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U.S. Department of Commerce
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Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, MD 20899

Guide to Computing and Reporting the Life Cycle Cost of Environmental Management Projects

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Abstract

Life-cycle cost (LCC) analysis is an economic measurement technique used to determine the total cost of an investment project or activity over its lifetime. This *Guide* applies the principles of LCC to the special requirements of Environmental Management (EM) projects. The approach integrates two ASTM International consensus standards: a widely used standard on LCC, and a recently adopted standard on the work breakdown structure expressed in the Environmental Cost Element Structure (ECES) developed by a Federal interagency working group concerned with efficient execution of EM projects. The LCC method described in the *Guide* can be applied to any EM project that has adopted the ECES cost management framework. Users of the *Guide* are assumed to be familiar with the ECES and the consensus standards that support it. The *Guide* covers economic comparisons across environmentally equivalent alternatives for an EM project addressing a single site as well as economic analysis of EM projects at different sites. Both one-time and recurring expenditures are covered as well as discounting on both an annual and a monthly basis. Several realistic case examples illustrate the method.

Keywords: discounting; economic evaluation; engineering economics; environmental management; investment analysis; life-cycle costing; present value; project evaluation; standards

Contents

Abstract…… iii

List of Exhibits and Figures vi

1. Introduction 1

1.1 Purpose 1
1.2 Scope 2
1.3 Overview 3

2. Defining the Environmental Management Project 5

2.1 Project Definition 5
2.2 Specifying Alternatives 5
2.3 Illustration: Report Form for Project Definition 5

3. Setting the LCC Parameters 9

3.1 Base Date 9
3.2 Study Period 9
3.3 Treatment of Sunk Costs 11
3.4 Discount Rate 11
3.5 Illustration: Report Form for LCC Parameters 13

4. Organizing ECES Cost Data 15

4.1 Timing of Costs 15
4.2 Treatment of Inflation or Deflation in Cost Estimates 15
4.3 Area Cost Factors 16
4.4 Illustration: Sample Cost Database 16

5. Computing the LCC of the EM Project 19

5.1 Computing the Present Value of a Single Amount 19
5.2 Discounting of Annual versus Monthly Costs 20
5.3 Computing the Present Value of Monthly Costs 22
5.4 Computing the Present Value of a Uniform Series 23
5.5 Illustration: Computing the LCC of the Sample Project 25
5.6 Interpreting the Total LCC 26

6. Comparing EM Alternatives Using LCC Analysis 27

6.1 Environmental Management Project Specification 27
6.2 Project Alternatives 27
6.3 Setting Analysis Parameters 28
6.4 Calculations of LCC for Both Alternatives 28
6.5 Calculation of the Adjusted LCC 29
6.6 Life-Cycle Cost Report 30
6.7 Conclusion 32

References… 33

Appendix A: Data for Sample Project without Alternatives.....35

Appendix B: Data for Case Study with Two Alternatives—In Situ Soil Vapor Extraction 43

Appendix C: Data for Case Study with Two Alternatives—Natural Attenuation.....47

Appendix D: Derivation of the Equation for Discounting Monthly Costs.....53

Appendix E: Blank Report Forms.....55

List of Exhibits and Figures

Exhibit 1: Project Definition..... 7

Exhibit 2: LCC Parameters..... 14

Exhibit 3: Excerpt from the Sample Cost Database..... 17

Exhibit 4: Illustrative Cost Data Extracted from the Sample Project in Appendix A 22

Exhibit 5: Illustrative Cost Data for a Uniform Series of Expenditures Extracted from the Sample Project in Appendix A 24

Exhibit 6: Present Value Costs for Phase 4 of Sample Project in Appendix A 25

Exhibit 7: Present Value Costs by Phase for Sample Project in Appendix A 26

Exhibit 8: Present Value Costs by Phase for In Situ Vapor Extraction (Alternative A) 29

Exhibit 9: Present Value Costs by Phase for Natural Attenuation (Alternative B) 29

Figure 1: Cash Flow over the Life Cycle of a Project 10

Figure 2: Uniform Series of Expenditures..... 23

1. Introduction

1.1 Purpose

Life-cycle cost (LCC) analysis is an economic measurement technique used to determine the total cost of an investment project or activity over its lifetime.[1] This *Guide* applies the general principles of LCC to the special requirements of Environmental Management (EM) projects. The approach defined and illustrated in the *Guide* provides a method for computing a single number that represents the total present value cost of an EM project over its entire life cycle. The approach is primarily based on a widely used consensus standard published by ASTM International (formerly known as the American Society for Testing and Materials).[2] While this standard was developed to be applied to building systems, the LCC method that it defines may be applied to any type of investment project. As the Forward to the published compilation of ASTM International building economics standards states, "Although the standards focus on buildings and building components, the standards are equally applicable to non-building investments. The same principles apply in evaluating any capital budget expenditure."

The LCC measure explicitly takes into account the time value of money, that is, the variation in the cost of an expenditure due to its timing.[3] Two types of variation are accounted for in the time value of money. One is the result of changes in prices due to inflation or deflation. The second arises from the real earning power of money over time. This real earning power means that identical dollar expenditures impose differing costs depending on when they are incurred. The *Guide* addresses both types of variation due to timing. The LCC measure presented here

[1] For background on the various methods of project evaluation and capital budgeting, of which LCC is one, see comprehensive engineering economics texts, such as Au, Tung and Au, Thomas P. 1992. *Engineering Economics for Capital Investment Analysis*. 2nd Edition. Englewood Cliffs, NJ: Prentice Hall, and Park, Chan S. 2001. *Contemporary Engineering Economics*. 3rd Edition. Englewood Cliffs, NJ: Prentice Hall College Division. For a thorough treatment of LCC itself, see Fuller, Sieglinde K., and Petersen, Stephen R. 1996. *Life-Cycle Costing Manual for the Federal Energy Management Program*. NIST Handbook 135. 1995 Edition. Gaithersburg, MD: National Institute of Standards and Technology.

[2] ASTM International. 2003. *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*. E 917-02. West Conshohocken, PA: ASTM International.

[3] Terminology, such as "time value of money," used in the *Guide* is consistent with the definitions given in: ASTM International. 2003. *Standard Terminology of Building Economics*. E 833-02a. West Conshohocken, PA: ASTM International.

represents the total cost of a project over its life, fully accounting for the timing of every expenditure.

1.2 Scope

The *Guide* describes how to apply the LCC technique to EM projects by using the work breakdown structure defined in the Environmental Cost Element Structure (ECES). The ECES has been developed and maintained by the Environmental Cost Engineering Committee, a Federal interagency working group concerned with efficient execution of EM projects.[4] The first two levels of the ECES have been adopted as a voluntary consensus industry standard, ASTM E 2150-02.[5] In addition, an Adjunct to this standard has recently been adopted to cover the remaining three levels of the ECES (Levels 3, 4, and 5).[6] The *Guide* uses examples that explicitly address all five levels of ECES covered by the published standard and the adjunct.

The LCC method described in the *Guide* can be applied to any EM project that has adopted the ECES cost management framework. The ECES work breakdown structure allows project managers to easily manage the costs, timing, and objectives associated with an EM project. This framework allows for straightforward calculation of the LCC of an EM project using the *Guide*.

The *Guide* may also be used to analyze projects whose data are organized and coded using other work breakdown structures, such as the Construction Specifications Institute MasterFormat system[7] or the ASTM International UNIFORMAT II system.[8] MasterFormat arranges related construction products and activities into 16 level-one titles, called divisions. Each division is further defined in MasterFormat by numbers and titles for levels two and three, and suggested titles for level four. Level-two numbers and titles identify clusters of products and activities having an identifying characteristic in common. UNIFORMAT II is a common elemental

[4] U.S. Department of Energy. 2002. *Environmental Cost Element Structure*. Washington, DC: Interagency Environmental Cost Engineering Committee.
[5] ASTM International. 2003. *Standard Classification for Life-Cycle Environmental Work Elements—Environmental Cost Element Structure*. E 2150-02. West Conshohocken, PA: ASTM International.
[6] ASTM International. 2002. *Environmental Cost Element Structure at Levels 3, 4 and 5 and Definitions. Adjunct to ASTM Classification Standard E 2150-02*. West Conshohocken, PA: ASTM International.
[7] Construction Specifications Institute, *MasterFormat 1995*, Alexandria, VA: Construction Specifications Institute.
[8] ASTM International. 2003. *Standard Classification for Building Elements and Related Sitework-UNIFORMAT II.* E 1557-02. West Conshohocken, PA: ASTM International.

classification for the description, economic analysis, and management of a building over its life cycle. Elements—often referred to as systems or assemblies—are major components common to most buildings that usually perform a given function regardless of the design specification, construction method, or materials use.

Users of the *Guide* are assumed to be familiar with the ECES and the ASTM International standard and adjunct that support it. It is further assumed that the cost data for EM projects to be analyzed by the method of this *Guide* are organized using ECES and that every cost item is coded as a specific element of ECES. Each cost item must be assigned to the specific time period in which it is expected to be incurred.

The LCC method defined in the *Guide* may be used to perform two types of analysis, prospective and retrospective. Prospective LCC analysis may be used to examine a single EM project that has not yet started. Prospective analysis will reliably compare alternative approaches to the same EM project, provided all alternatives are expected to achieve the same level of environmental performance over the same time period. The LCC estimates may also be used for budgetary purposes.

Retrospective LCC analysis examines EM projects that have been completed. The analysis may be used to look at past approaches to similar projects. The analysis of past projects may provide insight to improve the efficiency of future budget decisions. Comparisons across different EM projects require a geographic cost index factor to adjust for variations in construction costs throughout the country.

1.3 Overview

Section 2 describes how to define the particular EM project being analyzed. Section 3 explains how to establish the key LCC parameters used in calculating the LCC of any project and its alternatives. These parameters are the base date, the study period, and the discount rate. Section 4 discusses the organization of the cost data in terms of timing and cost conditions sensitive to geographic variation as well as the treatment of inflation. Section 5 explains and illustrates how to compute the LCC of a sample EM project that has only one environmental solution. Section 5

also covers the discounting of one-time expenditures as well as expenditures that recur over several time periods. It treats the discounting of both annual costs and monthly costs. Finally, Section 6 demonstrates how to compare the LCC of multiple alternatives. A case study with two alternative environmental solutions is included to illustrate the approach. Appendixes A, B, and C present tables of all the sample data used in the illustrations throughout the *Guide*.

2. Defining the Environmental Management Project

The *Guide* uses a comprehensive report form to organize and summarize the LCC analysis of an EM project. This LCC report form has four sections: (1) Project Definition; (2) LCC Parameters; (3) LCC by Phase and Alternative; and (4) Summary Table of LCC by Alternative. This section of the *Guide* discusses how to prepare the Project Definition section of the LCC report. Section 3 covers the LCC Parameters section of the report. Section 6 shows how to use the third and fourth sections of the report covering the results of the LCC analysis.

2.1 Project Definition

Define the EM project before performing any calculations. The project definition allows readers to understand the scope of the project analysis and provides them with information about important factors that may influence the results. Include the Title, Location, Type, Record of Decision Date, Analyst contact information, and Project Description in the Project Definition Section of the LCC report.

2.2 Specifying Alternatives

If the purpose of the LCC analysis is to evaluate alternative approaches to completing a single project, include a description of the alternatives in the project definition. Although the alternatives may employ different environmental remediation methods, they must all be designed to achieve the same level of environmental performance. The alternatives must be analyzed using the same base date, study period, and discount rate, as discussed in Section 3.

