ☐ Process Equipment and Appurtenances ☐ Non-Process Equipment ☐ Startup and Testing ☐ ________________ ☐ ________________
Demobilization of On-Site Extraction, Containment, or Treatment Systems[1]	Construction activity to dismantle or take down extraction, containment, or treatment facilities or equipment upon completion of remedial action.	☐ Demolition and Removal ☐ Well Abandonment ☐ ________________ ☐ ________________
Contingency	Costs to cover unknowns, unforeseen circumstances, or unanticipated conditions associated with construction/O&M activities.	☐ Scope Contingency ☐ Bid Contingency
<u>Professional/Technical Services</u>		
Five Year Reviews	Services to prepare five-year review reports (if hazardous substances, pollutants, or contaminants remain on-site above levels that allow for unrestricted use and unlimited exposure).	☐ Site Visit ☐ Field Data Collection ☐ Data Review and Analysis ☐ Report Preparation ☐ ________________ ☐ ________________
Groundwater Performance and Optimization Study	Services to analyze and optimize on-going groundwater pump and treat systems.	☐ Site Visit ☐ Field Data Collection ☐ Data Review and Analysis ☐ Report Preparation ☐ ________________ ☐ ________________

[1] Specify extraction, containment, or treatment system. Examples include groundwater extraction system, soil vapor extraction system, groundwater treatment facility, etc. More than one system may be associated with an individual alternative.

Exhibit 3-4 (cont.)
Periodic Cost Element Checklist

Cost Element	Description	Example Sub-Elements
Professional/Technical Services (cont.)		
Remedial Action Report	Services to prepare remedial action report upon completion of remedial action.	☐ Site Visit ☐ Field Data Collection ☐ Data Review and Analysis ☐ Report Preparation ☐ ______ ☐ ______
Institutional Controls	Periodic update or maintenance of non-engineering measures to reduce or minimize potential for exposure to site contamination or hazards.	☐ Institutional Controls Plan ☐ Restrictive Covenants ☐ Zoning ☐ Property Easements ☐ Deed Notice ☐ Advisories ☐ Groundwater Use Restrictions ☐ Site Information Database ☐ ______ ☐ ______

Chapter Four
Present Value Analysis

Remedial action projects typically involve construction costs that are expended at the beginning of a project (e.g., capital costs) and costs in subsequent years that are required to implement and maintain the remedy after the initial construction period (e.g., annual O&M costs, periodic costs). Present value analysis is a method to evaluate expenditures, either capital or O&M, which occur over different time periods. This standard methodology allows for cost comparisons of different remedial alternatives on the basis of a single cost figure for each alternative. This single number, referred to as the present value, is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as they are needed, assuming certain economic conditions (see "Present Value Basics" to right).[1]

A present value analysis of a remedial alternative involves four basic steps:

1. Define the period of analysis.
2. Calculate the cash outflows (payments) for each year of the project.
3. Select a discount rate to use in the present value calculation.
4. Calculate the present value.

The following chapter sections describe the general requirements for each of these steps.

4.1 Define the Period of Analysis

The period of analysis is the period of time over which present value is calculated. In general, the period of analysis should be

Present Value Basics

The present value (PV) of a future payment is calculated using the following equation:

$$PV = \frac{x_t}{(1+i)^t}$$

where x_t is the payment in year t ($t = 0$ for present or base year) and i is the discount rate. For example, suppose one needs to make a $1,000 payment in Year 5. Using a discount rate of 5%, the present value would be:

$$= \frac{\$1,000}{(1+0.05)^5} = \$783$$

Therefore, $783 would need to be set aside or invested in Year 0, at a discount or interest rate of 5%, in order to have $1,000 in Year 5.

For a stream or series of future payments, the total present value from 1 to n years would be calculated as:

$$PV_{total} = \sum_{t=1}^{t=n} \frac{x_t}{(1+i)^t}$$

If a $1,000 payment is needed for each of the next five years, then the total present value of these payments, at a discount rate of 5%, would be:

$$= \sum_{t=1}^{t=5} \frac{\$1,000}{(1+0.05)^t} = \$4,329$$

Therefore, $4,329 would need to be set aside in Year 0 to make a $1,000 payment in each of the next five years.

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[1] This guide uses primarily "present value," although "net present value" and "present worth" are other commonly used terms.

equivalent to the project duration, resulting in a complete life cycle cost estimate for implementing the remedial alternative. The project duration generally begins with the planning, design, and construction of the remedial alternative, continues through short- and long-term O&M, and ends with project completion and closeout. Each remedial alternative may have a different project duration. For example, one alternative may have a two-year construction period and no future O&M. Another alternative may have no construction period and many years of O&M.

Past USEPA guidance recommended the general use of a 30-year period of analysis for estimating present value costs of remedial alternatives during the FS (USEPA 1988). While this may be appropriate in some circumstances, and is a commonly made simplifying assumption, the blanket use of a 30-year period of analysis is not recommended. Site-specific justification should be provided for the period of analysis selected, especially when the project duration (i.e., time required for design, construction, O&M, and closeout) exceeds the selected period of analysis.[2]

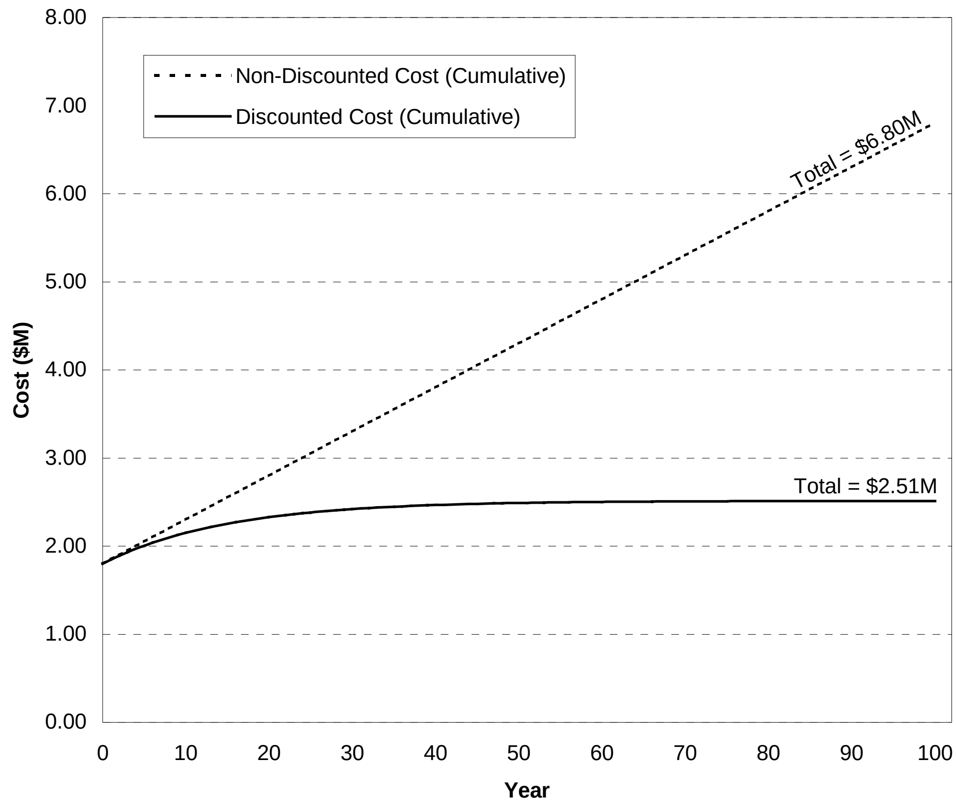
For long-term projects (e.g., project duration exceeding 30 years), it is recommended that the present value analysis include a "no discounting" scenario. A non-discounted constant dollar cash flow over time demonstrates the impact of a discount rate on the total present value cost and the relative amounts of future annual expenditures. Non-discounted constant dollar costs are presented for comparison purposes only and should not be used in place of present value costs in the Superfund remedy selection process. Exhibit 4-1 illustrates the impact of discounting for an example with a $1,800,000 initial capital cost and a $50,000 annual O&M cost spread out over 100 years at a discount rate of 7 percent. Section 4.4 provides more information on how the period of analysis is used in calculating present value.

- ***The period of present value analysis should not necessarily be limited to the commonly-used assumption of 30 years. Explanation should be provided whenever the period of analysis is less than the estimated project duration.***

[2] For example, a radioactive waste containment facility may require a 10,000-year design life (i.e., project duration) in order to protect human health and the environment, but the period of analysis for the cost estimate may be bounded at 1,000 years for calculation purposes.

Exhibit 4-1

Non-Discounted vs. Discounted Costs for an Example Project with a 100 Year Duration



4.2 Calculate Annual Cash Outflows

The second step of the present value analysis is to add up the capital and O&M cash outflows for each year of the project (i.e., annual cash outflow). These include capital costs to construct the remedial alternative, annual O&M costs to operate and maintain the remedial alternative over its planned life, and periodic costs for those capital or O&M costs that occur only once every few years. Usually, most or all of the capital costs are expended during the construction and startup of the project, before annual O&M begins. Although the present value of periodic costs is small for those that occur near the end of the project duration (e.g., closeout costs), these costs should be included in the present value analysis. See Chapter 3 for a complete discussion of capital and O&M cost elements for which annual cash outflows should be calculated.

Most FS cost analyses begin with a simplifying assumption that the duration of initial construction and startup will be less than one year (i.e., construction work will occur in "year zero" of the project). This "year zero" assumption can be modified if a preliminary project schedule has been developed and it is known that capital construction costs will be expended beyond one year.

