Designation: E 2137 – 01

Standard Guide for Estimating Monetary Costs and Liabilities for Environmental Matters[1]

This standard is issued under the fixed designation E 2137; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *Purpose*—The purpose of this document is to provide a standard guide in the United States for estimating *costs and liabilities* for environmental matters.[2] Many possible uses for estimates of *costs and liabilities* for environmental matters exist, including but not limited to business decision making, communications and negotiations involving change of property ownership, regulatory requirements, third-party lawsuits, insurance premium calculation and claim settlement, change of property use, revitalization, compliance planning, construction, analysis of remedial alternatives, budgeting, strategic planning, financing, and investment analysis by shareholders. The use of estimated *costs and liabilities* developed in accordance with this standard may be subject to other standards applicable to the matter involved. For example, it is not intended to supersede accounting and actuarial standards including those by the Financial Accounting Standards Board and the U.S. Security and Exchange Commission. This standard does not address the establishment of reserves or disclosure requirements.

1.2 *Objectives*—The objective of this standard is to provide guidance on approaches for estimating *costs and liabilities* for environmental matters.

2. Referenced Documents [3]

2.1 *ASTM Standards:*

E 1527 Environmental Site Assessments: Phase I Environmental Site Assessment Process[4]

E 1739 Risk-Based Corrective Action Applied at Petroleum Release Sites[4]

PS 104-98 Provisional Guide for Risk-Based Corrective Action[5]

2.2 *Other Document:*

EPA OSWER Directive 9610.17 concerning use of risk-based decision making, 1995.[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *allocation or allocated share*—the portion of cost or liability for which a party is responsible for payment or reimbursement.

3.1.2 *environmental compliance*—operations, permits, equipment, facilities, products, records, documentation, reports, training, procedures, inspections, certifications, monitoring, controls, or other conditions or activities that must conform to environmental statutes including, but not limited to, CAA, CWA, OPA, RCRA, CERCLA, TSCA, FIFRA, SDWA, and state and local laws.

3.1.3 *costs and liabilities*—economic expenses, accrued liabilities, and loss contingencies.

3.1.4 *estimator*—an individual or entity that prepares and analyzes *costs and liabilities*.

3.1.5 *event*—a condition or incident which occurred, or may occur, with respect to an environmental condition and/or *environmental compliance* issue, that affects or leads to potential *costs and liabilities*. Examples of events include: a new requirement for air emission controls (e.g., NO_x), a hazardous waste site that requires remediation, a claim for personal injury related to an alleged environmental incident, or the need to comply with NPDES standards as a result of a process change.

3.1.6 *liability*—an actual or potential obligation that may or may not be accrued.

3.1.7 *orphan share*—liability assigned to a PRP that cannot be located or that is insolvent, or the liability associated with pollutants which cannot be attributed to a PRP.

3.1.8 *potentially responsible party (PRP)*—any individual, legal entity, or government—including owners, operators, transporters, or generators—potentially responsible for, or contributing to, the environmental impacts at an event.

3.1.9 *studies*—investigations such as regulatory interpretations and applicability studies, compliance analysis, operating scenarios study, engineering design and analysis, cost estimation, process hazard analysis, modeling, communication plans,

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[2] For the purposes of this standard, costs and values are defined as monetary estimates.

[3] Appendix X1 includes citations for additional relevant documents and requirements from other organizations including FASB, SEC, and AICPA.

[4] *Annual Book of Standards*, Vol 11.04.

[5] Discontinued—see 1999 *Annual Book of Standards*, Vol 11.04.

[6] Available from U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW Washington, DC 20460.

preliminary investigation, sampling and analysis, site assessment, site characterization, Phase I and II studies, remedial action plan, remedial investigation, contamination assessment report, feasibility study, risk assessment, treatability study, ecological impact assessment, environmental impact report, work plans, ASTM Risk-Based Corrective Action (RBCA) analysis, RCRA facility investigation, RCRA facility assessment, report of waste discharge, corrective measures study, corrective action report, health and safety plan, quality assurance plan, and other studies.

3.2 *Acronyms:*

3.2.1 *AICPA*—American Institute of Certified Public Accountants.

3.2.2 *CAA*—Clean Air Act.

3.2.3 *CERCLA*—Comprehensive Environmental Response, Compensation and Liability Act of 1980 (as amended, 42 USC Section 9601 et seq.).

3.2.4 *CWA*—Clean Water Act.

3.2.5 *EPA*—United States Environmental Protection Agency.

3.2.6 *EV*—expected value; an estimate of the weighted mean value of an unknown quantity that represents a probability-weighted average over the range of all possible values.

3.2.7 *FASB*—Financial Accounting Standards Board.

3.2.8 *FIFRA*—Federal Insecticide, Fungicide and Rodenticide Act.

3.2.9 *MLV*—most likely value.

3.2.10 *NPDES*—national pollutant discharge elimination system.

3.2.11 *OPA*—Oil Pollution Act.

3.2.12 *PRP*—potentially responsible party.

3.2.13 *RBCA*—Risk-based corrective action.