2.3 Illustration: Report Form for Project Definition

To better illustrate the principles of LCC, a sample project has been developed based on an actual EM project. This project offers only one environmental solution, so that there is no need to evaluate and compare multiple alternatives. The examples given through Section 5 use data from this sample project. A table with all cost data for this sample project is in Appendix A. Section 6 presents a case study of a more complex project that involves two alternatives.

The sample EM project used through Section 5 is a decontamination of a former nuclear production facility. The clean-up site is a three-story building measuring approximately 27.4 m x 45.7 m x 45.7 m (90 ft x 150 ft x150 ft), constructed in 1950 to convert uranium hexafluoride (UF_6) to uranium tetrafluoride (UF_4). The production was initiated in 1953 and continued until 1957. This facility contains asbestos, radiological contamination, lead paint and flashing, and health risk due to biological contaminants such as bacteria found in soil and plant debris. The facility is located on 0.4 hectares (1 acre) of land, near the town of Lockport, in upstate New York. Cleaning the facility and surrounding area will begin in January 2004. Once the facility has been decontaminated, the site will be in long-term surveillance and maintenance (legacy management) until 2028. Exhibit 1 is the first section of the LCC report form, called Project Definition, filled out using information from the sample EM project. Blank versions of all four sections of the LCC report form can be found in Appendix E.

1. Project Definition

Project Title: Nuclear Production Facility Decontamination

Location (City / ST / Zip): Lockport / NY / 14094

Project Type (Circle One): (RCRA) CERCLA WM D&D

Record of Decision Date: January / 31 / 2003

Analyst: John Doe **Phone:** (XXX)XXX-XXXX **Email:** John.Doe@doe.gov

Project Description:

Decontamination, monitoring, and long-term stewardship of a former nuclear production facility. The facility was shut down and decommissioned when it was transferred into the environmental program. This is a three-story building measuring approximately 27 m x 46 m x 46 m (90 ft x 150 ft x 150 ft), constructed in 1950 to convert uranium hexafluoride (UF6) to uranium tetrafluoride (UF4). Production was initiated in 1953 and continued until 1957. This facility contains asbestos, radiological contamination, lead paint and flashing, and health risk due to biological debris. The facility consists of steel frame with steel roof and steel siding panels on the exterior. Some of the soil surrounding the facility is also contaminated.

Number of Alternatives: 1

List of Alternatives:

Short Name	Description
Alternative A	Decontamination

Exhibit 1: Project Definition

3. Setting the LCC Parameters

Several parameters must be defined before computing the LCC of an EM project.[9] The first is the base date, which is the date to which all expenditures are discounted. The second parameter is the length of the study period (also referred to as the time horizon), which establishes the start and end date of the project. The length of the study period thus determines the number of years and months over which project expenditures are included in the analysis. The third parameter is the discount rate used to account for the time value of money. **Use the same values for these three LCC parameters across all alternatives within a project.**

3.1 Base Date

The base date of a project is the date to which all future (and past) costs are discounted. Theoretically, the base date could be any point in time within or even outside the study period, but it usually coincides with the beginning of the study period. The date on which the LCC analysis is conducted (the Analysis Date) is also sometimes used as the base date. The base date may fall on any date, although the beginning of either a particular month or a particular year is recommended.

When performing a prospective analysis, define the timing of all costs included in the project relative to the base date. All cost elements should be denominated in terms of base-date dollars. If an analysis is performed in January 2004, all costs should be denominated in January 2004 dollars, regardless of the expected date of expenditure. Information on adjusting costs for changes in the price level can be found in Section 4.

3.2 Study Period

The study period of an LCC analysis is the length of the time period covered by the economic evaluation. With the exception of sunk costs (discussed in the next subsection), the study period

[9] Standard definitions for these parameters can be found in: American Society for Testing and Materials. 2003. *Standard Terminology of Building Economics*. E 833-02a. West Conshohocken, PA: American Society for Testing and Materials.

spans the very first expenditure and the last expenditure for the environmental clean up. This is illustrated in the typical cash flow diagram of Figure 1. The study period extends from the project start date (the beginning of the period in which the very first expenditure occurs) to the project end date (the end of the period in which the very last expenditure occurs). The analysis may be performed prior to the beginning of the study period.

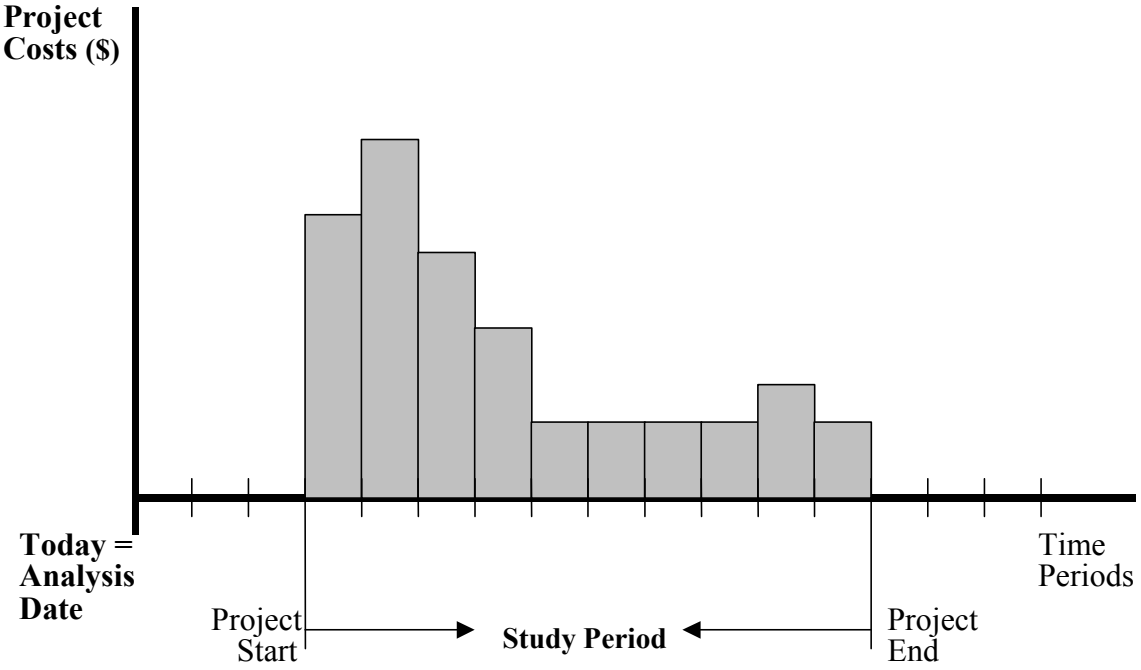

Figure 1: Cash Flow over the Life Cycle of a Project

When comparing multiple alternatives for a single project, the ASTM International LCC methodology requires that the study period be the same across all alternatives. If the alternatives have expenditures extending over different lengths of time, set the study period equal to the life of the longest project. Then match the same study period for all the other alternatives by adding the required number of periods assigned with zero costs. As long as all the alternatives are expected to have the same benefits, no further accounting is necessary. If the benefits vary across the alternatives, then develop economic estimates of the present value of the additional benefits and credit each alternative accordingly. For example, if one alternative makes the site available for a useful economic purpose earlier than the others, estimate the economic value of those additional periods of use. The case study in Section 6 illustrates how to develop and apply such credits.

3.3 Treatment of Sunk Costs

A sunk cost is any cost that has already been incurred prior to the date of the LCC analysis and that cannot be recovered regardless of present or future decisions.[10] Because sunk costs have already been spent prior to the analysis, they should not influence decisions about which alternative to select for an EM project. Thus when comparing multiple alternatives for the same EM site in a prospective analysis, ignore sunk costs. If the purpose of LCC analysis is retrospective, however, include all sunk costs.

3.4 Discount Rate

In LCC analysis the discount rate is the parameter used to represent the time value of money. It reflects the opportunity cost of capital to an investor over time. To illustrate the concept, suppose you must pay a bill of $1,000 one year from now. Consider how much you need now to be able to pay the bill at the end of the year. Suppose you could put your money in ank account that pays 5 % interest per year. If you deposit the full $1,000 now,you would have $1,050 in your account at the end of the year – $50 extra because of the interest you earned. How much should you deposit to end up with exactly $1,000 to pay the bill? The answer is found by discounting the $1,000 cost at the end of the year to its equivalent present value using the discount rate of 5 %. As explained in greater detail in Section 5, the amount you need to deposit is only $952.38.[11] Thus, the $1,000 cost due one year from now is worth $47.62 less than a $1,000 cost that is due immediately.

Because costs expended at different times have different values, costs of an EM project occurring at different times cannot be directly compared or summed. Costs must first be converted into their time-equivalent value at the base date before being combined to compute the total LCC of a project. This time-equivalent value is referred to as the Present Value (PV) of the costs. The discount rate is the interest rate used to convert (or "discount") future expenditures to

[10] Standard definitions for the LCC parameters can be found in: American Society for Testing and Materials. 2003. *Standard Terminology of Building Economics*. E 833-02a. West Conshohocken, PA: American Society for Testing and Materials. This definition of sunk costs draws on this standard as well as OMB Circular A-94 Revised 10/29/92, Definition of Terms.

[11] The computation is as follows: 1000/(1+0.05) = 952.38.

their present value at the base date, taking into account the investor's time value of money. The discount rate selected for LCC analysis must make an investor indifferent between a future cash amount and its present value.

Two types of discount rates are used in computing the present value: a "real" rate or a "nominal" rate. The real discount rate reflects the time value of money without accounting for the effects of inflation and deflation. That is, it reflects the real earning power of money over time. Use the real discount rate (excluding the rate of inflation) when all cost data are denominated in terms of "constant" dollars, that is, dollars with constant purchasing power. Nominal or market discount rates take into account general inflation or deflation plus the real earning power of money. Use a nominal rate when all cost data are denominated in "current" dollars, that is, dollars that change in value from year to year depending on the general price level. The need for a nominal or market discount rate often arises when the future cost estimates are based on a maintenance contract that is typically specified to be paid in current dollars in future time periods. For all illustrations in the *Guide*, a real discount rate is used, since all the cost estimate data in the sample projects are in terms of constant dollars. For more information on how to treat inflation, consult Section 4.

In the private sector, an individual investor's discount rate is determined by the investor's minimum acceptable rate of return (MARR) for investments, as governed by available investment opportunities and his or her risk tolerance. Because different investors have different investment opportunities available to them as well as different levels of acceptable risk, private discount rates vary greatly.

Most environmental projects using the ECES will be sponsored by government agencies rather than by private investors. Two government agencies annually publish discount rates to be used in the economic analysis of government projects.

The Department of Energy (DOE) establishes the specific discount rate to be used for energy and water conservation and renewable resource projects under the Federal Energy Management

Program (FEMP). This discount rate applies only to investments devoted to these specific objectives in federally owned or leased facilities. The rates are published annually on April 1.[12]

Other Federal projects are required to use the discount rates published in January of each year by the Office of Management and Budget (OMB). The real and nominal discount rates to be used for investment analyses of Federal projects are found in Appendix C of *OMB Circular A-94*. Appendix C is updated annually at the time of the President's budget submission to Congress in January. The rates vary by the length of the project with separate rates for 3-year, 5-year, 7-year, 10-year, and 30-year projects. The *Circular* requires use of the rate that corresponds to the length of the study period for the project and indicates that one should interpolate linearly where necessary. If the study period is longer than 30 years, the *Circular* says to use the 30-year rate.[13]

3.5 Illustration: Report Form for LCC Parameters

The sample EM project described below specifies decontamination beginning in January 2004. Once the facility has been decontaminated, it will be in surveillance and maintenance mode until 2028. The study period will be 24 years and 2 months. Analysis of the EM project will begin in 2003. The date of analysis and the base date are both January 1, 2003. The discount rate will be taken from the *OMB Circular A-94*, January 2003. Because the project will extend to 24 years, the discount rate should be interpolated, as recommended by OMB. The most recently published[14] OMB rates for 10 years and 30 years are 2.5 *%* and 3.2 *%*, respectively. Thus the interpolated rate for a 24-year project is 2.99 *%*.[15] The LCC Parameters should be entered into the appropriate fields in the Report Form.