☞ ***For FS present value analyses, most capital costs are assumed to occur in Year 0.***

Annual cash outflows for FS present value analyses should be estimated in constant dollars, denominated in terms of the base year (i.e., Year 0). Constant dollars, also called "real dollars," are not affected by general price inflation (i.e., they represent "units of stable purchasing power"). Thus, the cost of a particular good or service would be the same in Year 0, Year 1, Year 2, etc.

☞ ***Constant dollars, or "real dollars," are used for the present value analysis (i.e., no adjustment is made for inflation).***

The results of this step in the present value analysis should be an array of all costs in constant dollars for each year of the project, as shown by the example in Exhibit 4-2.

Exhibit 4-2
Example Array of Constant Dollar Costs for Present Value Analysis

Year	Capital Costs ($)	Annual O&M Costs ($)	Periodic Costs ($)	Total Cost ($)
0	1,800,000	0	0	1,800,000
1	0	50,000	0	50,000
2	0	50,000	0	50,000
3	0	50,000	0	50,000
4	0	50,000	0	50,000
5	0	50,000	10,000	60,000
6	0	50,000	0	50,000
7	0	50,000	0	50,000
8	0	50,000	0	50,000
9	0	50,000	0	50,000
10	0	50,000	50,000	100,000

4.3 Select a Discount Rate

The third step in the present value analysis is to select a discount rate. A discount rate, which is similar to an interest rate, is used to account for the time value of money. A dollar is worth more today than in the future because, if invested in an alternative use today, the dollar could earn a return (i.e., interest). Thus, discounting reflects the productivity of capital. If the capital were not employed in a specific use, it would have productive value in alternative uses. The choice of a discount rate is important because the selected rate directly impacts the present value of a cost estimate, which is then used in making a remedy selection decision. The higher the discount rate, the lower the present value of the cost estimate.

USEPA policy on the use of discount rates for RI/FS cost analyses is stated in the preamble to the NCP (55 FR 8722) and in Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20 entitled "*Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis*" (USEPA 1993). Based on the NCP and this directive, a discount rate of 7% should be used in developing present value cost estimates for remedial action alternatives during the FS. This specified rate of 7% represents a "real" discount rate in that it approximates the marginal pretax rate of return on an average investment in the private sector in recent years and has been adjusted to eliminate the effect of expected inflation. Therefore, this rate should be used with "constant" or "real" dollars that have not been adjusted for inflation (i.e., a dollar spent in future years is worth the same as a dollar spent in the present year), which is the typical situation for RI/FS cost analyses.

The 7% discount rate was established through an economic analysis performed by the Office of Management and Budget (OMB). USEPA's policy regarding the use of discount rates in present value calculations performed during the FS will be reevaluated periodically or when OMB updates Circular A-94.[3] Any changes to this policy will be contained in an update of OSWER Directive 9355.3-20, which can be found at *http://www.epa.gov/superfund/*.

OMB Circular A-94

The Office of Management and Budget (OMB) Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs*, provides guidance for the use of discount rates in economic analyses performed by the Federal government. The circular is available at *http://www.whitehouse.gov/OMB/circulars/a094/a094.html* or by contacting the OMB publications office at (202) 395-7332.

Appendix C of OMB Circular A-94, which contains discount rates that may be applicable to Federal facility sites, is updated annually in January/February.

There may be circumstances in which it would be appropriate to consider the use of a lower or higher discount rate than 7% for the FS present value analysis. If a different discount rate is selected for the analysis, a specific explanation should be provided. For cost estimates that have large future year expenditures or where the discount rate assumption is a sensitive cost factor, a sensitivity analysis can be performed to evaluate the impacts of the discount rate assumption on the present value cost. See Chapter 5 for a more complete discussion of sensitivity analyses.

For Federal facility sites being cleaned up using Superfund authority, it is generally appropriate to apply the real discount rates found in Appendix C of OMB Circular A-94. These rates, which are also used in the President's annual budget submission to Congress, are based on interest rates from Treasury notes and bonds. Because the Federal government has a different "cost of capital" than the private sector, these rates are appropriate to use for adjusting future year expenditures in a present value calculation for Federal facility remediation projects. Although an analogous situation exists for Federal-lead sites that will be cleaned up by USEPA using the Superfund trust fund (i.e., Fund-lead sites), there is always a chance that the site will actually be remediated by a private, or "potentially-responsible," party (i.e., PRP-lead cleanup). Therefore, the 7% discount rate should generally be used in calculating net present value costs for all non-Federal facility sites.

- ***A real discount rate of 7 percent should generally be used for all non-Federal facility sites. Real discount rates from Appendix C of OMB Circular A-94 should generally be used for all Federal facility sites.***

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[3] Appendix C of OMB Circular A-94 is updated on an annual basis around the time of the President's budget submission to Congress (i.e., January/February timeframe). However, the 7% discount rate contained in the main portion of the circular is not updated on an annual basis.

For FS cost analyses, the same discount rate should be used in evaluating all remedial alternatives for a site, even if the period of analysis differs from one to another. Exhibit 4-3 shows a present value comparison of six remedial alternatives with varying amounts of initial capital costs, annual O&M costs, and years of analysis. Alternative F has the second highest total cost in base year dollars, but the lowest present value cost. This is because much of its total costs are in the future, which become quite small after the discount rate is applied. The cost of Alternative C is less than that of alternative D, but its present value is higher, since it has large upfront capital costs. This example illustrates the effect of varying initial capital cost, annual O&M costs, and period of analysis on the present value cost of alternatives.

☞ ***The same discount rate should be used for all remedial alternatives, even if the period of analysis varies from one to another.***

Exhibit 4-3
Comparison of Present Value of Six Remedial Alternatives

Remedial Alternative	Initial Capital Cost ($000)	Annual O&M Cost ($000)	Period of Analysis* (Years)	Total Cost ($000)	Present Value at 7% ($000)
Alternative A	0	0	0	0	0
Alternative B	3,650	583	15	12,400	8,960
Alternative C	10,800	548	30	27,200	17,600
Alternative D	2,850	696	50	37,700	12,500
Alternative E	5,500	230	80	23,900	8,770
Alternative F	2,000	120	220	28,400	3,710

* In this example, the period of analysis is the same as project duration.

4.4 Calculate the Present Value

The last step is to calculate the present value. The present value of a remedial alternative represents the sum of the present values of all future payments associated with the project. For example, if the project will entail capital and O&M costs each year for 12 years, the present value is the sum of the present values of each of the 12 payments, or expenditures.

The present value of a future payment is the actual value that will be disbursed, discounted at an appropriate rate of interest. Present value for payment x_t in year t at a discount rate of i is calculated as follows:

$$PV = \frac{1}{(1+i)^t} \cdot x_t$$

The first operand in this equation, $1/(1+i)^t$, can be referred to as a "discount factor." Exhibit 4-4 provides annual discount factors at a rate of 7% for up to 200 years. Exhibit 4-5 illustrates the use of these factors for a remedial alternative with construction costs of $1,800,000 in Year 0, annual O&M costs of $50,000 for ten years, and periodic costs of $10,000 in Years 5 and 10 and $40,000 in Year 10.[4]

Exhibit 4-4
Annual Discount Factors at 7%

Year	Factor	Year	Factor	Year	Factor	Year	Factor	Year	Factor
1	0.935	23	0.211	45	0.0476	67	0.0107	89	0.00243
2	0.873	24	0.197	46	0.0445	68	0.0100	90	0.00227
3	0.816	25	0.184	47	0.0416	69	0.00939	91	0.00212
4	0.763	26	0.172	48	0.0389	70	0.00877	92	0.00198
5	0.713	27	0.161	49	0.0363	71	0.00820	93	0.00185
6	0.666	28	0.150	50	0.0339	72	0.00766	94	0.00173
7	0.623	29	0.141	51	0.0317	73	0.00716	95	0.00162
8	0.582	30	0.131	52	0.0297	74	0.00669	96	0.00151
9	0.544	31	0.123	53	0.0277	75	0.00625	97	0.00141
10	0.508	32	0.115	54	0.0259	76	0.00585	98	0.00132
11	0.475	33	0.107	55	0.0242	77	0.00546	99	0.00123
12	0.444	34	0.100	56	0.0226	78	0.00511	100	0.00115
13	0.415	35	0.0937	57	0.0211	79	0.00477	110	0.000586
14	0.388	36	0.0875	58	0.0198	80	0.00446	120	0.000298
15	0.362	37	0.0818	59	0.0185	81	0.00417	130	0.000151
16	0.339	38	0.0765	60	0.0173	82	0.00390	140	0.0000770
17	0.317	39	0.0715	61	0.0161	83	0.00364	150	0.0000391
18	0.296	40	0.0668	62	0.0151	84	0.00340	160	0.0000199
19	0.277	41	0.0624	63	0.0141	85	0.00318	170	0.0000101
20	0.258	42	0.0583	64	0.0132	86	0.00297	180	0.00000514
21	0.242	43	0.0545	65	0.0123	87	0.00278	190	0.00000261
22	0.226	44	0.0509	66	0.0115	88	0.00260	200	0.00000133

Annual discount factor $= \frac{1}{(1+i)^t}$ where i = 0.07 and t = year (i.e., the present value of one dollar paid in year t at 7%)

[4] For present value analyses during the FS, distinction is generally not made as to what time of the year the total cost for each year is incurred (e.g., beginning, middle, or end). This simplifying assumption would not necessarily be used for budgeting purposes, but is appropriate for FS cost estimating purposes.