3.2.14 *RCRA*—Resource Conservation and Recovery Act (as amended 42 USC Section 6901 et seq.).

3.2.15 *SDWA*—Safe Drinking Water Act.

3.2.16 *SEC*—Securities and Exchange Commission.

3.2.17 *TSCA*—Toxic Substances Control Act.

4. Significance and Use

4.1 *Use*—The standard is intended for use on a voluntary basis by an estimator of *costs and liabilities* for environmental matters. The user may elect to apply this standard for any or all uses outlined in the Purpose. Application of this standard for one use does not compel application of the standard for all or any other use.

4.2 *Principles*—The following principles are an integral part of this standard and should be used to resolve ambiguity or dispute regarding the interpretation of estimated *costs and liabilities* for environmental matters.

4.2.1 *Uncertainty Not Eliminated*—Even though an estimate of *costs and liabilities* for environmental matters is prepared in accordance with this standard, uncertainty remains with regard to, among other things, the resolution of contractual, technological, regulatory, legislative, and judicial issues, which could affect the *costs and liabilities*.

4.2.2 *Periodic Review of Assumptions and Estimates*—Assumptions underlying these estimates should be reviewed periodically for the purpose of incorporating additional information that may become available. For example, changes in regulatory requirements, technology, property use, inflation, or other issues may affect the basis for the estimates, therefore necessitating revisions.

4.2.3 *Comparison with Subsequent Estimates*—Subsequent estimates based on additional information should not be construed as indicating the prior estimates of *costs and liabilities* for environmental matters were unreasonable at the time they were made. Estimates should be evaluated on the reasonableness of analyses and judgments made at the time and under the circumstances in which they were made. Subsequent improvements in estimates should be made as more information becomes available, but these improved estimates should not be considered valid standards on which to measure the reasonableness of a prior estimate based on hindsight, new information, use of developing analytical techniques, or other factors. However, information on trends in estimates over time may be of value to a user of financial statements or other users of the cost and liability estimates.

4.2.4 *Not Exhaustive*—Estimation of *costs and liabilities* for environmental matters does not necessarily require an exhaustive evaluation of all possible outcomes. A point exists at which the cost of obtaining information or the time required to gather it outweighs improvement in the quality of the estimate.

4.2.5 *Assessment of Risk*—The actual or potential risk to human health and the environment should be considered in assessing environmental matters. The degree of risk should be a factor in developing the cost and liability estimates associated with those matters.

4.2.6 *Estimator Selection*—An appropriate estimator or group of estimators will consist of those individuals or groups who possess sufficient knowledge, training, and experience to develop appropriate estimates for the *costs and liabilities* being estimated. It is the responsibility of the entity sponsoring the cost and liability estimates to select an estimator with the appropriate level of knowledge, training, and experience for the parts of the estimation effort for which that estimator is responsible.

5. Procedures for Estimating *Costs and Liabilities* for Environmental Matters

5.1 *Determination of Relevant Information and Types of Costs and Liabilities*:

5.1.1 There are many types of *costs and liabilities* for environmental matters, including, but not limited to:

5.1.1.1 Studies,

5.1.1.2 Response action,

5.1.1.3 *Environmental compliance*,

5.1.1.4 Defense and legal fees,

5.1.1.5 Fines and penalties,

5.1.1.6 Reimbursement of agency oversight, or

5.1.1.7 Damages arising from resource damages, ecological damages, property damage, business interruption, bodily injury, or tort claims such as nuisance and negligence claims.

5.1.2 After identifying the conditions giving rise to potential *costs and liabilities* for environmental matters, existing relevant information should be considered to estimate *costs and liabilities* identified in 5.1.1, including, but not limited to:

5.1.2.1 Event type (for example, new EPA air emission control requirements, leaking landfill, site PRP notice, compliance audit findings),

5.1.2.2 Number and location of affected operations/facilities,

5.1.2.3 Use of surrounding property,

5.1.2.4 Past, current, and potential future site uses,

5.1.2.5 Studies,

5.1.2.6 Environmental risks posed by the event,[7]

5.1.2.7 Bodily injury or other claims related to the event,

5.1.2.8 Relevant state or other regulatory requirements and alternatives,

5.1.2.9 State or federal agency involvement,

5.1.2.10 Public involvement,

5.1.2.11 Planned or completed remedial activities,

5.1.2.12 Decision documents (for example, Records of Decision),

5.1.2.13 Litigation activities related to the event (for example, claims, suits, actions, demands, requests for payment, notices),

5.1.2.14 Resources, tasks, and deadlines,

5.1.2.15 Available technologies and designs,

5.1.2.16 Type and extent of contamination,

5.1.2.17 Number of operable units (CERCLA) or solid waste management units (RCRA),

5.1.2.18 Involvement of various parties at the event, and

5.1.2.19 Information on prior experience with similar events.

5.1.3 The organization and application of the foregoing information may be further subject to corporate, accounting, or regulatory policy decisions. The user will need to determine what these policy decisions are, and assess their effect on the cost estimate. Examples of such policy decisions include, but are not limited to:

5.1.3.1 Measuring and recording of contingent liabilities,

5.1.3.2 Technical policy decisions or interpretations to be made by regulatory agencies,

5.1.3.3 Acceptable levels of risk (for example, business risk, human health risk, ecological risk),

5.1.3.4 The degree to which societal or external costs and benefits are considered,

5.1.3.5 Whether or not life cycle costs are considered,

5.1.3.6 The degree to which sustainability/sustainable development are considered,

5.1.3.7 Local environmental management system criteria, including trade-off of emissions across environmental media, alternative methods and permitting options, auditability, and performance oriented metrics.