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[12] The most recent edition can be found in: Fuller, Sieglinde K., and Rushing, Amy S. 2002. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - April 2002*. NISTIR 85-3273-17. Gaithersburg, MD: National Institute of Standards and Technology. Updated annually.

[13] Office of Management and Budget (OMB). 2003. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. Circular A-94. Washington, DC: Office of Management and Budget. The OMB tables of rates are available online at http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html. The complete Circular can be found at http://www.whitehouse.gov/omb/circulars/a094/a094.html, and a table of past years' rates is located at http://www.whitehouse.gov/omb/circulars/a094/DISCHIST-2003.pdf. Updates of the appendix are also available upon request from the OMB Office of Economic Policy (202-395-3381).

[14] January 31, 2003

[15] The 24 year rate is interpolated as follows:

$i_{low} + [(\text{study period} - \text{year}_{low}) / (\text{year}_{high} - \text{year}_{low})] * (i_{high} - i_{low}) = i.$

$2.5 + (24-10)/(30-10) * (3.2-2.5) = 2.99.$

2. LCC Parameters

Study Period (Years): 24 Years, 2 Months **Discount Rate:** 2.99 %

Analysis Date: 01 / 01 / 2003 **Base Date:** 01 / 01 / 2003

Exhibit 2: LCC Parameters

4. Organizing ECES Cost Data

Before performing the LCC analysis, all relevant costs associated with a project must be compiled. The ECES provides a hierarchical list of elements representing all cost components that are expected to occur over the life-cycle of an EM project. Each cost element represents a task or activity performed during environmental projects. For easy reporting and analysis, compile cost data into the work breakdown structure defined by the ECES classification. For more information on designing and documenting the cost estimates for an EM project, consult the Environmental Protection Agency's Guide to Developing and Documenting Cost Estimates During the Feasibility Study.[16]

4.1 Timing of Costs

In addition to compiling all costs, include the timing of each cost. The timing is needed to correctly discount each cost to its equivalent present value. Discounting is keyed to a single point in time (that is, the distance in time from the base date). The most appropriate approach would be to discount from the exact date at which the expenditure takes place. However, it is common practice to model expenditures that are incurred at varying times within a period as if they were all incurred either at the beginning of the period, middle of the period, or the end of the period. For example, ASTM International uses the end-of-year convention in its pre-calculated discount factor tables.[17]

4.2 Treatment of Inflation or Deflation in Cost Estimates

General price inflation/deflation causes a reduction/increase in the purchasing power of the dollar over time. The analysis can be calculated in constant-dollar terms (explicitly excluding changes in the general price level) or in current-dollar terms (including changes in the general price level). When excluding inflation, express all costs in terms of base date dollars and use

[16] U.S. Environmental Protection Agency. 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study.* Washington, DC.

[17] ASTM International. 2003. *Discount Factor Tables: Adjunct to ASTM Practice E 917, for Measuring Life-Cycle Costs of Buildings and Building Systems.* West Conshohocken, PA: ASTM International.

the real discount rate. On the other hand, if costs are expressed in current dollars (i.e., if they include changes in prices), then a consistent projection of general price inflation must be used throughout the cost estimates. In this case, the LCC analysis must take account of this price inflation by using the nominal discount rate as discussed in Section 3 and published by the OMB. It is preferable to use constant-dollar analysis since it eliminates the need to estimate the rate of inflation over the duration of the study period. Current-dollar analysis may be used if there are budgeting considerations based on current dollars included in the analysis. For example, if cost data are based on a multiyear contract with fixed current dollar amounts, adjust future expenditures for inflation.

4.3 Area Cost Factors

Projects may have different construction costs based on the geographic location of the site. When comparing alternatives for the same site, use the area cost factors appropriate for that site for all cost estimates. However, when comparing the LCCs of two projects at different sites, the costs have to be adjusted by their area cost factors to put them on a common locality basis.

4.4 Illustration: Sample Cost Database

The costs may be arranged in any way convenient for the analysis. List each cost element by Phase and Level and include the description, the cost, and the time period during which the task will be performed. Exhibit 3 is an excerpt from a sample database showing costs for the case study.

Phase	2nd	3rd	4th	5th	Description	Cost	Date
2	.09	.01			Prepare and Ship Environmental Samples	$5,000	Apr-2004
2	.09	.04			Provide Sample Management	$6,600	Apr-2004
2	.09	.08			Data Reduction, Tabulation and Evaluation	$7,040	Apr-2004
3	.02	.01			Project Management Support/Administration	$16,624	Mar-2005
3	.04	.12	.01		Preliminary Design	$17,955	Mar-2005
3	.04	.12	.02		Intermediate Design	$3,217	Mar-2005
3	.04	.12	.03		Pre-final/Final Design	$26,434	Mar-2005
3	.02	.05	.02	.01	Support preparation of solicitation package	$2,089	Mar-2005
3	.02	.05	.02	.03	Advertising/soliciting of bids	$1,200	Mar-2005
3	.02	.05	.02	.05	Pre-bid (pre-solicitation) meetings	$350	Mar-2005
3	.02	.05	.03		Perform Pre-Award Activities	$3,520	Mar-2005
4	.02	.01			Project Management Support/Administration	$2,707,041	Aug-2005
4	.05	.01			Mobilization	$78,281	Aug-2005
4	.05	.36			Demobilization	$27,398	Aug-2005
4	.07	.08			Air Monitoring and Sampling	$10,560	Aug-2005

Exhibit 3: Excerpt from the Sample Cost Database

5. Computing the LCC of the EM Project

The total LCC of an EM project is the sum of all project-related expenditures. Before being totaled all costs must be discounted to their present value. The primary formula for computing the present-value LCC of a project is:[18]

$$PVLCC = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t} \qquad (1)$$

where:

$PVLCC$	=	total Life-Cycle Cost in present value dollars at the base date;
C_t	=	costs occurring in period t, where t=1…N discounting periods;
N	=	the number of time periods in the study period; and
i	=	the discount rate in decimal form (e.g., 5 % is entered as 0.05).

This general formula discounts an individual cost, C_t, to the base date. Then all costs are summed to calculate the *PVLCC*. The first step in calculating the *PVLCC* for an EM is to compute the present value of a single expenditure.

5.1 Computing the Present Value of a Single Amount

The LCC calculated in Equation (1) is the sum of all costs associated with a project. Before the costs are summed, they must be converted to their present value. The formula used to convert a single future cost to present value is:

$$P = F * \frac{1}{(1+i)^t} \qquad (2)$$

where:

F	=	the future cost;
P	=	discounted present value of the expenditure.

The future cost, F, is equivalent to one of the costs included in C_t in the $PVLCC$ formula, Equation (1). To calculate the discounted present value, F is multiplied by a discount factor. The factor is dependent upon the discount rate, i, and the time, t, that is expected to elapse between the base date and the date of expenditure.

Consider an example where a project manager will incur an expense of $10,000 in ten years. The manager can earn a 5 % return on investments. The present-value equation can be used to calculate how much money the manager must set aside today to be able to pay $10,000 in ten years. Using Equation (2),

$$P = \$10,000 * \frac{1}{(1+0.05)^{10}} = \$6,139$$

The present value of the $10,000 cost paid ten years from now is $6,139. The manager is indifferent between paying $6,139 now and $10,000 ten years from now, given a discount rate of 5 %.

5.2 Discounting of Annual versus Monthly Costs

The above example discounts the future value using annual discounting, that is, each period is one year long. Discounting using year-long periods is common. Most discount rates, including those published by OMB, are intended for annual discounting.[19] When using annual discounting, it is most often assumed that the cost occurs at the last day of the year. For example, an expenditure occurring as early as January of 2005 will be calculated as if it occurred on December 31, 2005. This may cause a problem when paying the expense in January. Annual discounting assumes that interest will be earned on capital throughout 2005. There would be insufficient funds to pay earlier in the year.

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[18] As defined in: ASTM International. 2003. *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.* E 917-02. West Conshohocken, PA: ASTM International.

[19] See OMB Circular No. A-94 APPENDIX C (Revised January 2003). A copy of the updated appendix can be obtained at http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html. For more information on discount rates see section 3.4.

Using shorter periods will reduce the magnitude of this problem. Shorter discounting periods allow for more precise timing of expenditures. The period used for discounting can be of any length and is determined by the timing of the project's expenditures. The costs of EM projects are usually defined by month, so discounting of monthly costs will be used to calculate the LCC. The equation used for the discounting of monthly costs is:

$$P = F * \frac{1}{(1+i)^{mon/12}} \qquad (3)$$

where:

mon = the number of months elapsed since the base date.

Equation (3) calculates the present value where *i* is the annual discount rate and *mon* is the number of months between the base date and the date of expenditure. Appendix D discusses the derivation of Equation (3) and its relationship to the standard annual discounting formula, Equation (2).

To illustrate the difference in the two present-value calculation methods, consider the example used above. With a discount rate of 5 % and the time elapsed equal to ten years, the present value was $6,139. Suppose the cost was incurred in the first month of the 9th year instead of the last. The time elapsed would be 109 months instead of 120. The annually discounted present value can be compounded into the future using the following equation:

$$F = P * (1+i)^{mon/12} \qquad (4)$$

The compounding of the annually discounted present value of $6,139, occurring 109 months in the future, yields:

$$F = \$6,139 * (1+0.05)^{109/12} = \$9,562$$

The annual discounting approach will fall $438 short at the date of expenditure. The more accurate approach of discounting monthly costs finds the present value:

$$P = \$10,000 * \frac{1}{(1+0.05)^{109/12}} = \$6,420$$

The present value found with Equation (3), $6,420, represents an expenditure of $10,000 in 109 months.

5.3 Computing the Present Value of Monthly Costs

The cost and task data from the sample project is documented in the data table in Appendix A. As can be seen in Exhibit 4, a small section of data extracted from the data table, all dates of expenditure in the sample project are given in terms of both month and year.

Phase	2nd	3rd	4th	5th	Description	Cost	Date
4	.05	.36			Demobilization	$27,398	Aug-2005
4	.07	.08			Air Monitoring and Sampling	$10,560	Aug-2005
4	.07	.14	.01		Hand Scanning	$109,927	Aug-2005
4	.07	.14	.02		Smears and Swipes	$274,817	Aug-2005
4	.07	.14	.03		Destructive Sampling	$164,890	Aug-2005

Exhibit 4: Illustrative Cost Data Extracted from the Sample Project in Appendix A

In the sample project, several of the expenditures occur only a few months after the base date. For example, task item number 4.07.14.01, "Hand Scanning," will be completed in August 2005, for a cost of $109,927. This is only 32 months after the base date of January 2003. Assuming the OMB discount rate of 2.99 % defined in Exhibit 2, Equation (3) is used to discount the monthly cost:

$$P = \$109,927 * \frac{1}{(1+0.0299)^{32/12}} = \$101,621$$

The final column of the spreadsheet in Appendix A lists the present values of all costs for the sample project.