Exhibit 4-5
Example Present Value Calculation for a Remedial Alternative

Year	Capital Costs ($)	Annual O&M Costs ($)	Periodic Costs ($)	Total Cost ($)	Discount Factor at 7%	Total Present Value Cost at 7% ($)
0	1,800,000	0	0	1,800,000	1.000	1,800,000
1	0	50,000	0	50,000	0.935	46,800
2	0	50,000	0	50,000	0.873	43,700
3	0	50,000	0	50,000	0.816	40,800
4	0	50,000	0	50,000	0.763	38,200
5	0	50,000	10,000	60,000	0.713	42,800
6	0	50,000	0	50,000	0.666	33,300
7	0	50,000	0	50,000	0.623	31,200
8	0	50,000	0	50,000	0.582	29,100
9	0	50,000	0	50,000	0.544	27,200
10	0	50,000	50,000	100,000	0.508	50,800
Total	1,800,000	560,000		2,360,000	-	2,180,000

For a stream or series of payments from 1 to *n* years, the total present value is:

$$PV_{total} = \sum_{t=1}^{t=n} \frac{1}{(1+i)^t} \cdot x_t$$

When the annual cost, x_t, is constant over a period of years, beginning at Year 1, the calculations can be simplified by using a multi-year discount factor, which is the sum of the first operand in the above equation. Exhibit 4-6 provides multi-year discount factors at a rate of 7% for up to 200 years, as well as the formula to calculate multi-year discount factors at discount rates other than 7%. For example, the factor for 30 years at 7% is 12.409. Thus, the present value of $1,000 per year for 30 years is $1,000 x 12.409 = $12,400.

Exhibit 4-6
Multi-Year Discount Factors at 7%

Years	Factor	Years	Factor	Years	Factor	Years	Factor
1	0.935	29	12.278	57	13.984	85	14.240
2	1.808	30	12.409	58	14.003	86	14.243
3	2.624	31	12.532	59	14.022	87	14.246
4	3.387	32	12.647	60	14.039	88	14.249
5	4.100	33	12.754	61	14.055	89	14.251
6	4.767	34	12.854	62	14.070	90	14.253
7	5.389	35	12.948	63	14.084	91	14.255
8	5.971	36	13.035	64	14.098	92	14.257
9	6.515	37	13.117	65	14.110	93	14.259
10	7.024	38	13.193	66	14.121	94	14.261
11	7.499	39	13.265	67	14.132	95	14.263
12	7.943	40	13.332	68	14.142	96	14.264
13	8.358	41	13.394	69	14.152	97	14.266
14	8.745	42	13.452	70	14.160	98	14.267
15	9.108	43	13.507	71	14.169	99	14.268
16	9.447	44	13.558	72	14.176	100	14.269
17	9.763	45	13.606	73	14.183	110	14.277
18	10.059	46	13.650	74	14.190	120	14.281
19	10.336	47	13.692	75	14.196	130	14.284
20	10.594	48	13.730	76	14.202	140	14.285
21	10.836	49	13.767	77	14.208	150	14.285
22	11.061	50	13.801	78	14.213	160	14.285
23	11.272	51	13.832	79	14.218	170	14.286
24	11.469	52	13.862	80	14.222	180	14.286
25	11.654	53	13.890	81	14.226	190	14.286
26	11.826	54	13.916	82	14.230	200	14.286
27	11.987	55	13.940	83	14.234		
28	12.137	56	13.963	84	14.237		

Multi-year discount factor $= \sum_{t=1}^{t=n} \frac{1}{(1+i)^t} = \frac{(1+i)^n - 1}{i(1+i)^n}$, where i = 0.07, t = year, and n = total years

(i.e., the present value of one dollar paid per year from 1 to *n* years at 7%)

NOTE: These factors only apply when annual costs are constant.

Multi-year factors shown in Exhibit 4-6 cannot be used when periodic costs are added to the annual O&M cost for the years in which they occur. In cases like these, when future expenditures are not constant from year to year, discount factors taken from Exhibit 4-4 (or other list of factors if 7% is not used) should be applied to each future year's expenditure to convert into present value.

As Exhibits 4-4 and 4-6 indicate, discounted values of even large costs incurred far in the future tend to be negligible. For example, for a 200-year project with constant annual costs of $500,000 at 7%, 99.9% of the discounted O&M costs are incurred in the first 100 years, 97% in the first 50 years, and 88% in the first 30 years. The period of present value analysis, however, should not be shortened to less than the project duration (Section 4.1), particularly when O&M costs are significant, or when major costs, such as replacement or corrective maintenance, are expected to occur in the future. In addition, evaluation of a "no discounting" scenario would be recommended pursuant to discussion in Section 4.1.

In addition to calculating discount factors as shown in Exhibits 4-4 and 4-6, present value can be calculated using functions found in many spreadsheet software programs. For example, the PV function in Excel can be used to calculate the present value of a series of future payments by providing the interest rate, total number of payments, and payment made each period. When using spreadsheet functions or formulas, it is important that calculations be independently checked to ensure that the functions are being applied correctly.

Chapter Five
How to Develop the Cost Estimate

This chapter presents steps to develop a basic cost estimate for a remedial alternative during the FS. Although a variety of estimating methods or tools may be utilized, these steps follow a general activity-based approach, where the cost estimate is divided into discrete, quantifiable activities or elements for each alternative. The steps are as follows:

1. Describe the alternative.
2. Identify the cost element structure for capital, annual O&M, and periodic costs.
3. Estimate construction/O&M activities costs.
4. Apply contingency.
5. Estimate professional/technical services costs.
6. Estimate institutional controls costs, if applicable.
7. Conduct present value analysis.
8. If appropriate, conduct a sensitivity analysis.
9. Review estimate.

These steps are presented as a flowchart in Exhibit 5-1 and described in further detail in the following chapter sections.

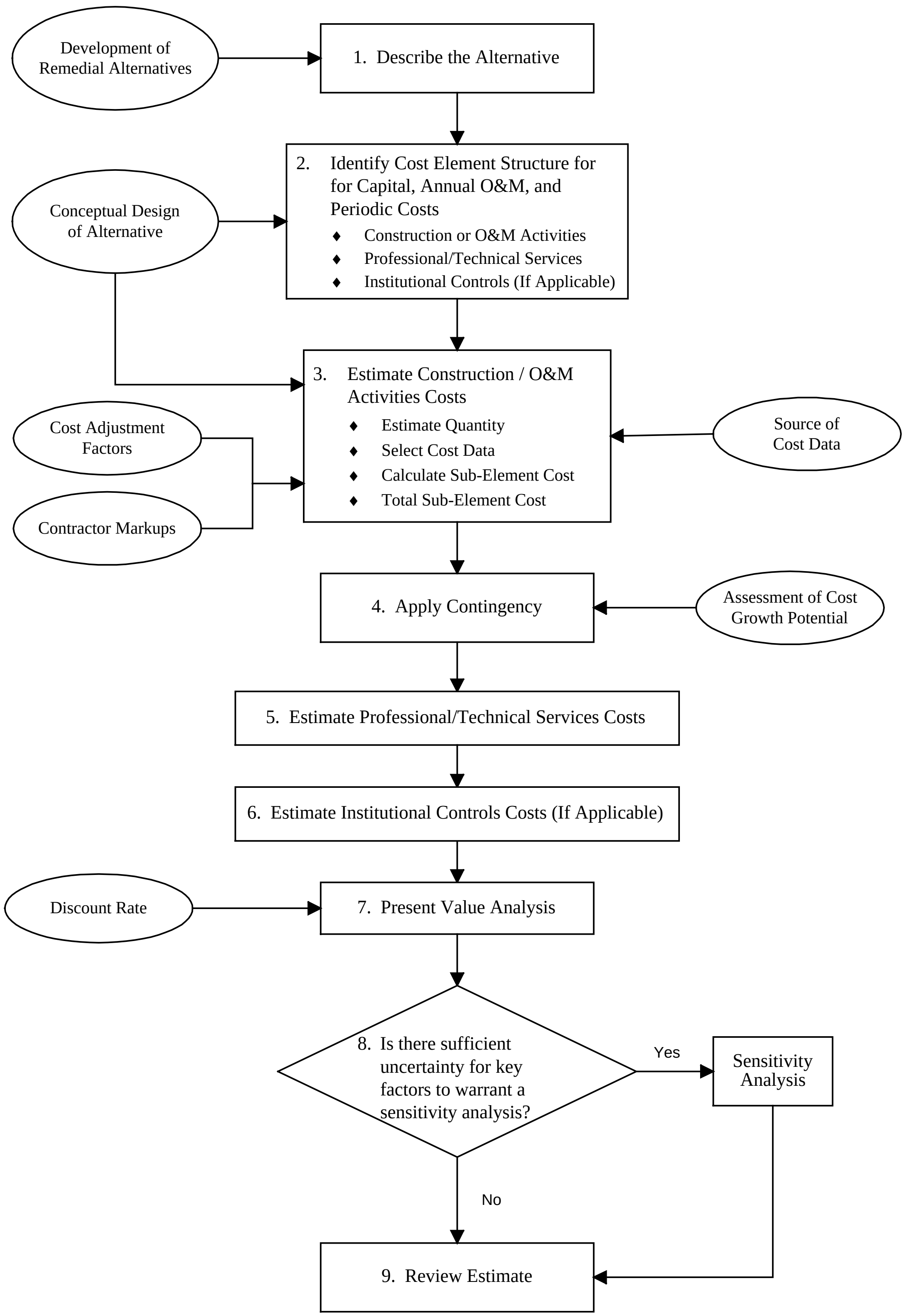
> **Types of Cost Estimating Methods**
>
> Two main types of methods used to estimate the cost of remedial alternatives are the detailed and parametric approach.
>
> The detailed approach estimates costs on an item-by-item basis. Detailed methods typically rely on quantity take-offs and compiled sources of unit cost data for each item, taken from either a built-in database (if part of a software package, for example) or other sources (e.g., cost estimating references). This method, also known as "bottom up" estimating, is used when design information is available.
>
> The parametric approach relies on relationships between cost and design parameters. These relationships are usually "statistically-based" or "model-based." Statistically-based approaches rely on "scaled-up" or "scaled-down" versions of projects where historical cost data is available. Model-based approaches utilize a generic design that is linked to a cost database and adjusted by the user for site-specific information. This method, also known as "top down" estimating, is used when design information is not available.
>
> Some resources that utilize these methods can be found in Appendix A.

5.1 Describe the Alternative

As the first step in development of the cost estimate, the remedial alternative should be described in general terms. An example of a descriptive narrative for an alternative that utilizes the technologies of air sparging, soil vapor extraction, and passive treatment wall is as follows:

> "Alternative 3 consists of air sparging and soil vapor extraction to treat soil and groundwater contaminated with volatile organic compounds in the source area. Also includes a passive treatment wall along the leading edge of the plume to treat groundwater migrating off-site. Capital costs occur in Year 0. Annual O&M costs occur in Years 1-15. Periodic costs occur in Years 5, 10, and 15."

Exhibit 5-1
Steps to Develop a Basic Cost Estimate for a Remedial Alternative



In addition to the above, the name and location of the site, phase of project (e.g., FS), and date of estimate preparation should be noted. The remedial alternative, as part of the alternative development process, will typically be described in greater detail in the body of the FS report. This detail should state remedial action objectives, including cleanup goals. At the time the estimate is developed, a conceptual design of the remedial alternative should have been completed or should be in progress. The identification of the cost element structure (Step 2), as well as estimation of quantities (included in Step 3), is directly related to the conceptual design of the alternative (i.e., level of project definition). The narrative, as shown in the above example, is not meant to describe every detail of the alternative, but provide a point of reference for developing the cost estimate.

5.2 Identify Cost Element Structure

Following the description, the second step is to identify the cost element structure for the alternative. A separate structure should be identified for capital, annual O&M, and periodic costs. This can be done with the help of checklists presented in Chapter 3 or standard work breakdown structures. For capital, annual O&M, and periodic cost element structures, the following steps apply:

1. Identify construction or O&M activities cost elements.
2. Identify professional/technical services cost elements.
3. Identify institutional controls cost elements, if applicable.

Construction or O&M activities include labor, equipment, and material costs for the contractor constructing the remedial action or for the contractor operating, maintaining, and/or monitoring the remedial action. Sub-elements should be identified, as required, to adequately describe each construction or O&M activity.

Professional/technical services support construction or operation and maintenance of the remedial action. Sub-elements for professional/technical services costs may be identified, as appropriate. Institutional controls can be a one-time (e.g., capital) or recurring cost (e.g., annual O&M, periodic). Sub-elements should generally be identified for institutional controls, as appropriate.

An example cost element structure for a remedial alternative that utilizes the technologies of air sparging (AS), soil vapor extraction (SVE), and a passive treatment wall is shown in Exhibit 5-2.

Exhibit 5-2
Example Cost Element Structure

Capital Costs

- Mobilization / Demobilization

  Construction Equipment and Facilities
  Submittals/Implementation Plans
  Temporary Facilities & Utilities
  Post-Construction Submittals

- Monitoring, Sampling, Testing, and Analysis

  SVE Monitoring Wells
  Treatment Wall Monitoring Wells

- Site Work

  Clearing and Grubbing
  Seeding/Mulch/Fertilizer

- Air Sparging / Soil Vapor Extraction

  Mobilize SVE System
  AS Injection Wells
  AS Blower
  AS Piping
  SVE System
  SVE Extraction Wells
  SVE Piping
  Electrical Hookup
  Startup and Testing

- Passive Treatment Wall

  Construct Slurry Trench
  Install Reactive Media

- Off-Site Treatment/Disposal

  Off-Site Transport of Soil Cuttings
  Off-Site Disposal of Soil Cuttings
  Wastewater Discharge/Testing

- Project Management
- Remedial Design
- Construction Management
- Institutional Controls

  Institutional Controls Plan
  Groundwater Use Restriction
  Site Information Database

Annual O&M Costs

- Performance Monitoring

  SVE Vapor Monitoring
  SVE Emissions Monitoring
  Treatment Wall - Groundwater Sampling
  Treatment Wall - Groundwater Analysis

- Site Monitoring

  Groundwater Sampling
  Groundwater Laboratory Analysis

- Air Sparging / Soil Vapor Extraction

  Operations Labor
  Maintenance Labor
  Equipment Repair
  Utilities

- Off-Site Treatment/Disposal

  Wastewater Discharge/Testing

- Project Management
- Technical Support
- Institutional Controls

  Site Information Database

Periodic Costs

- Five Year Reviews
- Demobilization of AS/SVE System
- Well Abandonment
- Remedial Action Report
- Update Institutional Controls Plan

5.3 Estimate Construction/O&M Activities Costs

Following the description and identification of cost element structure, the cost of each construction or O&M activity is estimated. If the cost element is broken down into sub-elements, the cost of each sub-element should be estimated and then added for a cost element subtotal. The steps in this process include:

1. Estimate quantity.
2. Select cost data.
3. Calculate sub-element cost, including adjustments and application of markups.
4. Total sub-element costs.

These steps are described in more detail below.

Estimate Quantity

The estimation of quantities is directly related to the quality and quantity of site characterization data. For example, the estimated quantity of soil or groundwater contaminated above a cleanup goal or action level (i.e., quantity to be "cleaned up") is dependent upon data collected during the RI to determine nature and extent of contamination. Likewise, the estimated soil vapor extraction rate or groundwater pumping rate is dependent on the methods used to estimate air permeability or hydraulic conductivity (e.g., estimated values based on soil type, field pumping tests), as well as the operating capacity of the equipment (e.g., sizing of pumps, blowers, etc.). Other factors can affect the quantity estimate, such as the expected "swell" or "fluff" in volume of excavated material for an ex situ soil cleanup and the anticipated number of aquifer volumes to remove for an ex situ groundwater cleanup.

Quantity calculations used to support a cost estimate should be adequately documented. Supporting information can include boring logs, chemical analysis results, and scaled drawings to show lateral and vertical extent of contamination and to estimate physical characteristics such as porosity and dry unit weight which affect the quantity estimate. Assumptions used to estimate quantities should be clearly presented.

Using the example cost element structure shown in Exhibit 5-2, example quantities for capital costs would be the number of SVE monitoring wells, acres of clearing and grubbing, lineal feet of SVE piping, cubic yards of reactive media, etc. Example quantities for annual O&M costs would be the number of groundwater sampling events for site monitoring, number of months of operations labor for the AS/SVE system, etc.

Select Cost Data

Cost data can be selected from a variety of sources, including:

- Cost estimating guides/references
- Vendor or contractor quotes

- Experience with similar projects
- Cost estimating software/databases

Cost estimating guides or references (e.g., unit price books) can provide costs for a wide variety of construction activities, including those related to remedial actions. Some guides are specifically tailored to estimate costs for environmental remediation projects. Cost data in these references are sometimes broken down into labor, equipment, and material categories, and may or may not include contractor markups. Generally, each cost is associated with a specific labor and equipment crew and production rate. Costs are typically provided on a national average basis for the year of publication of the reference. Some of these guides or references are listed in Appendix A.

Quotes from vendors or construction contractors can provide costs that are more site-specific in nature than costs taken from standard guides and references. These quotes usually include contractor markups and are usually provided as a total cost rather than categorized as labor, equipment, or materials. If possible, more than one vendor quote should be obtained. Quotes from multiple sources can be averaged, or the highest quote can be used in the cost estimate if the collected quotes seem to be at the low end of the industry range. Vendors or contractors can also be an important source of design-related information, including operating capacity, production rates, operating life, and maintenance schedules that may have implications for O&M costs.

Experience with similar projects, including both estimates and actual costs, can also be used as a source of cost data. Engineering judgement should be exercised where cost data taken from another project needs to be adjusted to take into account site- or technology-specific parameters. Sources of actual cost data from government remediation projects are maintained by various Federal agencies. These sources include the Historical Cost Analysis System (HCAS) (*http://www.frtr.gov/cost/ec2/index.html*) and Federal Remediation Technologies Roundtable (FRTR) cost and performance reports (*http://www.frtr.gov/cost/*). HCAS and the FRTR reports are two initiatives that are currently being used to collect and record treatment technology costs in a standardized format. Some of these sources of historical cost data are listed in Appendix A.

Cost estimating software and databases can also be used as sources of cost data. The majority of available software tools are designed to estimate the cost for all or selected cost elements of an alternative. Government-sponsored software tools include Micro Computer Aided Cost Engineering System (MCACES), which is used by the U.S. Army Corps of Engineers and is linked to the Unit Price Book (UPB) database (*http://www.hnd.usace.army.mil/traces/*), and the Remedial Action Cost Engineering and Requirements (RACER), which is sponsored by the U.S. Air Force (*http://www.talpart.com/products/racer/index.html*). Some of these software or databases, both private and publicly sponsored, are listed in Appendix A.

Calculate Sub-Element Cost

Calculating the cost of each sub-element consists of calculating a unit cost from a source of cost data, including adjustments for site- or project-specific factors, and multiplying by the estimated quantity. Adjustments may include the following:

- ♦ Apply productivity factors per health and safety level of protection
- ♦ Escalate costs to base year of estimate
- ♦ Apply area cost factors
- ♦ Add contractor markups

As the level of health and safety protection (e.g., personal protective equipment, monitoring requirements) is increased, productivity is decreased and costs are increased. For applicable cost elements, factors that reflect decreased productivity due to required health and safety levels of protection should be applied to labor and equipment costs. More information on productivity factors and how to apply them is provided in Appendix B.