5.4 Computing the Present Value of a Uniform Series

Often an expense will be repeated over several consecutive time periods. This is not uncommon in EM projects where some testing or maintenance tasks must be repeated annually. Figure 2 below, illustrates the timing of a six-period uniform series of expenditures. Starting in period 5, there will be an annual cost that is repeated for 6 years. The final expenditure of the series is scheduled for the end of period 11.

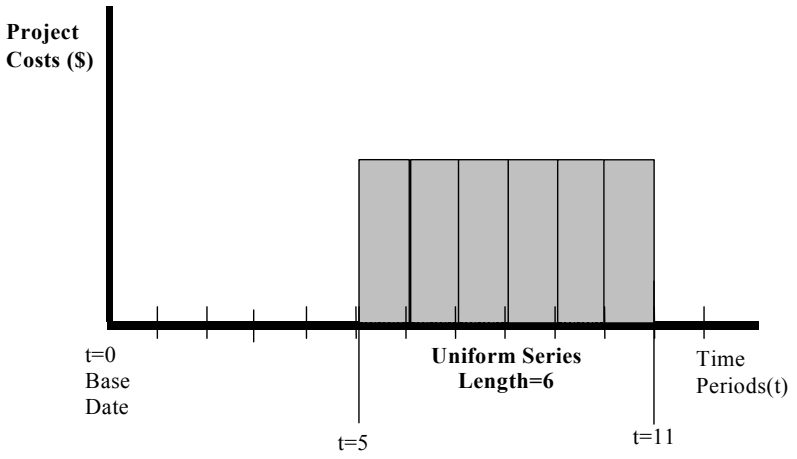

Figure 2: Uniform Series of Expenditures

When calculating the present value of a series of annually repeated expenses, each occurrence could be calculated individually. It is more efficient, however, to use an equation to calculate the discounted value of the entire series of expenditures. The following equation calculates the discounted future value of a uniform series:

$$FVS = A * \frac{(1+i)^t - 1}{i(1+i)^{t-1}} \qquad (5)$$

where

FVS	=	Future value of the uniform series;
t	=	the number of years the cost is incurred;
A	=	the annual cost of the series.

Equation (5) discounts the entire value of the series back to the date of the first expenditure. Using the example in Figure 2, the series would be discounted to the last day in period 5. This is the date that the first expenditure of the series is incurred. The *FVS* is the total of all the expenditures in the series discounted to the time of the first occurrence of the uniform series. To calculate the present value of the series, the *FVS* must be further discounted back to the base date. To calculate the present value, use Equation (3):

$$P = FVS * \frac{1}{(1+i)^{mon/12}}$$

In the sample project, there are maintenance tasks that must be repeated in Phase 6, Surveillance. Exhibit 5 shows an expense that must be repeated for five years starting in 2010.

Phase	2nd	3rd	4th	5th	Description	Cost	Date
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2010
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2011
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2012
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2013
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2014

Exhibit 5: Illustrative Cost Data for a Uniform Series of Expenditures Extracted from the Sample Project in Appendix A

The future value of the series is calculated using Equation (5):

$$FVS = \$6,336 * \frac{(1+0.0299)^5 - 1}{(0.0299)(1+0.0299)^4} = \$6,336 * \frac{.1587}{(0.0299)(1.1251)} = \$29,890$$

The total cost of the series has been discounted to February 2010, the beginning of the series. To calculate the value in terms of base date dollars, the $29,890 must be discounted back 86 months to the base date in January 2003. Using Equation (3) the calculation would be:

$$P = \$29,890 * \frac{1}{(1+0.0299)^{86/12}} = \$24,201$$

Phase	2nd	3rd	4th	5th	Description	Cost	Date	PVC
4	.02	.01			Project Management/Support/Administration	$2,707,041	Aug-2005	$2,502,503
4	.05	.01			Mobilization	$78,281	Aug-2005	$72,366
4	.05	.36			Demobilization	$27,398	Aug-2005	$25,328
4	.07	.08			Air Monitoring and Sampling	$10,560	Aug-2005	$9,762
4	.07	.14	.01		Hand Scanning	$109,927	Aug-2005	$101,621
4	.07	.14	.02		Smears and Swipes	$274,817	Aug-2005	$254,052
4	.07	.14	.03		Destructive Sampling (Including Removal of Paints, Drilling, Cutting of Structures/Equipment, etc)	$164,890	Aug-2005	$152,431
4	.15	.04			Asbestos Abatement	$1,553,564	Aug-2005	$1,436,180
4	.15	.05			Piping & Pipeline Removal	$288,428	Aug-2005	$266,635
4	.19	.01			Contaminated Soil Collection (Excavation)	$623,308	Aug-2005	$576,212
4	.31	.08	.06		Surface Decontamination of Floors	$1,181,105	Aug-2005	$1,091,864
4	.31	.08	.07		Surface Decontamination of Walls	$966,359	Aug-2005	$893,343
4	.31	.08	.19		Decontamination Area/Facility for Equipment and Vehicles	$62,625	Aug-2005	$57,893
4	.31	.08	.20		Decontamination Area/Facility for Personnel (i.e., Showers, Changing Rooms, Monitors, Waste Handling)	$15,656	Aug-2005	$14,473
4	.32	.01			Waste Stream Handling/Packaging	$1,243,720	Aug-2005	$1,149,747
4	.32	.11			Transportation by truck	$1,854,400	Aug-2005	$1,714,286
4	.33	.08			Off-Site Commercial Disposal Costs, Fees, and Taxes	$3,231,217	Aug-2005	$2,987,074
						Phase 4 Total LCC:		**$13,305,773**

Exhibit 6: Present Value Costs for Phase 4 of Sample Project in Appendix A

5.5 Illustration: Computing the LCC of the Sample Project

The present value of each cost element of the sample project is included in the far right column of the worksheet in Appendix A. Exhibit 6 is an excerpt of the cost worksheet consisting of all costs incurred during Phase 4, which covers construction activities.

The final step in computing the LCC of an entire project is to sum all present value costs associated with the project. Exhibit 7 lists the LCC of each Phase of the sample project as well as the total LCC of the project.

Phase	Description	Present Value
1	Assessment	$147,494
2	Studies	$6,229,478
3	Design	$66,809
4	**Construction**	**$13,305,773**
5	Operations and Maintenance	$383,778
6	Surveillance	$1,624,700
	Total LCC:	**$21,758,032**

Exhibit 7: Present Value Costs by Phase for Sample Project in Appendix A

5.6 Interpreting the Total LCC

The total LCC may be used for budgetary purposes or for comparison across multiple EM projects. Note that when using the LCC for budget planning, the total LCC is an estimate. It is only as accurate as estimations of the cost elements.

The total LCC can be helpful in comparing EM projects addressing similar environmental conditions. When comparing across projects, use the same discount rate to calculate the individual LCCs for all projects. There are other factors that can contribute to differences in cost estimates. To make projects comparable be sure to account for differences in location with area cost factors. The scale of the project will also impact the estimate and should be considered when making comparisons.

6. Comparing EM Alternatives Using LCC Analysis

When determining the best treatment for an EM project that addresses a single site, it is common to examine multiple alternatives. In this section a detailed case study is used to illustrate the application of LCC analysis to find the most cost-effective solution for an EM site. The proper method for analyzing these multiple alternative projects is to compute the LCC for each alternative and then select the one with the least cost, as indicated in ASTM E 1185-02, the standard guide for selecting economic analysis methods.[20] This ASTM International guide identifies types of design and system decisions that require economic analysis and recommends the appropriate economic methods for each decision type. It cautions that alternatives being compared must all offer the same benefits over the same study period. This issue of equal benefits and study period is treated in Subsection 6.5.

6.1 Environmental Management Project Specification

This illustrative case study is an EM project that includes the costs of program and project management, characterization, feasibility study, design, remediation, monitoring, and long-term stewardship activities associated with clean-up of a gasoline spill site located in north central California, near Sacramento. The site was used as a refueling station from 1975 to 1992. The soil and the surrounding groundwater were contaminated as a result of leaking gasoline tanks. The contaminants of concern include lead and volatile organic compounds. The contaminated area is approximately 3,720 m^2 (40,000 ft^2) and about 4.5 m to 15.2 m (15 ft to 50 ft) deep.

6.2 Project Alternatives

Two alternatives have been identified as options for remediation. Alternative A, In Situ Soil Vapor Extraction, would begin in January 2004 and continue until August 2007. It would then be monitored until September 2016. Alternative B is Natural Attenuation. Natural Attenuation consists of initial model development and continued operation of the model and the sampling and analysis conducted at the site. This alternative would also start in January 2004. The Natural Attenuation alternative would continue until December 2034. After this period, air monitoring,

[20] ASTM International. 2003. *E 1185-02 Standard Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems*. West Conshohocken, PA: ASTM International.

records management, and other activities would be performed at the site until August 2043. Note that the Vapor Extraction alternative would make the site available for other uses much earlier than the Natural Attenuation alternative. To make the economic comparison valid, a credit must be assigned to the Vapor Extraction alternative to account for the benefit of these additional years of use of the site.

6.3 Setting Analysis Parameters

Before computing the LCC of multiple alternatives, a base date, study period, and discount rate must be selected. The base date will be the date of analysis. The study period must be the same across all alternatives. Most alternatives will have different life-cycle lengths. In this case, Natural Attenuation will take longer than In Situ Vapor Extraction. When alternatives have different lengths, the study period is defined using the completion date of the longest project. This assumes all remediation for the shorter project has been completed. The shorter projects will assume zero costs for any year after their completion, and benefits of earlier use should be included, if applicable. Annual benefits for the remainder of the study period will be treated separately below. In this example the study period will end in August 2043, a total of 40 years and 8 months from the base date of January 1, 2003. The In Situ Vapor Extraction alternative, which will be completed in September 2016, will record an annual cost of $0 from 2017 to 2043. In addition to the zero costs, the shorter project will be credited with benefits received from earlier use of the land.

Finally, the discount rate used in the analysis must be the same for all cash flows. For more information on selecting the appropriate discount rate, consult Section 3. In this example we use the discount rate of 3.2 %, as currently prescribed by OMB for projects lasting 30 years or longer.

6.4 Calculations of LCC for Both Alternatives

The cost data and LCC calculations for the two alternatives are included in Appendices B and C. Exhibits 8 and 9 give summaries of the LCC results by Phase for each alternative.

Phase	Description	Present Value
1	Assessment	$80,989
2	Studies	$3,507,900
3	Design	$89,438
4	Construction	$8,929,017
5	Operations and Maintenance	$2,501,762
6	Surveillance	$78,985
	Total LCC:	**$15,188,091**

Exhibit 8: Present Value Costs by Phase for In Situ Vapor Extraction (Alternative A)

Phase	Description	Present Value
1	Assessment	$80,989
2	Studies	$3,507,913
3	Design	$8,499
4	Construction	$4,670,585
5	Operations and Maintenance	$0
6	Surveillance	$50,355
	Total LCC:	**$8,318,341**

Exhibit 9: Present Value Costs by Phase for Natural Attenuation (Alternative B)

6.5 Calculation of the Adjusted LCC

When comparing the LCC of these two alternatives, any differences in the length of the clean-up process must be analyzed further. Using Vapor Extraction will make the site available much earlier than Natural Attenuation. The additional years of usage is a benefit of the alternative and must be quantified and subtracted from the LCC of the alternative that makes it available (Vapor Extraction).

An appropriate credit could be established by examining the real estate values in the area. One method requires finding comparable land in the area that is leased and assigning an estimated lease value for the intervening period. Comparable sale prices for similar land in the area could also be used to establish a value. In this case, the credit is calculated by comparing the present values of the proceeds of a sale of the land when available under each of the two alternatives.