Health and Safety Impacts

Factors that may affect both capital and O&M cost elements due to health and safety precautions include:

- ♦ Decontamination facilities and operations
- ♦ Protective equipment cost and disposal
- ♦ Additional labor for health and safety personnel
- ♦ Rest periods required to prevent heat stress or cold weather impacts
- ♦ Time to suit-up, decontaminate, and change air tanks
- ♦ Personnel training
- ♦ Health and safety briefings and meetings

Some of these costs can be accounted for in overhead or specific cost elements. How to account for the impacts of health and safety level of protection on labor and equipment productivity is described in Appendix B.

Unit costs that are obtained from sources that are one year old or more need to be updated or escalated to the base year, which is usually the current year. This can be done using escalation factors as described in Appendix B.

Area cost factors should be applied to unit costs from sources based on a national average (e.g., standard cost guides) or from other geographic locations (e.g., similar projects). Area cost factors are further described in Appendix B.

Contractor markups, or overhead and profit, which may vary between sub-elements, should be added. Markups include overhead and profit for the prime contractor and any subcontractors. Markups should generally be applied to individual cost elements or sub-elements, but, alternatively, can be applied to the total of those elements, if the source of cost data for each is the same. Markups should not be duplicated or applied to elements that have already been "marked up."

The source of cost data can dictate how, or if, markups should be applied. For example, a vendor or contractor quote may include overhead and profit (i.e., "burdened"), whereas a unit price taken from a standard cost estimating guide may not (i.e., "non-burdened"). Typically, costs taken from pricing guides need to have overhead and profit added.

Overhead includes two main types: (1) job or field office overhead, also known as general conditions, and (2) home office overhead, also known as general and administrative (G&A) costs. Field office overhead can include costs for field supervision and office personnel, temporary facilities and utilities, telephone and communications, permits and licenses, travel and per diem, personal protective equipment, quality control, insurance, bond, and taxes. Home office overhead is the contractor's overall cost of doing business, as shared by the project. Profit is the return on the contractor's investment in the project.

- ***Field office overhead can range from about 5 to 25 percent of total project costs that range from greater than $500,000 to less than $50,000, respectively. Home office overhead is usually about 5 percent of total project cost.***

- ***Profit typically ranges from 8 to 10 percent of total project cost.***

An example of how a unit cost for a sub-element might be calculated is shown in Exhibit 5-3 for construction cost of a soil vapor extraction well.

Exhibit 5-3
Example Calculation of Sub-Element Unit Cost

Costs per extraction well:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL
Mob/demob	1	LS	-	-	-	100	100
Setup & Decon	1	HR	-	-	-	125	125
Drill & Install	15	FT	-	-	-	55	825
Wellhead Completion	1	LS	-	-	-	950	950
IDW Handling	1	HR	-	-	-	175	175
Drilling Oversight	7	HR	110	-	-	110	770
SUBTOTAL							2,945
Prime Contractor Overhead						15%	442
SUBTOTAL							3,387
Prime Contractor Profit						10%	339
TOTAL UNIT COST							$3,725

In this example, costs are based on a quote from a local drilling subcontractor, itemized by activity. The assumed health and safety level of protection is built into the quote; therefore, no outside adjustment is made for health and safety productivity. Likewise, no costs are escalated, since the base year is the current year, and no area cost factor is applied, since the quote is local. Subcontractor overhead and profit are included in the quote. Prime contractor overhead and profit are added. Unit prices taken from standard cost estimating guides typically are broken down into labor, equipment, and materials categories. However, since these were not provided in the quote, these are not shown except for oversight, which is based on typical labor rates in the area for a geologist and technician.

Using the above example, if eight soil vapor extraction wells are to be installed, then the total cost of this sub-element would be 8 x $3,725 = $29,800.

Total Sub-Element Costs

After the cost for each sub-element has been calculated, then the cost of the associated cost element can be calculated by totaling the sub-element costs. An example is shown in Exhibit 5-4 for construction cost of an air sparging / soil vapor extraction system.

Exhibit 5-4
Example Estimation of Cost Element

Air Sparging / Soil Vapor Extraction				
Mobilize SVE System	1	EA	$1,534	$1,534
Impermeable Surface Cover	105,000	SF	$0.84	$88,200
SVE Extraction Wells	8	EA	$3,725	$29,803
AS Injection Wells	2	EA	$4,645	$9,290
SVE System	1	EA	$93,510	$93,510
AS Blower	1	EA	$5,712	$5,712
SVE Piping	400	LF	$8.66	$3,464
AS Piping	100	LF	$5.03	$503
Electrical Hookup	1	LS	$9,898	$9,898
Startup and Testing	1	LS	$10,936	$10,936
SUBTOTAL				$252,851

This example includes the sub-element “SVE Extraction Well” from Exhibit 5-3.

5.4 Apply Contingency

Contingency is factored into a cost estimate to cover unknowns, unforeseen circumstances, or unanticipated conditions that are not possible to evaluate from the data on hand at the time the estimate is prepared. It is used to reduce the risk of possible cost overruns.

For the purposes of the FS, contingency is typically applied as a percentage of the total cost of construction or O&M activities costs, rather than applied to individual cost elements. The contingency percentage is based on either a qualitative or quantitative assessment of “cost growth,” or “cost risk,” potential.[1] Detailed quantitative methods used to evaluate cost growth potential include element by element risk scoring and weighting techniques and risk analysis software such as CostRisk, which is currently under development for use by USACE. A more common approach for the FS, however, is to assign a contingency percentage based on engineering judgement.

The two main types of contingency are scope and bid. Scope contingency covers unknown costs due to scope changes that may occur during design. Bid contingency covers unknown costs associated with constructing or implementing a given project scope. The relationship of scope, bid, and total contingency as a project moves through its various phases is illustrated in Exhibit 5-5.

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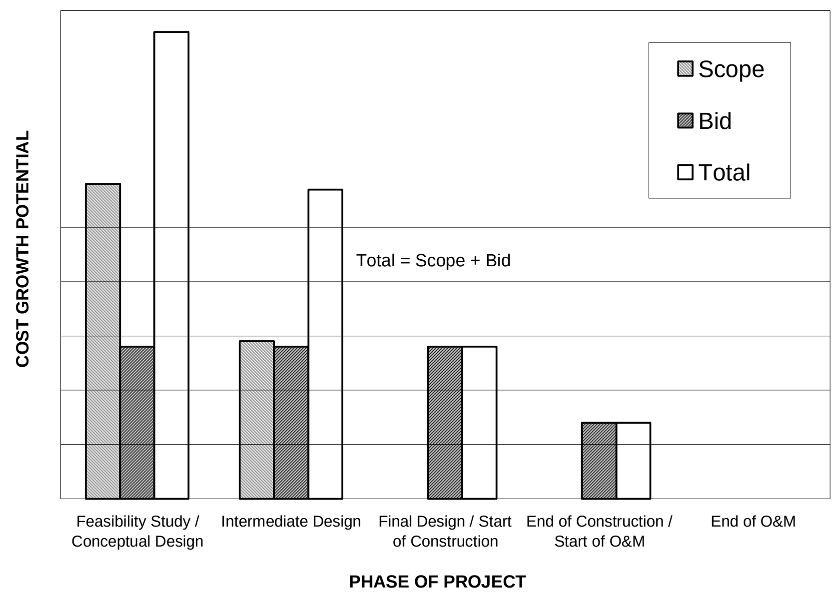
[1] Factors that affect the potential for cost growth in remediation projects include the project definition and the complexity of the media, waste, and technical aspects of the project.

Exhibit 5-5
Relationship of Scope, Bid, and Total Contingency



Scope Contingency

Scope contingency represents project risks associated with an incomplete design. This type of contingency represents costs, unforeseeable at the time of estimate preparation, which are likely to become known as the remedial design proceeds (Exhibit 5-5). For this reason, scope contingency is sometimes referred to as "design" contingency, which is the term commonly used by the USACE. In general, scope contingency should decrease as design progresses and should be 0% at the 100% design stage.

At the early stages of remedial design (e.g., FS which represents 0%-10% design completion), concepts are not typically developed enough to identify all project components or quantities. Contributing factors include limited experience with certain technologies, potential requirements due to regulatory or policy changes, and inaccuracies in defining quantities or characteristics. Scope contingency would be expected to be higher for newer or emerging remedial technologies than for more well-documented systems. For these reasons, scope contingency may vary between alternatives.

👍 ***Scope contingency typically ranges from 10 to 25 percent. Higher values may be justified for alternatives with greater levels of cost growth potential.***

Exhibit 5-6 shows example rule-of-thumb percentage ranges to use for scope contingency during the FS, based on type of remedial technology. A low percentage for scope contingency indicates an opinion that the project scope will undergo minimal change during design. A high percentage indicates an opinion that the project scope may change considerably between the FS and final design.

Exhibit 5-6
Example FS-Level Scope Contingency Percentages

Remedial Technology	Scope Contingency (%)
Soil Excavation	15-55
Groundwater Treatment (Multiple)	15-35
On-Site Incineration	15-35
Extraction Wells	10-30
Vertical Barriers	10-30
Synthetic Cap	10-20
Sludge Stabilization	10-20
Off-Site Disposal	5-15
Off-Site Incineration	5-15
Drum Processing	5-15
Bulk Liquid Processing	5-15
Groundwater Treatment (Single)	5-10
Clay Cap	5-10
Surface Grading/Diking	5-10
Revegetation	5-10

While not accounting for every type of remedial technology, this exhibit provides a range of values to consider for scope contingency. Engineering judgement should be used whenever selecting a scope contingency percentage and the value used should be clearly identified in the cost estimate. The values in Exhibit 5-6 may be weighted by cost element, either qualitatively or quantitatively, to derive a single value to apply to the total of construction or O&M activities costs.

Bid Contingency

Bid contingency represents costs, unforeseeable at the time of estimate preparation, which are likely to become known as the remedial action construction or O&M proceeds (Exhibit 5-5). For this reason, bid contingency is sometimes referred to as "construction" contingency, which is the term commonly used by the USACE.