Alternative A (Vapor Extraction) makes the land available for sale October 1, 2016 (165 months from the base date), while Alternative B (Natural Attenuation) makes it available September 1, 2043 (488 months from the base date). Thus, if the value of the uncontaminated commercial land is $600,000 in today's prices, then compute the present values of the amount for the two dates using Equation (3) for each computation. The difference is the credit earned by the Vapor Extraction alternative.

$$Credit = \$600,000 * \frac{1}{(1+0.032)^{165/12}} - \$600,000 * \frac{1}{(1+0.032)^{488/12}}$$
$$Credit = \$389,095 - \$166,665 = \$222,430$$

Subtract the credit calculated from the LCC of the Vapor Extraction alternative.

$$Adjusted\ LCC = LCC - Credit = \$15,188,091 - \$222,430$$
$$Adjusted\ LCC = \$14,965,661$$

6.6 Life-Cycle Cost Report

The following is the Life-Cycle Cost Report form completed for this case study. Section 1, Project Definition, provides information about the project, its location, and the alternatives being examined with LCC analysis. Section 2 of the report defines the LCC parameters used for analysis. Section 3, Life-Cycle Costs by Phase and Alternative, provides a cost breakdown by ECES phase and alternative. The final section, Section 4, lists the total LCCs for each alternative. It also lists the credit to be granted to the alternative where applicable, and the Adjusted LCC.

1. Project Definition

Project Title: Gasoline Spill Clean Up

Location (City / ST / Zip): Sacramento / CA / 95838

Project Type (Cirlce One): **RCRA** **(CERCLA)** **WM** **D&D**

Record of Decision Date: 01 / 31 / 2003

Analyst: John Doe **Phone:** (XXX) XXX-XXXX **Email:** John.Doe@doe.gov

Project Description:

The program and project management, characterization, feasibility study, design, remediation, monitoring and long-term stewardship activities for clean-up of a gasoline spill site. The site was a refueling station from 1975 to 1992. The soil and surrounding groundwater were contaminated as a result of gasoline tanks leaking. Contaminants include lead and volatile organic compounds. The contaminated area is 3,720 m^2 (40,000 ft^2).

Number of Alternatives: 2

List of Alternatives:

Short Name	Description
Alternative A	In Situ Soil Vapor Extraction
Alternative B	Natural Attenuation

2. LCC Parameters

Study Period (Years): 40 Years, 8 months **Discount Rate:** 3.2 %

Analysis Date: 01 / 01 / 2003 **Base Date:** 01 / 01 / 2003

3. Life-Cycle Costs by Phase and Alternative

Phase	Alternative A	Alternative B
Assessment	$80,989	$80,989
Studies	$3,507,900	$3,507,913
Design	$89,438	$8,499
Construction	$8,929,017	$4,670,585
O&M	$2,501,762	$0
SLTM	$78,985	$50,355
Total LCC	**$15,188,091**	**$8,318,341**

4. Summary Table of Life-Cycle Costs by Alternative

Alternative	Total LCC	Credit	Adjusted Total LCC
Alternative A	$15,188,091	$222,430	$14,965,661
Alternative B	**$8,318,341**	**$0**	**$8,318,341**

6.7 Conclusion

In this prospective LCC analysis two alternatives for a EM project addressing a single site were compared. Each alternative would achieve the objective of cleaning gasoline spills to the same level. The total cost for each alternative was calculated using LCC. Alternative A, the Vapor Extraction approach, has a significantly higher LCC than Alternative B, Natural Attenuation. However, the more aggressive extraction approach used in Alternative A allows for earlier economic use of the land for other purposes. To account for the benefits expected from the earlier availability, a value was estimated to account for the extra years of use and credited to that alternative. Even after the value of the land is taken into account, the natural attenuation method is economically preferred. The savings achieved from selecting Alternative B over A are $6,647,320.

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Appendix A: Data for Sample Project without Alternatives

Sample Project: Nuclear Production Facility Decontamination

Location: Lockport, NY
Base Date: January 2003
Study Period: 24 Years, 2 Months
Discount Rate: 2.99%

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
1	.02	.01	.01		Project Management	$28,445	Jan-2004	13	$27,551
1	.02	.01	.02		Support Subcontracting Activities	$3,346	Jan-2004	13	$3,241
1	.07	.01	.07	.01	Collection and review of existing documents	$109,927	Jan-2004	13	$106,474
1	.07	.08			Air Monitoring and Sampling	$10,560	Jan-2004	13	$10,228
2	.02	.01			Project Management/Support/Administration	$479,930	Apr-2004	16	$461,443
2	.02	.03	.05		Regulatory Permitting (e.g., RCRA Part B Permit)	$639,377	Apr-2004	16	$614,748
2	.03	.02			Chemical Data Acquisition Plan	$2,816	Apr-2004	16	$2,708
2	.03	.03			Sampling and Analysis Plan	$3,520	Apr-2004	16	$3,384
2	.03	.10			Risk Assessment Plan	$1,760	Apr-2004	16	$1,692
2	.03	.11			Technical Project Goals and Objectives	$1,584	Apr-2004	16	$1,523
2	.04	.02			Human Health Risk Assessment	$18,000	Apr-2004	16	$17,307
2	.04	.03			Ecological Risk Assessment	$18,000	Apr-2004	16	$17,307
2	.04	.04			Risk Assessment Documentation	$16,800	Apr-2004	16	$16,153
2	.04	.05			Environmental Investigation Report	$11,000	Apr-2004	16	$10,576
2	.04	.06			Develop Environmental Alternatives	$7,200	Apr-2004	16	$6,923
2	.04	.07			Screen Environmental Alternatives	$4,224	Apr-2004	16	$4,061
2	.04	.08			Evaluate Alternatives	$4,200	Apr-2004	16	$4,038
2	.04	.09			Refinement of Alternatives	$3,520	Apr-2004	16	$3,384
2	.04	.10			Document FS (CMS)	$10,560	Apr-2004	16	$10,153
2	.04	.16			Engineering Evaluation/Cost Analysis	$2,112	Apr-2004	16	$2,031
2	.04	.17			Record of Decision	$4,200	Apr-2004	16	$4,038
2	.07	.03			Site Contaminant Surveys/Radiation Monitoring	$47,520	Apr-2004	16	$45,689
2	.07	.08			Air Monitoring and Sampling	$6,336	Apr-2004	16	$6,092
2	.07	.11	.01		Surface Soil Sample Collection	$26,500	Apr-2004	16	$25,479
2	.07	.11	.02		Subsurface Soil Sample Collection	$70,000	Apr-2004	16	$67,304
2	.07	.14	.01		Hand Scanning	$824,453	Apr-2004	16	$792,694
2	.07	.14	.02		Smears and Swipes	$2,061,128	Apr-2004	16	$1,981,731

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
2	.07	.14	.03		Destructive Sampling (Including Removal of Paints, Drilling, Cutting of Structures/Equipment, etc)	$1,236,677	Apr-2004	16	$1,189,039
2	.08	.04			Soil/Sediment Sample Analysis	$604,500	Apr-2004	16	$581,214
2	.08	.07			Solid Material/Waste Sampling	$354,500	Apr-2004	16	$340,844
2	.09	.01			Prepare and Ship Environmental Samples	$5,000	Apr-2004	16	$4,807
2	.09	.04			Provide Sample Management	$6,600	Apr-2004	16	$6,346
2	.09	.08			Data Reduction, Tabulation and Evaluation	$7,040	Apr-2004	16	$6,769
3	.02	.01			Project Management/Support/Administration	$16,624	Mar-2005	27	$15,557
3	.04	.12	.01		Preliminary Design	$17,955	Mar-2005	27	$16,803
3	.04	.12	.02		Intermediate Design	$3,217	Mar-2005	27	$3,011
3	.04	.12	.03		Pre-final/Final Design	$26,434	Mar-2005	27	$24,738
3	.02	.05	.02	.01	Support preparation of solicitation package	$2,089	Mar-2005	27	$1,955
3	.02	.05	.02	.03	Advertising/soliciting of bids	$1,200	Mar-2005	27	$1,123
3	.02	.05	.02	.05	Pre-bid (pre-solicitation) meetings	$350	Mar-2005	27	$328
3	.02	.05	.03		Perform Pre-Award Activities	$3,520	Mar-2005	27	$3,294
4	.02	.01			Project Management/Support/Administration	$2,707,041	Aug-2005	32	$2,502,503
4	.05	.01			Mobilization	$78,281	Aug-2005	32	$72,366
4	.05	.36			Demobilization	$27,398	Aug-2005	32	$25,328
4	.07	.08			Air Monitoring and Sampling	$10,560	Aug-2005	32	$9,762
4	.07	.14	.01		Hand Scanning	$109,927	Aug-2005	32	$101,621
4	.07	.14	.02		Smears and Swipes	$274,817	Aug-2005	32	$254,052
4	.07	.14	.03		Destructive Sampling (Including Removal of Paints, Drilling, Cutting of Structures/Equipment, etc)	$164,890	Aug-2005	32	$152,431
4	.15	.04			Asbestos Abatement	$1,553,564	Aug-2005	32	$1,436,180
4	.15	.05			Piping & Pipeline Removal	$288,428	Aug-2005	32	$266,635
4	.19	.01			Contaminated Soil Collection (Excavation)	$623,308	Aug-2005	32	$576,212
4	.31	.08	.06		Surface Decontamination of Floors	$1,181,105	Aug-2005	32	$1,091,864
4	.31	.08	.07		Surface Decontamination of Walls	$966,359	Aug-2005	32	$893,343
4	.31	.08	.19		Decontamination Area/Facility for Equipment and Vehicles	$62,625	Aug-2005	32	$57,893
4	.31	.08	.20		Decontamination Area/Facility for Personnel (i.e., Showers, Changing Rooms, Monitors, Waste Handling)	$15,656	Aug-2005	32	$14,473
4	.32	.01			Waste Stream Handling/Packaging	$1,243,720	Aug-2005	32	$1,149,747
4	.32	.11			Transportation by truck	$1,854,400	Aug-2005	32	$1,714,286
4	.33	.08			Off-Site Commercial Disposal Costs, Fees, and Taxes	$3,231,217	Aug-2005	32	$2,987,074

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
5	.02	.01			Project Management/Support/Administration	$35,058	Sep-2005	33	$32,330
5	.07	.14	.01		Hand Scanning	$67,822	Sep-2005	33	$62,543
5	.07	.14	.02		Smears and Swipes	$169,554	Sep-2005	33	$156,359
5	.07	.14	.03		Destructive Sampling (Including Removal of Paints, Drilling, Cutting of Structures/Equipment, etc)	$101,732	Sep-2005	33	$93,815
5	.31	.08	.20		Decontamination Area/Facility for Personnel (I.e. Showers, Changing Rooms, Monitors, Waste Handling)	$42,000	Sep-2005	33	$38,731
6	.02	.01			Project Management/Support/Administration	$13,885	Feb-2008	62	$11,924
6	.02	.01			Project Management/Support/Administration	$7,134	Feb-2009	74	$5,949
6	.02	.01			Project Management/Support/Administration	$7,414	Feb-2010	86	$6,003
6	.02	.01			Project Management/Support/Administration	$7,515	Feb-2011	98	$5,908
6	.02	.01			Project Management/Support/Administration	$8,039	Feb-2012	110	$6,136
6	.02	.01			Project Management/Support/Administration	$8,387	Feb-2013	122	$6,216
6	.02	.01			Project Management/Support/Administration	$8,761	Feb-2014	134	$6,305
6	.02	.01			Project Management/Support/Administration	$9,164	Feb-2015	146	$6,403
6	.02	.01			Project Management/Support/Administration	$9,596	Feb-2016	158	$6,511
6	.02	.01			Project Management/Support/Administration	$18,827	Feb-2017	170	$12,403
6	.02	.01			Project Management/Support/Administration	$10,561	Feb-2018	182	$6,755
6	.02	.01			Project Management/Support/Administration	$11,098	Feb-2019	194	$6,893
6	.02	.01			Project Management/Support/Administration	$11,676	Feb-2020	206	$7,041
6	.02	.01			Project Management/Support/Administration	$12,297	Feb-2021	218	$7,200
6	.02	.01			Project Management/Support/Administration	$12,964	Feb-2022	230	$7,371
6	.02	.01			Project Management/Support/Administration	$13,682	Feb-2023	242	$7,553
6	.02	.01			Project Management/Support/Administration	$14,453	Feb-2024	254	$7,747
6	.02	.01			Project Management/Support/Administration	$15,282	Feb-2025	266	$7,953
6	.02	.01			Project Management/Support/Administration	$16,174	Feb-2026	278	$8,173
6	.02	.01			Project Management/Support/Administration	$39,046	Feb-2027	290	$19,159
6	.02	.04	.04		Land Record Management	$2,640	Feb-2008	62	$2,267
6	.02	.04	.04		Land Record Management	$2,640	Feb-2009	74	$2,201
6	.02	.04	.04		Land Record Management	$2,640	Feb-2010	86	$2,137
6	.02	.04	.04		Land Record Management	$2,640	Feb-2011	98	$2,075
6	.02	.04	.04		Land Record Management	$2,640	Feb-2012	110	$2,015
6	.02	.04	.04		Land Record Management	$2,640	Feb-2013	122	$1,957
6	.02	.04	.04		Land Record Management	$2,640	Feb-2014	134	$1,900

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
6	.02	.04	.04		Land Record Management	$2,640	Feb-2015	146	$1,845
6	.02	.04	.04		Land Record Management	$2,640	Feb-2016	158	$1,791
6	.02	.04	.04		Land Record Management	$2,640	Feb-2017	170	$1,739
6	.02	.04	.04		Land Record Management	$2,640	Feb-2018	182	$1,689
6	.02	.04	.04		Land Record Management	$2,640	Feb-2019	194	$1,640
6	.02	.04	.04		Land Record Management	$2,640	Feb-2020	206	$1,592
6	.02	.04	.04		Land Record Management	$2,640	Feb-2021	218	$1,546
6	.02	.04	.04		Land Record Management	$2,640	Feb-2022	230	$1,501
6	.02	.04	.04		Land Record Management	$2,640	Feb-2023	242	$1,457
6	.02	.04	.04		Land Record Management	$2,640	Feb-2024	254	$1,415
6	.02	.04	.04		Land Record Management	$2,640	Feb-2025	266	$1,374
6	.02	.04	.04		Land Record Management	$2,640	Feb-2026	278	$1,334
6	.02	.04	.04		Land Record Management	$2,640	Feb-2027	290	$1,295
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2008	62	$1,360
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2009	74	$1,321
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2010	86	$1,282
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2011	98	$1,245
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2012	110	$1,209
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2013	122	$1,174
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2014	134	$1,140
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2015	146	$1,107
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2016	158	$1,075
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2017	170	$1,043
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2018	182	$1,013
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2019	194	$984
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2020	206	$955
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2021	218	$927
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2022	230	$901
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2023	242	$874
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2024	254	$849
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2025	266	$824
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2026	278	$800
6	.02	.04	.05		Transferred Property Restriction	$1,584	Feb-2027	290	$777
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2008	62	$1,649
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2009	74	$1,601

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2010	86	$1,555
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2011	98	$1,509
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2012	110	$1,466
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2013	122	$1,423
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2014	134	$1,382
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2015	146	$1,342
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2016	158	$1,303
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2017	170	$1,265
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2018	182	$1,228
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2019	194	$1,192
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2020	206	$1,158
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2021	218	$1,124
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2022	230	$1,092
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2023	242	$1,060
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2024	254	$1,029
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2025	266	$999
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2026	278	$970
6	.02	.04	.06		Verification of Institutional Controls	$1,920	Feb-2027	290	$942
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2008	62	$15,802
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2009	74	$15,343
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2010	86	$14,898
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2011	98	$14,465
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2012	110	$14,045
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2013	122	$13,637
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2014	134	$13,242
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2015	146	$12,857
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2016	158	$12,484
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2017	170	$12,121
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2018	182	$11,770
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2019	194	$11,428
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2020	206	$11,096
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2021	218	$10,774
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2022	230	$10,461
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2023	242	$10,157
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2024	254	$9,863

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2025	266	$9,576
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2026	278	$9,298
6	.06	.03	.01		Surveillance and Inspections	$18,400	Feb-2027	290	$9,028
6	.06	.03	.02		Facility/Building Maintenance	$31,600	Feb-2008	62	$27,138
6	.06	.03	.02		Facility/Building Maintenance	$33,970	Feb-2009	74	$28,326
6	.06	.03	.02		Facility/Building Maintenance	$36,518	Feb-2010	86	$29,567
6	.06	.03	.02		Facility/Building Maintenance	$39,257	Feb-2011	98	$30,862
6	.06	.03	.02		Facility/Building Maintenance	$42,201	Feb-2012	110	$32,213
6	.06	.03	.02		Facility/Building Maintenance	$45,366	Feb-2013	122	$33,624
6	.06	.03	.02		Facility/Building Maintenance	$48,768	Feb-2014	134	$35,096
6	.06	.03	.02		Facility/Building Maintenance	$52,426	Feb-2015	146	$36,633
6	.06	.03	.02		Facility/Building Maintenance	$56,358	Feb-2016	158	$38,237
6	.06	.03	.02		Facility/Building Maintenance	$60,585	Feb-2017	170	$39,912
6	.06	.03	.02		Facility/Building Maintenance	$65,129	Feb-2018	182	$41,660
6	.06	.03	.02		Facility/Building Maintenance	$70,013	Feb-2019	194	$43,484
6	.06	.03	.02		Facility/Building Maintenance	$75,264	Feb-2020	206	$45,388
6	.06	.03	.02		Facility/Building Maintenance	$80,909	Feb-2021	218	$47,375
6	.06	.03	.02		Facility/Building Maintenance	$86,977	Feb-2022	230	$49,450
6	.06	.03	.02		Facility/Building Maintenance	$93,501	Feb-2023	242	$51,616
6	.06	.03	.02		Facility/Building Maintenance	$100,513	Feb-2024	254	$53,876
6	.06	.03	.02		Facility/Building Maintenance	$108,052	Feb-2025	266	$56,235
6	.06	.03	.02		Facility/Building Maintenance	$116,155	Feb-2026	278	$58,697
6	.06	.03	.02		Facility/Building Maintenance	$124,867	Feb-2027	290	$61,268
6	.06	.03	.04		Major Facility Repairs	$63,750	Feb-2008	62	$54,749
6	.06	.03	.04		Major Facility Repairs	$79,688	Feb-2017	170	$52,496
6	.06	.03	.04		Major Facility Repairs	$199,219	Feb-2027	290	$97,750
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2008	62	$5,441
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2009	74	$5,283
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2010	86	$5,130
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2011	98	$4,981
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2012	110	$4,836
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2013	122	$4,696
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2014	134	$4,560
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2015	146	$4,427
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2016	158	$4,299

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2017	170	$4,174
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2018	182	$4,053
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2019	194	$3,935
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2020	206	$3,821
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2021	218	$3,710
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2022	230	$3,602
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2023	242	$3,498
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2024	254	$3,396
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2025	266	$3,298
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2026	278	$3,202
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2027	290	$3,109
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2008	62	$5,441
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2017	170	$4,174
6	.07	.08	.04		Air Monitoring and Sampling	$6,336	Feb-2027	290	$3,109
							Total LCC:		$21,758,032

Appendix B: Data for Case Study with Two Alternatives—In Situ Soil Vapor Extraction

Sample Project: Gasoline Spill Clean-up
Alternative A: In Situ Soil Vapor Extraction
Location: Sacramento, CA
Base Date: January 2003
Study Period: 40 Years, 8 Months
Discount Rate: 3.2%

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
1	.02	.01	.01		Project Management	$16,760	Jan-2004	13	$16,198
1	.02	.01	.02		Support Subcontracting Activities	$6,080	Jan-2004	13	$5,876
1	.07	.01	.07	.01	Collection and review of exisiting documents	$50,400	Jan-2004	13	$48,709
1	.07	.08			Air Monitoring and Sampling	$10,560	Jan-2004	13	$10,206
2	.02	.01			Project Management/Support/Administration	$322,437	Mar-2004	15	$309,988
2	.02	.03	.05		Regulatory Permitting(e.g, RCA Part B Permit)	$639,377	Mar-2004	15	$614,692
2	.03	.03			Sampling and Analysis Plan	$3,520	Mar-2004	15	$3,384
2	.03	.10			Risk Assessment Plan	$1,760	Mar-2004	15	$1,692
2	.03	.11			Technical Project Goals and Objectives	$2,112	Mar-2004	15	$2,030
2	.04	.02			Human Health Risk Assessment	$27,600	Mar-2004	15	$26,534
2	.04	.03			Ecological Risk Assessment	$18,000	Mar-2004	15	$17,305
2	.04	.04			Risk Assessment Documentation	$19,320	Mar-2004	15	$18,574
2	.04	.05			Environmental Investigation Report	$14,520	Mar-2004	15	$13,959
2	.04	.06			Develop Environmental Alternatives	$9,600	Mar-2004	15	$9,229
2	.04	.07			Screen Environmental Alternatives	$5,632	Mar-2004	15	$5,415
2	.04	.08			Evaluate Alternatives	$4,200	Mar-2004	15	$4,038
2	.04	.09			Refinement of Alternatives	$4,211	Mar-2004	15	$4,048
2	.04	.10			Document FS(CMS)	$12,060	Mar-2004	15	$11,594
2	.04	.16			Engineering Evaluation/Cost Analysis	$2,112	Mar-2004	15	$2,030
2	.04	.17			Record of Decision	$5,040	Mar-2004	15	$4,845
2	.07	.03			Site Contaminant Surveys/Radiation Monitoring	$21,120	Mar-2004	15	$20,305
2	.07	.08			Air Monitoring and Sampling	$12,672	Mar-2004	15	$12,183
2	.07	.11	.02		Subsurface Soil Sample Collection	$460,000	Mar-2004	15	$442,240
2	.07	.09			Groundwater Sampling/Monitoring	$354,500	Mar-2004	15	$340,813
2	.08	.04			Soil/Sediment Sample Analysis	$1,155,000	Mar-2004	15	$1,110,407
2	.08	.06			Liquid Material/Waste Sample Analysis	$503,220	Mar-2004	15	$483,792
2	.09	.01			Prepare and Ship Environmental Samples	$5,000	Mar-2004	15	$4,807
2	.09	.04			Provide Sample Management	$17,600	Mar-2004	15	$16,920