Bid contingency accounts for changes that occur after the construction contract is awarded. This contingency represents a reserve for quantity overruns, modifications, change orders, and/or claims during construction. Considerations include the technological, geotechnical, and other unknowns applicable to the construction phase. Examples include changes due to adverse weather, material or supply shortages, or new regulations.

☝ ***Bid contingency typically ranges from 10 to 20 percent.***

Bid and scope contingency may be added together and applied to the total of construction or O&M activities costs as shown in the example in Exhibit 5-7 for capital costs.

Exhibit 5-7
Example Contingency Application

Capital Costs:	
Mobilization / Demobilization	$106,723
Monitoring, Sampling, Testing, and Analysis	$60,838
Site Work	$12,940
Air Sparging / Soil Vapor Extraction	$252,851
Passive Treatment Wall	$2,028,564
Off-Site Treatment / Disposal	$1,550
SUBTOTAL	$2,463,465
Contingency (10% scope + 15% bid)	615,866

In general, for a cost estimate developed during the FS, the same level of risk associated with remedial design for capital costs can be carried over to annual O&M costs. In addition, the relative number of unknowns associated with operating and maintaining a remedial action would be expected to be at least the same or greater than those associated with construction.

☝ ***The total contingency value (bid + scope) that is applied to annual O&M costs is typically equal to or greater than the contingency applied to capital costs.***

Using the example in Exhibit 5-6, the total contingency to apply to the total of "O&M activities" costs might be 30 percent (10% scope + 20% bid), or slightly greater than that for capital "construction activities" costs.

5.5 Estimate Professional/Technical Services Costs

Professional/technical services cost elements can be broken down into sub-elements and estimated in similar fashion to construction or O&M activities costs (Section 5.3). However, these costs are most often estimated by applying a percentage to the total of construction or O&M activities costs plus contingency. The total capital, annual O&M, or periodic cost, therefore, is the total of construction or O&M activities costs, contingency, and professional/technical services. Professional/technical services cost elements include:

- Project Management
- Remedial Design
- Construction Management
- Technical Support

For professional/technical services capital costs, Exhibit 5-8 shows rule-of-thumb percentages that can be used for project management, remedial design, and construction management as a percentage of total construction cost. The percentages shown apply to the average remediation project and are provided as a guide. These values may be adjusted up for more complex projects or down for less complex projects, based on engineering judgement, which might consider actual cost data from similar projects.

Exhibit 5-8
Example Percentages for Professional/Technical Services Capital Costs

Capital Cost Element	< $100K (%)	$100K-$500K (%)	$500K-$2M (%)	$2M-$10M (%)	> $10M (%)
Project Management	10	8	6	5	5
Remedial Design	20	15	12	8	6
Construction Management	15	10	8	6	6

Professional/technical services costs are further described below.

Project Management

Project management, which can apply to either capital or O&M cost, includes services that are not specific to remedial design, construction management, or technical support of O&M activities. Project management includes planning and reporting, community relations support during construction or O&M, bid or contract administration, permitting (not already provided by the construction or O&M contractor), and legal services outside of institutional controls (e.g., licensing).

☝ ***For capital costs, project management can be estimated using Exhibit 5-8. For O&M costs, project management generally ranges from 5 to 10 percent of total annual O&M cost.***

Remedial Design

Remedial design applies to capital cost and includes services to design the remedial action. Activities that are part of remedial design include pre-design collection and analysis of field data, engineering survey for design, treatability study (e.g., pilot-scale), and the various design components such as design analysis, plans, specifications, cost estimate, and schedule at the preliminary, intermediate, and final design phases.

☝ ***The percentage of total capital cost for remedial design can be estimated using Exhibit 5-8.***

Construction Management

Construction management applies to capital cost and includes services to manage construction or installation of the remedial action, except any similar services provided as part of regular construction activities. Activities include review of submittals, design modifications, construction observation or oversight, engineering survey for construction, preparation of O&M manual, documentation of quality control/quality assurance, and record drawings.

☝ ***The percentage of total capital cost for construction management can be estimated using Exhibit 5-8.***

Technical Support

Technical support during O&M includes services to monitor, evaluate, and report progress of remedial action (i.e., all O&M professional/technical services not provided under project management). This includes oversight of O&M activities, update of O&M manual, and progress reporting.

☝ ***O&M technical support generally ranges from 10 to 20 percent of total annual O&M cost.***

An example of how professional/technical services cost elements would be estimated using percentages and added to the total of construction cost elements plus contingency is shown in Exhibit 5-9 for capital costs.

Exhibit 5-9
Example Estimation of Professional/Technical Services Costs

CONSTRUCTION SUBTOTAL	$2,463,465
Contingency (10% scope + 15% bid)	615,866
SUBTOTAL	$3,079,331
Project Management (5%)	153,967
Remedial Design (8%)	246,346
Construction Management (6%)	184,760
TOTAL	$3,664,404

5.6 Institutional Controls

Institutional controls, which can have one-time or recurring costs (capital, annual O&M, or periodic), are non-engineering or legal/administrative measures to reduce or minimize the potential for exposure to site contamination or hazards by limiting or restricting site access.

Examples include institutional controls plan, restrictive covenants, property easements, zoning, deed notices, advisories, groundwater use restrictions, and site information database. An institutional controls plan would describe the controls for a site and how to implement them. A site information database would provide a system for managing data necessary to characterize the current nature and extent of contamination.

Institutional controls are project-specific costs that can be an important component of a remedial alternative and, as such, should generally be estimated separately from other costs, usually on a sub-element basis. Institutional controls may need to be updated or maintained, either annually or periodically. Contingency is generally not applied to institutional control cost elements. An example of how institutional controls cost elements would be estimated as for capital costs is shown in Exhibit 5-10.

Exhibit 5-10
Example Estimation of Institutional Controls Costs

Institutional Controls				
Institutional Controls Plan	1	EA	$5,000	$5,000
Groundwater Use Restriction	1	LS	$3,200	$3,200
Site Information Database	1	LS	$4,800	$4,800
SUBTOTAL				$13,000

5.7 Present Value Analysis

To allow for comparison of different alternatives on the basis of a single cost figure, the present value of capital, annual O&M, and periodic costs should be analyzed according to the procedures in Chapter 4. Discount factors, either single-year or multi-year, should be carefully selected depending on the period of analysis to which they are applied. An example present value analysis of the different types of cost for a remedial alternative is shown in Exhibit 5-11.

Exhibit 5-11
Example Present Value Analysis

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE
Capital Cost	0	$3,677,404	$3,677,404	1.000	$3,677,404
Annual O&M Cost	1-15	$4,590,763	$306,051	9.108	$2,787,511
Periodic Cost	5	$14,800	$14,800	0.713	$10,552
Periodic Cost	10	$14,800	$14,800	0.508	$7,518
Periodic Cost	15	$48,458	$48,458	0.362	$17,542
		$8,346,000			$6,501,000

5.8 Sensitivity Analysis

Sensitivity analysis is a type of uncertainty analysis that measures the project impact of changing one or more input values. In the development of a remedial alternative cost estimate, a sensitivity analysis should be considered for those factors that have a relatively-high degree of uncertainty and that, with only a small change in their value, could significantly affect the overall cost of the alternative. This type of analysis is considered separate from a "cost growth" or "cost risk" analysis used to determine the amount of contingency to apply to the cost estimate (Section 5.4). However, a sensitivity analysis could be used to support a contingency analysis (e.g., to help select site-specific contingency factors).

Factors to consider in a cost sensitivity analysis for a remedial alternative include:

- Nature and Extent of Contamination – Estimated volumes of contaminated media or material and degree of contamination (i.e., concentrations) are dependent on assumptions about site conditions.
- Remedy Failure / Effective Life of Technology - The potential failure of a remedy or components thereof would require substantial additional costs for replacement of the remedy or its components. Particularly relevant for technologies or processes that are unproven and lack sufficient performance history.
- Project Duration – The time required for a remedial action, or components thereof, to achieve remedial action objectives can be a major factor, particularly for those actions requiring many years of O&M.
- Discount Rate – Although a rate of 7% should normally be used to compare alternatives, a range of values both below and above 7% can be used to investigate uncertainty concerning future economic conditions.

A sensitivity analysis might vary the values for these factors (e.g., low, medium, high), while keeping the values for other factors the same, and noting the impact on the total estimated cost. Advantages of a sensitivity analysis include:

- Helps identify critical factors where additional data collection resources may need to be spent during subsequent phases of remedial design.
- Provides potential answers to “what if” scenarios.
- Does not require the use of probabilities as do other methods, such as Monte Carlo analysis.

The results of a sensitivity analysis should be reported in terms of total present value for each scenario. The baseline, or original estimate, should be included for comparison. An example of how the results of a sensitivity analysis might be presented is shown in Exhibit 5-12. Scenario 1 is the baseline. In Scenario 2, the project duration is extended by ten years. In Scenario 3, a major capital expenditure is required in Year 8 (e.g., replacement of reactive iron in a treatment wall).

Exhibit 5-12
Example Sensitivity Analysis

YEAR	PRESENT VALUE COST 1	2	3
0	$3,677,404	$3,677,404	$3,677,404
1	$286,029	$286,029	$286,029
2	$267,317	$267,317	$267,317
3	$249,829	$249,829	$249,829
4	$233,485	$233,485	$233,485
5	$228,762	$228,762	$228,762
6	$203,935	$203,935	$203,935
7	$190,593	$190,593	$190,593
8	$178,124	$178,124	$1,358,767
9	$166,471	$166,471	$166,471
10	$163,104	$163,104	$163,104
11	$145,403	$145,403	$145,403
12	$135,890	$135,890	$135,890
13	$127,000	$127,000	$127,000
14	$118,692	$118,692	$118,692
15	$128,490	$116,291	$128,490
16		$103,670	
17		$96,888	
18		$90,549	
19		$84,626	
20		$82,914	
21		$73,915	
22		$69,080	
23		$64,560	
24		$60,337	
25		$65,318	
TOTAL	**$6,501,000**	**$7,280,000**	**$7,681,000**

1. Baseline - original estimate.
2. Project duration is increased by 10 years.
3. Reactive iron for treatment wall is replaced in Year 8.