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
2	.09	.08			Data Reduction, Tabulation and Evaluation	$28,160	Mar-2004	15	$27,073
3	.02	.01			Project Management/Support/Administration	$10,126	Sep-2004	21	$9,583
3	.04	.12	.01		Preliminary Design	$44,380	Sep-2004	21	$42,000
3	.04	.12	.02		Intermediate Design	$23,880	Sep-2004	21	$22,599
3	.04	.12	.03		Pre-final/Final Design	$7,040	Sep-2004	21	$6,662
3	.02	.05	.02	.01	Support preparation of solicitation package	$3,520	Sep-2004	21	$3,331
3	.02	.05	.02	.03	Advertising/soliciting of bids	$1,200	Sep-2004	21	$1,136
3	.02	.05	.02	.05	Pre-bid (pre-soliciatation) meetings	$840	Sep-2004	21	$795
3	.02	.05	.03		Perform Pre-Award Activities	$3,520	Sep-2004	21	$3,331
4	.02	.01			Project Management/Support/Administration	$1,018,888	Dec-2004	24	$956,681
4	.02	.04	.03		Fencing/Barriers	$132,361	Dec-2004	24	$124,280
4	.05	.01			Mobilization	$78,281	Dec-2004	24	$73,502
4	.05	.36			Demobilization	$27,398	Dec-2004	24	$25,725
4	.07	.08			Air Monitoring and Sampling	$10,560	Dec-2004	24	$9,915
4	.07	.09			Groundwater Sampling/Monitoring	$18,304	Dec-2004	24	$17,186
4	.08	.01			Air/Gas Sample Analysis	$68,000	Dec-2004	24	$63,848
4	.08	.06			Liquid Material/Waste Sample Analysis	$80,000	Dec-2004	24	$75,116
4	.08	.04			Solid Material/Wast Sample Analysis	$92,000	Dec-2004	24	$86,383
4	.09	.01			Prepare and Ship Environmental Samples	$1,340	Dec-2004	24	$1,258
4	.26	.04			Air Stripping	$53,476	Dec-2004	24	$50,211
4	.26	.23			Granular Activated Carbon Absorption-Liquid	$6,196	Dec-2004	24	$5,818
4	.26	.30			Oil/Water Separation	$12,323	Dec-2004	24	$11,571
4	.27	.04			Steam/Hot Water Injection Vacuum Extraction	$1,572,153	Dec-2004	24	$1,476,167
4	.31	.08	.20		Decontamination Area/Facility for Personnel	$9,000	Dec-2004	24	$8,451
4	.32	.01			Waste Steam Handling Packaging	$1,243,720	Dec-2004	24	$1,167,786
4	.32	.11			Transportation by truck	$1,854,400	Dec-2004	24	$1,741,181
4	.33	.08			Off-site Commerical Disposal Costs, Fees and T	$3,231,217	Dec-2004	24	$3,033,938
5	.02	.01			Project Management/Support/Administration	$94,568	Aug-2005	32	$86,949
5	.02	.01			Project Management/Support/Administration	$85,318	Aug-2006	44	$76,012
5	.02	.01			Project Management/Support/Administration	$74,682	Aug-2007	56	$64,473
5	.02	.04	.03		Fencing/Barriers	$840	Aug-2005	32	$772
5	.02	.04	.03		Fencing/Barriers	$840	Aug-2006	44	$748
5	.02	.04	.03		Fencing/Barriers	$990	Aug-2007	56	$855
5	.07	.08			Air Monitoring and Sampling	$7,040	Aug-2005	32	$6,473
5	.07	.08			Air Monitoring and Sampling	$7,040	Aug-2006	44	$6,272
5	.07	.08			Air Monitoring and Sampling	$5,632	Aug-2007	56	$4,862

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
5	.07	.09			Groundwater Sampling/Monitoring	$7,040	Aug-2005	32	$6,473
5	.07	.09			Groundwater Sampling/Monitoring	$7,040	Aug-2006	44	$6,272
5	.07	.09			Groundwater Sampling/Monitoring	$7,040	Aug-2007	56	$6,078
5	.08	.01			Air/Gas Sample Analysis	$27,200	Aug-2005	32	$25,009
5	.08	.01			Air/Gas Sample Analysis	$27,200	Aug-2006	44	$24,233
5	.08	.01			Air/Gas Sample Analysis	$27,200	Aug-2007	56	$23,482
5	.08	.06			Liquid Material/Waste Sample Analysis	$32,000	Aug-2005	32	$29,422
5	.08	.06			Liquid Material/Waste Sample Analysis	$32,000	Aug-2006	44	$28,510
5	.08	.06			Liquid Material/Waste Sample Analysis	$32,000	Aug-2007	56	$27,626
5	.08	.07			Solid Material/Waste Sample Analysis	$36,800	Aug-2005	32	$33,835
5	.08	.07			Solid Material/Waste Sample Analysis	$36,800	Aug-2006	44	$32,786
5	.08	.07			Solid Material/Waste Sample Analysis	$36,800	Aug-2007	56	$31,769
5	.09	.01			Prepare and Ship Environmental Samples	$4,300	Aug-2005	32	$3,954
5	.09	.01			Prepare and Ship Environmental Samples	$4,300	Aug-2006	44	$3,831
5	.09	.01			Prepare and Ship Environmental Samples	$4,300	Aug-2007	56	$3,712
5	.26	.04			Air Stripping	$54,008	Aug-2005	32	$49,657
5	.26	.04			Air Stripping	$59,409	Aug-2006	44	$52,929
5	.26	.04			Air Stripping	$55,808	Aug-2007	56	$48,179
5	.26	.23			Granular Activated Carbon Absorption-Liquid	$54,008	Aug-2005	32	$49,657
5	.26	.23			Granular Activated Carbon Absorption-Liquid	$46,807	Aug-2006	44	$41,702
5	.26	.23			Granular Activated Carbon Absorption-Liquid	$36,005	Aug-2007	56	$31,083
5	.26	.30			Oil/Water Separation	$9,001	Aug-2005	32	$8,276
5	.26	.30			Oil/Water Separation	$9,001	Aug-2006	44	$8,019
5	.26	.30			Oil/Water Separation	$9,001	Aug-2007	56	$7,771
5	.27	.04			Steam/Hot Water Injection Vacuum Extraction	$574,440	Aug-2005	32	$528,160
5	.27	.04			Steam/Hot Water Injection Vacuum Extraction	$483,739	Aug-2006	44	$430,975
5	.27	.04			Steam/Hot Water Injection Vacuum Extraction	$393,038	Aug-2007	56	$339,309
5	.31	.08	.20		Decontamination Area/Facility for Personnel	$139,000	Aug-2005	32	$127,801
5	.31	.08	.20		Decontamination Area/Facility for Personnel	$139,000	Aug-2006	44	$123,839
5	.31	.08	.20		Decontamination Area/Facility for Personnel	$139,000	Aug-2007	56	$119,999
6	.02	.01			Project Management/Support/Administration	$957	Sep-2007	57	$824
6	.02	.01			Project Management/Support/Administration	$957	Sep-2008	69	$798
6	.02	.01			Project Management/Support/Administration	$957	Sep-2009	81	$774
6	.02	.01			Project Management/Support/Administration	$957	Sep-2010	93	$750
6	.02	.01			Project Management/Support/Administration	$957	Sep-2011	105	$726
6	.02	.01			Project Management/Support/Administration	$957	Sep-2012	117	$704

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Months	PVC
6	.02	.01			Project Management/Support/Administration	$957	Sep-2013	129	$682
6	.02	.01			Project Management/Support/Administration	$957	Sep-2014	141	$661
6	.02	.01			Project Management/Support/Administration	$957	Sep-2015	153	$640
6	.02	.01			Project Management/Support/Administration	$957	Sep-2016	165	$621
6	.02	.04	.04		Land Record Management	$1,650	Sep-2007	57	$1,421
6	.02	.04	.04		Land Record Management	$1,650	Sep-2008	69	$1,377
6	.02	.04	.04		Land Record Management	$1,650	Sep-2009	81	$1,334
6	.02	.04	.04		Land Record Management	$1,650	Sep-2010	93	$1,293
6	.02	.04	.04		Land Record Management	$1,650	Sep-2011	105	$1,253
6	.02	.04	.04		Land Record Management	$1,650	Sep-2012	117	$1,214
6	.02	.04	.04		Land Record Management	$1,650	Sep-2013	129	$1,176
6	.02	.04	.04		Land Record Management	$1,650	Sep-2014	141	$1,140
6	.02	.04	.04		Land Record Management	$1,650	Sep-2015	153	$1,104
6	.02	.04	.04		Land Record Management	$1,650	Sep-2016	165	$1,070
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2007	57	$1,364
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2008	69	$1,322
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2009	81	$1,281
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2010	93	$1,241
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2011	105	$1,202
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2012	117	$1,165
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2013	129	$1,129
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2014	141	$1,094
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2015	153	$1,060
6	.02	.04	.05		Transferred Property Restriction	$1,584	Sep-2016	165	$1,027
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2007	57	$5,456
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2008	69	$5,286
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2009	81	$5,122
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2010	93	$4,964
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2011	105	$4,810
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2012	117	$4,661
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2013	129	$4,516
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2014	141	$4,376
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2015	153	$4,240
6	.07	.08			Air Monitoring and Sampling	$6,336	Sep-2016	165	$4,109
								Total LCC:	**$15,188,090**

Appendix C: Data for Case Study with Two Alternatives—Natural Attenuation

Sample Project: Gasoline Spill Clean-Up
Alternative B : Natural Attenuation
Location: Sacramento, CA
Base Date: January 2003
Study Period: 40 Years, 8 Months
Discount Rate: 3.2%

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Month	PVC
1	.02	.01	.01		Project Management	$16,760	Jan-2004	13	$16,198
1	.02	.01	.02		Support Subcontracting Activities	$6,080	Jan-2004	13	$5,876
1	.07	.01	.07	.01	Collection and review of existing documents	$50,400	Jan-2004	13	$48,709
1	.07	.08			Air Monitoring and Sampling	$10,560	Jan-2004	13	$10,206
2	.02	.01			Project Management/Support/Administration	$322,437	Mar-2004	15	$309,988
2	.02	.03	.05		Regulatory Permitting (e.g., RCRA Part B Permit	$639,377	Mar-2004	15	$614,692
2	.03	.03			Sampling and Analysis Plan	$3,520	Mar-2004	15	$3,384
2	.03	.10			Risk Assessment Plan	$1,760	Mar-2004	15	$1,692
2	.03	.11			Technical Project Goals and Objectives	$2,112	Mar-2004	15	$2,030
2	.04	.02			Human Health Risk Assessment	$27,600	Mar-2004	15	$26,534
2	.04	.03			Ecological Risk Assessment	$18,000	Mar-2004	15	$17,305
2	.04	.04			Risk Assessment Documentation	$19,320	Mar-2004	15	$18,574
2	.04	.05			Environmental Investigation Report	$14,520	Mar-2004	15	$13,959
2	.04	.06			Develop Environmental Alternatives	$9,600	Mar-2004	15	$9,229
2	.04	.07			Screen Environmental Alternatives	$5,632	Mar-2004	15	$5,415
2	.04	.08			Evaluate Alternatives	$4,200	Mar-2004	15	$4,038
2	.04	.09			Refinement of Alternatives	$4,224	Mar-2004	15	$4,061
2	.04	.10			Document FS (CMS)	$12,060	Mar-2004	15	$11,594
2	.04	.16			Engineering Evaluation/Cost Analysis	$2,112	Mar-2004	15	$2,030
2	.04	.17			Record of Decision	$5,040	Mar-2004	15	$4,845
2	.07	.03			Site Contaminant Surveys/Radiation Monitoring	$21,120	Mar-2004	15	$20,305
2	.07	.08			Air Monitoring and Sampling	$12,672	Mar-2004	15	$12,183
2	.07	.11	.02		Subsurface Soil Sample Collection	$460,000	Mar-2004	15	$442,240
2	.07	.09			Groundwater Sampling/Monitoring	$354,500	Mar-2004	15	$340,813
2	.08	.04			Soil/Sediment Sample Analysis	$1,155,000	Mar-2004	15	$1,110,407
2	.08	.06			Liquid Material/Waste Sample Analysis	$503,220	Mar-2004	15	$483,792
2	.09	.01			Prepare and Ship Environmental Samples	$5,000	Mar-2004	15	$4,807
2	.09	.04			Provide Sample Management	$17,600	Mar-2004	15	$16,920