5.9 Review Estimate

The last step in the process is to review the estimate for completeness. Exhibit 5-13 is a checklist to help review the cost estimate for a remedial alternative.

Exhibit 5-13
Key Questions to Ask when Reviewing a Remedial Alternative Cost Estimate

1. Has a description of the alternative been provided?

   - If so, are key processes or technologies identified per the development process and conceptual design of alternative?
   - Have the site, location, and project phase been noted?

2. Have the capital, annual O&M, and periodic cost element structures been fully developed?

   - Have all applicable construction or O&M activities costs elements been identified?
   - Have all applicable professional/technical services cost elements been identified?
   - Have all applicable institutional controls cost elements been identified?

3. Have quantities for construction and O&M activities cost elements been estimated with sufficient backup?

   - Have calculation sheets, drawings, vendor information, or similar supporting data been included?
   - Have assumptions used to estimate quantities been clearly identified?

4. Have unit costs for construction and O&M activities cost elements been estimated with sufficient backup?

   - Is the source of cost data identified? Is the source appropriate?
   - Are sub-elements described in sufficient detail with assumptions clearly identified?
   - Have all assumptions been taken into account?
   - Have labor, equipment, and materials been included?
   - Has crew production rate or cost been adjusted to account for inefficiency associated with health and safety level of protection?
   - If a cost has been taken from another estimate or a published cost reference, has it been adjusted it to account for different location (area cost factor) and for different time (escalation to base year)?
   - Has subcontractor, if applicable, and prime contractor markups (i.e., overhead, profit) been added?
   - Are the percentages used for overhead and profit appropriate?
   - Have any markups been duplicated?
   - Are quotations from suppliers and subcontractors documented in the backup?

5. Has contingency been applied to the total of construction or O&M activities costs?

   - Have both scope and bid contingency been considered?
   - Are the values used for percentages appropriate, considering the technologies utilized by the alternative?

Exhibit 5-13 (cont.)
Key Questions to Ask when Reviewing a Remedial Alternative Cost Estimate

6. Have the applicable professional/technical services costs been added?

   – If estimated on a percentage basis, are the values used appropriate, considering the total project cost and complexity?

7. If applicable, have the costs associated with implementing and maintaining institutional controls been estimated?

8. Were guidelines followed for the present value analysis?

   – Is the period of present value analysis different than the anticipated project duration (i.e., time required for design, construction, O&M, and closeout)? If so, is explanation provided?
   – Are all capital, annual O&M, and periodic costs included in the present value analysis?
   – Is the discount rate used consistent with USEPA policy (e.g., 7%)? If not, is explanation provided?
   – Is the same discount rate used across all of the alternatives analyzed?
   – If discount factors were used, have the appropriate single-year or multi-year factors been applied, considering the period of analysis for each type of cost (i.e., capital, annual O&M, periodic)?

9. Is there sufficient uncertainty for key factors to warrant a sensitivity analysis? If a sensitivity analysis was done, are results presented clearly in terms of total present value of the alternative?

Chapter Six
How to Document the Cost Estimate

Cost estimates of remedial alternatives developed during the FS should be documented within the FS report such that costs and underlying assumptions are clearly presented and understood. Documentation for the FS should be structured using the following three components:

- Detailed cost backup
- Cost summary of individual remedial alternatives
- Comparative cost summary of all remedial alternatives

These components are described further in the following three chapter sections. The fourth section provides information on post-RI/FS documentation of the cost estimate of the proposed or selected remedy.

6.1 Detailed Cost Backup

Detailed cost backup for remedial alternative cost estimates should be provided in an appendix to the FS report. This material can include cost calculation sheets, quantity calculation sheets, records of communication for vendor quotes, and conceptual design calculations. If cost estimating software is used to estimate all or part of the costs for remedial alternatives, input/output from these software applications should be provided as part of the detailed backup.

For each cost element or sub-element, a standard worksheet can be used to document the calculation of the total unit cost as shown in Exhibit 6-1 for the example of an SVE extraction well. This type of cost worksheet, together with quantity calculation sheets and other supporting information, can be used to trace each cost shown in the cost summary of an alternative to its underlying assumptions.

6.2 Individual Cost Summary

The cost estimate of each remedial alternative should be presented in a one- to two-page cost summary table such as the example shown in Exhibit 6-2. The individual cost summary should present all capital costs, annual O&M costs, any periodic costs, and present value analysis for the remedial alternative. The cost summary should be an activity-based format that identifies all cost elements and sub-elements of the alternative. Individual cost summaries should be provided within the individual analysis section of the FS report or within a cost estimate appendix to the FS report.

6.3 Comparative Cost Summary

The total estimated cost for all remedial alternatives should be presented within the comparative analysis section of the FS report in a summary table such as the example shown in Exhibit 6-3. Alternatively, costs for remedial alternatives can be compared as part of the detailed analysis table, typically provided in FS reports to compare the alternatives against each of the nine NCP criteria. The total cost presented for each alternative should include total capital cost, annual O&M cost, total periodic cost (if any), and total present value. The project duration in years should be noted as this impacts the present value analysis. It should also be noted when the period of present value analysis differs from the project duration. If there are different annual O&M costs for different periods of time, this may need to be broken out in the comparative cost summary.

6.4 Cost Estimate of Proposed or Selected Remedy

Following the RI/FS, as part of the remedy selection process, the cost estimate of the selected remedy is summarized in the record of decision (ROD). In addition, cost information for proposed remedies that meet certain cost-based criteria is submitted to the National Remedy Review Board (NRRB) for review. The following paragraphs, primarily intended for the audience of remedial project managers and program managers, provide more detail on these two topics.

Record of Decision

The same type of one- to two-page format shown in Exhibit 6-2 for remedial alternative cost estimates developed during the FS can be used to present the cost summary of the selected remedy in the ROD. During remedy selection, the preferred alternative presented in the proposed plan can undergo changes as a result of public comment or new information such as additional site characterization data. Any changes to the selected remedy should be reflected in the cost summary presented in the ROD. In addition, if the remedy selection process has spanned a considerable amount of time (e.g., more than 1 year), the estimated costs should be escalated to a new base year. Standard cost estimate disclaimer language should be added to acknowledge the uncertainty associated with cost estimates (see highlight box to right). For more information on the presentation of estimated remedy costs in the ROD, see *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Documents* (USEPA 1999).

Standard Cost Estimate Disclaimer Language

"The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the administrative record file, an explanation of significant differences, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within –30 to +50 percent of the actual project cost."

Source: *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* (USEPA 1999)

National Remedy Review Board

The NRRB is a peer review group comprised of USEPA managers and senior technical policy experts that reviews proposed Superfund cleanup decisions meeting cost-based review criteria to assure that they are consistent with Superfund law, regulations, and guidance. In general, the NRRB reviews those cleanup decisions that exceed specific cost criteria. For more information on the NRRB, its procedures, and cost criteria that trigger reviews, visit *http://www.epa.gov/superfund/programs/nrrb/*.

The following provides guidance for submitting remedy cost estimate information to the NRRB that should accompany briefing materials to allow the NRRB to more accurately assess the cost-effectiveness of the proposed remedy:

1. The summary materials should contain sufficient information to provide an estimate of total resource costs over time (i.e., life cycle costs). Pursuant to the NCP, this estimate should include the capital costs, annual operations and maintenance costs, and net present value of capital and O&M costs. Cost information should be provided for the preferred alternative, as well as each alternative evaluated in the detailed analysis of the FS (or which will be listed in the proposed plan).

2. Cost estimate summaries should address the following:

    a. The key cost components/elements for both RA and O&M activities;
    b. The major sources of uncertainty in the cost estimate;
    c. The discount rate used;
    d. The time expected to achieve remedial action objectives and remediation goals;
    e. Periodic capital and/or O&M costs anticipated in future years of the project (e.g., remedy replacement or rebuild);
    f. The methods and resources used for preparing the cost estimate (e.g., estimating guides, vendor quotes, computer cost models).

3. For "contingency remedy decisions," the total project costs for implementing the contingency should be provided in addition to the costs for the conditional action. This estimate should include treatability study costs, if applicable.

4. The assumptions used to develop the cost estimate should be consistent with the stated remedial action objectives and remediation goals (e.g., duration of the cost estimate should match time to achieve cleanup objectives).

This kind of information is generally considered useful in other management-level review settings as well.

Exhibit 6-1
Example Cost Worksheet

Alternative 3
Capital Cost Sub-Element
SVE EXTRACTION WELL

COST WORKSHEET

Site: Former Industrial Site
Location: Any City, Any State
Phase: Feasibility Study (-30% to +50%)
Base Year: 2000

Prepared By: MPM **Date:** 4/12/00
Checked By: JMR **Date:** 4/12/00

Work Statement:

Install SVE extraction well to total depth of 15 feet with 10-foot factory-slotted screen. Installation includes drilling with hollow-stem auger, continuous soil sampling, installation of 4-inch Schedule 40 PVC blank and screen with filter pack and grout seal, setup and decontamination, containerization of investigation-derived waste (IDW), and wellhead completion (concrete, flush-mount vault with lock, tee with valve and flexible coupling). Health and safety protection is Level D.

Cost Analysis:

Costs per extraction well:

DESCRIPTION	QTY	UNIT	LABOR	EQUIP	MTRL	UNIT TOTAL	TOTAL	
Mob/demob	1	LS	-	-	-	100	100	% of mob/demob for all wells
Setup & Decon	1	HR	-	-	-	125	125	
Drill & Install	15	FT	-	-	-	55	825	Includes well materials
Wellhead Completion	1	LS	-	-	-	950	950	Includes vault, tee with fittings
IDW Handling	1	HR	-	-	-	175	175	Includes drums
Drilling Oversight	7	HR	110	-	-	110	770	$65/hr geo + $45/hr technician
SUBTOTAL							2,945	
Prime Contractor Overhead						15.0%	442	
SUBTOTAL							3,387	
Prime Contractor Profit						10.0%	339	
TOTAL UNIT COST							$3,725	

Source of Cost Data:

3-20-00 quote from John Smith, ABC Drilling Services, tel. no. 999-999-9999. Rates for geologist and technician are based on typical labor rates for area.

Cost Adjustment Checklist:

	FACTOR:	NOTES:
✓	H&S Productivity (labor & equip only)	Quote is for Level D.
✓	Escalation to Base Year	Current year (2000) is base year.
✓	Area Cost Factor	Quote is from local vendor.
✓	Subcontractor Overhead and Profit	Included in quote.
✓	Prime Contractor Overhead and Profit	Includes 15% overhead and 10% profit.

Exhibit 6-2
Example Remedial Alternative Cost Summary

Alternative 3
IN SITU TREATMENT

COST ESTIMATE SUMMARY

Site: Former Industrial Site
Location: Any City, Any State
Phase: Feasibility Study (-30% to +50%)
Base Year: 2000
Date: April 12, 2000

Description: Alternative 3 consists of air sparging in combination with soil vapor extraction to treat soil and groundwater in the source area. Also includes passive treatment wall along leading edge of plume to treat groundwater migrating off-site. Capital costs occur in Year 0. Annual O&M costs occur in Years 1-15. Periodic costs occur in Years 5, 10, and 15.

CAPITAL COSTS:

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Mobilization / Demobilization					
Construction Equipment & Facilities	1	LS	$8,829	$8,829	Excavators, loaders, etc.
Submittals/ Implementation Plans	1	LS	$33,761	$33,761	QAPP, SSHP, etc.
Temporary Facilities & Utilities	1	LS	$49,664	$49,664	Fence, roads, signs, trailers, etc.
Post-Construction Submittals	1	LS	$14,469	$14,469	Post-const. reports
SUBTOTAL				$106,723	
Monitoring, Sampling, Testing, and Analysis					
Monitoring Wells - SVE	7	EA	$1,577	$11,040	Install to water table depth
Monitoring Wells - Trtmt. Wall - Shallow	5	EA	$2,965	$14,826	Shallow well at each of 5 clusters
Monitoring Wells - Trtmt. Wall - Deep	5	EA	$6,212	$31,061	Deep well at each of 5 clusters
Geotechnical Testing	17	EA	$230	$3,910	MW screen interval soil samples
SUBTOTAL				$60,838	
Site Work					
Clearing and Grubbing	5	AC	$1,161	$5,804	Work area
Seeding/Mulch/Fertilizer	5	AC	$1,427	$7,136	Revegetate work area
SUBTOTAL				$12,940	
Air Sparging / Soil Vapor Extraction					
Mobilize SVE System	1	EA	$1,534	$1,534	Mobile unit
Impermeable Surface Cover	105,000	SF	$0.84	$88,200	Low density polyethylene liner
SVE Extraction Wells	8	EA	$3,725	$29,803	4" wells to water table depth
AS Injection Wells	2	EA	$4,645	$9,290	Well depth = midpoint of aquifer
SVE System	1	EA	$93,510	$93,510	Mobile unit (250 scfm)
AS Blower	1	EA	$5,712	$5,712	
SVE Piping	400	LF	$8.66	$3,464	Pipe, valves, fittings, etc.
AS Piping	100	LF	$5.03	$503	Pipe, valves, fittings, etc.
Electrical Hookup	1	LS	$9,898	$9,898	
Startup and Testing	1	LS	$10,936	$10,936	
SUBTOTAL				$252,851	
Passive Treatment Wall					
Construct Slurry Trench	1,800	CY	$187	$337,194	Operate excavator/clamshell
Install Reactive Media	1,800	CY	$940	$1,691,370	Prepare & inject iron/guar gum slurry
SUBTOTAL				$2,028,564	
Off-Site Treatment / Disposal					
Off-Site Transport of Soil Cuttings	25	EA	$15	$375	Transport of drums to SWLF
Disposal of Soil Cuttings	25	EA	$35	$875	SWLF drum disposal fee
Wastewater Discharge/Testing	300	GAL	$1.00	$300	City fee - development water
SUBTOTAL				$1,550	
SUBTOTAL				$2,463,465	
Contingency	25%			615,866	10% scope + 15% bid
SUBTOTAL				$3,079,331	
Project Management	5%			153,967	
Remedial Design	8%			246,346	
Construction Management	6%			184,760	
Institutional Controls					
Institutional Controls Plan	1	EA	$5,000	$5,000	Describe controls / implementation
Groundwater Use Restriction	1	LS	$3,200	$3,200	Legal fees
Site Information Database	1	LS	$4,800	$4,800	Setup data management system
SUBTOTAL				$13,000	
TOTAL CAPITAL COST				**$3,677,404**	

Exhibit 6-2 (cont.)
Example Remedial Alternative Cost Summary

Alternative 3
IN SITU TREATMENT

COST ESTIMATE SUMMARY

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Performance Monitoring					
SVE Vapor Monitoring	96	EA	$308	$29,532	1 sample/month * 8 extraction wells
SVE Emissions Monitoring	12	EA	$308	$3,692	1 sample/month - SVE exhaust
Treatment Wall - Groundwater Sampling	4	QTR	$2,449	$9,795	Sample 10 wells/qtr
Treatment Wall - Groundwater Lab Analysis	4	QTR	$5,714	$22,856	Analysis for above
SUBTOTAL				$65,875	
Site Monitoring					
Groundwater Sampling	4	QTR	$1,820	$7,280	Sample 8 wells/qtr VOCs, WQ, metals
Groundwater Laboratory Analysis	4	QTR	$5,460	$21,839	Analysis for above
SUBTOTAL				$29,119	
Air Sparging / Soil Vapor Extraction					
Operations Labor	12	MO	$6,120	$73,440	136 manhours per month
Maintenance Labor	12	MO	$720	$8,640	16 manhours per month
Equipment Repair	1	LS	$500	$500	
Utilities	12	MO	$1,928	$23,134	Electricity + fuel
SUBTOTAL				$105,714	
Off-Site Treatment / Disposal					
Wastewater Discharge/Testing	1,600	GAL	$1.00	$1,600	City fee - purge & knockout water
SUBTOTAL				$202,308	
Contingency	30%			60,692	10% scope + 20% bid
SUBTOTAL				$263,001	
Project Management	5%			13,150	
Technical Support	10%			26,300	
Institutional Controls - Site Info Database	1	LS	$3,600	$3,600	Update and maintain database
TOTAL ANNUAL O&M COST				**$306,051**	

PERIODIC COSTS:

DESCRIPTION	YEAR	QTY	UNIT	UNIT COST	TOTAL	NOTES
Five Year Review Report	5	1	EA	$12,000	$12,000	1 report at end of Year 5
Update Institutional Controls Plan	5	1	EA	$2,800	$2,800	Update plan
SUBTOTAL					$14,800	
Five Year Review Report	10	1	EA	$12,000	$12,000	1 report at end of Year 10
Update Institutional Controls Plan	10	1	EA	$2,800	$2,800	Update plan
SUBTOTAL					$14,800	
Demobilize AS/SVE System	15	1	LS	$21,375	$21,375	Remove equipment and piping
Well Abandonment	15	27	EA	$350	$9,450	
Contingency (% of Sum)		25%			7,706	% of construction activities
Project Mgt. (% of Sum + Cont.)		5%			1,927	% of construction + contingency
Remedial Action Report	15	1	EA	$8,000	$8,000	
SUBTOTAL					$48,458	

PRESENT VALUE ANALYSIS:

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR (7%)	PRESENT VALUE	NOTES
Capital Cost	0	$3,677,404	$3,677,404	1.000	$3,677,404	
Annual O&M Cost	1-15	$4,590,763	$306,051	9.108	$2,787,511	
Periodic Cost	5	$14,800	$14,800	0.713	$10,552	5-year review, update i.c. plan
Periodic Cost	10	$14,800	$14,800	0.508	$7,518	5-year review, update i.c. plan
Periodic Cost	15	$48,458	$48,458	0.362	$17,542	Demob, abandon, RA report
		$8,346,000			$6,501,000	
TOTAL PRESENT VALUE OF ALTERNATIVE					**$6,501,000**	

Exhibit 6-3
Example Comparative Cost Summary

COMPARISON OF TOTAL COST OF REMEDIAL ALTERNATIVES

Site:	Former Industrial Site	**Base Year:**	2000
Location:	Any City, Any State	**Date:**	April 12, 2000
Phase:	Feasibility Study (-30% to +50%)		

DESCRIPTION	**Alternative 1** No Action	**Alternative 2** Limited Action/ Natural Attenuation	**Alternative 3** In Situ Treatment	**Alternative 4** Ex Situ Treatment
Total Project Duration (Years)	0	30	15	15
Capital Cost	$0	$147,000	$3,677,000	$5,300,000
Annual O&M Cost	$0	$41,000	$306,000	$146,000
Total Periodic Cost	$0	$68,000	$72,000	$43,000
Total Present Value of Alternative	**$0**	**$690,000**	**$6,501,000**	**$6,649,000**

Chapter Seven
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