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Month	PVC
2	.09	.08			Data Reduction, Tabulation and Evaluation	$28,160	Mar-2004	15	$27,073
3	.04	.01			Project Management/Support/Administration	$962	Sep-2004	21	$910
3	.04	.12	.01		Preliminary Design	$1,055	Sep-2004	21	$998
3	.04	.12	.02		Intermediate Design	$1,938	Sep-2004	21	$1,834
3	.04	.12	.03		Pre-final/Final Design	$2,254	Sep-2004	21	$2,133
3	.02	.05	.02	.01	Support preparation of solicitation package	$569	Sep-2004	21	$538
3	.02	.05	.02	.03	Advertising/soliciting of bids	$625	Sep-2004	21	$591
3	.02	.05	.02	.05	Pre-bid (pre-solicitation) meetings	$521	Sep-2004	21	$493
3	.02	.05	.03		Perform Pre-Award Activities	$1,057	Sep-2004	21	$1,000
4	.02	.01			Project Management/Support/Administration	$48,471	Dec-2004	24	$45,512
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2005	36	$19,294
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2006	48	$18,696
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2007	60	$18,116
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2008	72	$17,554
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2009	84	$17,010
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2010	96	$16,482
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2011	108	$15,971
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2012	120	$15,476
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2013	132	$14,996
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2014	144	$14,531
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2015	156	$14,081
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2016	168	$13,644
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2017	180	$13,221
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2018	192	$12,811
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2019	204	$12,414
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2020	216	$12,029
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2021	228	$11,656
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2022	240	$11,294
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2023	252	$10,944
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2024	264	$10,605
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2025	276	$10,276
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2026	288	$9,957
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2027	300	$9,649
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2028	312	$9,349
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2029	324	$9,060
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2030	336	$8,779

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Month	PVC
4	.02	.01			Project Management/Support/Administration	$21,206	Dec-2031	348	$8,506
4	.02	.01			Project Management/Support/Administration	$23,776	Dec-2032	360	$9,242
4	.02	.01			Project Management/Support/Administration	$26,903	Dec-2033	372	$10,133
4	.02	.01			Project Management/Support/Administration	$27,977	Dec-2034	384	$10,211
4	.02	.04	.03		Fencing/Barriers	$132,361	Dec-2004	24	$124,280
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2005	36	$764
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2006	48	$741
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2007	60	$718
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2008	72	$695
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2009	84	$674
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2010	96	$653
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2011	108	$633
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2012	120	$613
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2013	132	$594
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2014	144	$576
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2015	156	$558
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2016	168	$540
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2017	180	$524
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2018	192	$507
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2019	204	$492
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2020	216	$476
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2021	228	$462
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2022	240	$447
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2023	252	$434
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2024	264	$420
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2025	276	$407
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2026	288	$394
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2027	300	$382
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2028	312	$370
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2029	324	$359
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2030	336	$348
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2031	348	$337
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2032	360	$327
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2033	372	$316
4	.02	.04	.03		Fencing/Barriers	$840	Dec-2034	384	$307
4	.21	.08			Natural Attenuation	$271,562	Dec-2004	24	$254,982

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Month	PVC
4	.21	.08			Natural Attenuation	$211,217	Dec-2005	36	$192,172
4	.21	.08			Natural Attenuation	$211,217	Dec-2006	48	$186,213
4	.21	.08			Natural Attenuation	$211,217	Dec-2007	60	$180,439
4	.21	.08			Natural Attenuation	$211,217	Dec-2008	72	$174,844
4	.21	.08			Natural Attenuation	$211,217	Dec-2009	84	$169,422
4	.21	.08			Natural Attenuation	$211,217	Dec-2010	96	$164,169
4	.21	.08			Natural Attenuation	$211,217	Dec-2011	108	$159,079
4	.21	.08			Natural Attenuation	$211,217	Dec-2012	120	$154,146
4	.21	.08			Natural Attenuation	$211,217	Dec-2013	132	$149,366
4	.21	.08			Natural Attenuation	$211,217	Dec-2014	144	$144,735
4	.21	.08			Natural Attenuation	$211,217	Dec-2015	156	$140,247
4	.21	.08			Natural Attenuation	$211,217	Dec-2016	168	$135,898
4	.21	.08			Natural Attenuation	$211,217	Dec-2017	180	$131,684
4	.21	.08			Natural Attenuation	$211,217	Dec-2018	192	$127,601
4	.21	.08			Natural Attenuation	$211,217	Dec-2019	204	$123,644
4	.21	.08			Natural Attenuation	$211,217	Dec-2020	216	$119,810
4	.21	.08			Natural Attenuation	$211,217	Dec-2021	228	$116,095
4	.21	.08			Natural Attenuation	$211,217	Dec-2022	240	$112,495
4	.21	.08			Natural Attenuation	$211,217	Dec-2023	252	$109,007
4	.21	.08			Natural Attenuation	$211,217	Dec-2024	264	$105,627
4	.21	.08			Natural Attenuation	$211,217	Dec-2025	276	$102,352
4	.21	.08			Natural Attenuation	$211,217	Dec-2026	288	$99,178
4	.21	.08			Natural Attenuation	$211,217	Dec-2027	300	$96,103
4	.21	.08			Natural Attenuation	$211,217	Dec-2028	312	$93,123
4	.21	.08			Natural Attenuation	$211,217	Dec-2029	324	$90,235
4	.21	.08			Natural Attenuation	$211,217	Dec-2030	336	$87,437
4	.21	.08			Natural Attenuation	$211,217	Dec-2031	348	$84,726
4	.21	.08			Natural Attenuation	$236,917	Dec-2032	360	$92,088
4	.21	.08			Natural Attenuation	$268,219	Dec-2033	372	$101,023
4	.21	.08			Natural Attenuation	$278,926	Dec-2034	384	$101,798
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2034	380	$525
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2035	392	$509
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2036	404	$493
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2037	416	$478
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2038	428	$463
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2039	440	$449

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Month	PVC
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2040	452	$435
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2041	464	$421
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2042	476	$408
6	.02	.01			Project Management/Support/Administration	$1,424	Aug-2043	488	$396
6	.02	.04	.04		Land Record Management	$1,650	Aug-2034	380	$609
6	.02	.04	.04		Land Record Management	$1,650	Aug-2035	392	$590
6	.02	.04	.04		Land Record Management	$1,650	Aug-2036	404	$571
6	.02	.04	.04		Land Record Management	$1,650	Aug-2037	416	$554
6	.02	.04	.04		Land Record Management	$1,650	Aug-2038	428	$537
6	.02	.04	.04		Land Record Management	$1,650	Aug-2039	440	$520
6	.02	.04	.04		Land Record Management	$1,650	Aug-2040	452	$504
6	.02	.04	.04		Land Record Management	$1,650	Aug-2041	464	$488
6	.02	.04	.04		Land Record Management	$1,650	Aug-2042	476	$473
6	.02	.04	.04		Land Record Management	$1,650	Aug-2043	488	$458
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2034	380	$584
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2035	392	$566
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2036	404	$549
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2037	416	$532
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2038	428	$515
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2039	440	$499
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2040	452	$484
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2041	464	$469
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2042	476	$454
6	.02	.04	.05		Transferred Property Restriction	$1,584	Aug-2043	488	$440
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2034	380	$2,308
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2035	392	$2,236
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2036	404	$2,167
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2037	416	$2,100
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2038	428	$2,035
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2039	440	$1,972
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2040	452	$1,911
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2041	464	$1,851
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2042	476	$1,794
6	.02	.18	.03		Electronic Records Management	$6,258	Aug-2043	488	$1,738
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2034	380	$1,753
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2035	392	$1,698

Phase	2nd	3rd	4th	5th	Description	Cost	Date	Month	PVC
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2036	404	$1,646
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2037	416	$1,595
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2038	428	$1,545
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2039	440	$1,497
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2040	452	$1,451
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2041	464	$1,406
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2042	476	$1,362
6	.07	.08			Air Monitoring and Sampling	$4,752	Aug-2043	488	$1,320
							Total LCC:		**$8,318,341**

Appendix D: Derivation of the Equation for Discounting Monthly Costs

The monthly discounting method allows for more accurate timing of expenditures. However, the method assumes that interest is compounded monthly. The discount rates calculated by the OMB and DOE represent annual rates of return on investment and cannot be directly used for monthly discounting. The standard equation for finding the present value of a future expenditure using monthly discounting is:

$$P = F * \frac{1}{(1 + i/12)^{mon}} \qquad (1)$$

The monthly compounding of interest in this equation has the consequence of substituting a higher effective discount rate than the annual discount rates published by OMB and DOE.

For example, assume the interest rate is 6 %. With the monthly discounting method, the monthly interest rate will be 6 %/12, or .5 %. The return on the investment at the end of the year includes the compounding of interest and is calculated by $(1.005)^{12}$=1.0617. The 6.17 % rate of return is higher than the annual interest rate of 6 %. Using this monthly discount rate will underestimate the present value of expenditures.

Because the discount rates used are intended for annual calculations, the monthly compounding of interest will calculate an inaccurate present value. To take advantage of the improved timing accuracy of monthly discounting, an alternative method must be used. The correct monthly interest rate to use is the rate that, when compounded, will result in the annual discount rate. Assume that *moni* is the monthly discount rate:

$$(1 + moni)^{12} = (1 + i)$$
$$moni = (1 + i)^{1/12} - 1 \qquad (2)$$

Using the example above, where the annual interest rate is 6 %, the equivalent monthly discount rate will be 0.00487. This is lower than the 0.005 monthly rate calculated in Equation (1) by simply dividing the annual rate by 12.

Equation (2) can be entered into the present value formula in place of the traditional monthly discount rate, $i/12$.

$$P = \frac{1}{\left(1+(1+i)^{1/12}-1\right)^{mon}} * F \qquad (3)$$

$$P = \frac{1}{(1+i)^{mon/12}} * F$$

Equation (3) here, is identical to Equation (3) in Section 5. This version of the present value equation allows for monthly timing, without incorrectly compounding interest. Thus, we have the benefit of more accurate monthly timing, while preserving the annual compounding appropriate to the OMB and DOE annual discount rates.

Appendix E: Blank Report Forms

1. Project Definition

Project Title: _____

Location (City / ST / Zip): _____

Project Type (Circle One): **RCRA** **CERCLA** **WM** **D&D**

Record of Decision Date: _____

Analyst: _____ **Phone:** _____ **Email:** _____

Project Description:

_____

_____

_____

_____

_____

Number of Alternatives: _____

List of Alternatives:

Short Name	**Description**
Alternative A	_____
Alternative B	_____

2. LCC Parameters

Study Period (Years): _____ **Discount Rate:** _____

Date of Study: _____ **Base Date:** _____

3. Life-Cycle Costs by Phase and Alternative

Phase	Alternative A	Alternative B
Assessment Studies Design Construction O&M SLTM		
Total LCC		

4. Summary Table of Life-Cycle Costs by Alternative

Alternative	Total LCC	Credit	Adjusted Total LCC
Alternative A			
Alternative B			