5.1.3.8 Level of organizational involvement and scrutiny,

5.1.3.9 The degree of communication and involvement with the public.

5.1.4 In the absence or insufficiency of such information, an assessment should be made of the applicable regulatory and industry standard requirements, and a determination made as to whether based on these requirements, significant *costs and liabilities* for environmental matters may be incurred that would indicate the need for further data creation and analysis in the future.

5.2 *Selection of Estimation Approaches*—A decision framework for estimating *costs and liabilities* for environmental matters is required. For purposes of naming various estimating methods, the following terminology is used:

Expected Value (EV)
Most Likely Value (MLV)
Range of Values
Known Minimum Value

5.2.1 The decision to use one or more of these four estimating methods or another method for a particular purpose is not arbitrary. The informational value of the estimate supplied by any one method is not equivalent to the others. When the uncertainties are great (for example, when an event is first identified) it may not be possible to make a reasonable cost estimate.

5.2.2 The robustness and comprehensiveness of an estimate and the quantification of uncertainty about the estimate, given adequate information, generally decreases moving from top to bottom of this list of methods. (See Fig. 1.) Depending on availability of information and circumstances, the level of effort required to prepare estimates at the top of the list is typically greater than the bottom of the list. However, given the principles cited in Section 4, it is not necessarily true that the "best" estimate for a given set of circumstances will always be the expected value.

5.2.3 The estimator should take into account the number of events and quality of the information available or obtainable

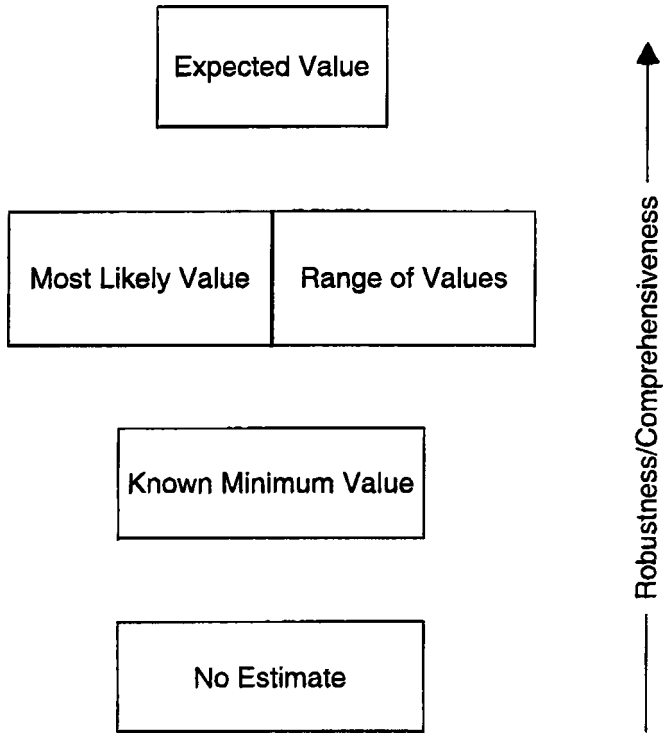

FIG. 1 Hierarchy of Approaches for Estimating *Costs and Liabilities* for Environmental Matters

[7] See Guide E 1739; PS104-98; EPA Risk Characterization Program; The Presidential/Congressional Commission on Risk Assessment and Risk Management; and EPA OSWER Directive 961.17 concerning use of risk-based decision making, 1995.

when selecting the cost and liability estimation approach to be used.

5.3 *Sources of Uncertainty in Estimation*:

5.3.1 For environmental issues, multiple outcomes often exist for a given issue as it develops toward resolution. Regulatory actions, event characterization information, remedial action effectiveness, legal matters, insurance aspects, and the like, are variables that are often not predictable with certainty. These uncertainties indicate multiple possible outcomes, each having its own probability of occurrence. Each outcome, if it occurs, has its own estimated value based upon its component outcomes.

5.3.2 The accuracy of an estimate, or sum of estimates (for application to multiple independent events), is ultimately measured by comparison of the predicted cost or liability to the actual outcome. There are at least two dimensions to accuracy in this context: the probabilities that certain outcomes will occur, and the component cost estimates for each of the outcomes.

5.3.3 To predict the value of each outcome, cost estimates are prepared that can range from very imprecise to rough approximations to engineering estimates of increasing degrees of detail. It may be possible to prepare a very accurate engineering estimate for a technical solution to a compliance or remediation requirement, but unless that specific technical solution is actually used in resolution of the event, the value of the precision may not be realized. Hence, the estimate's accuracy is affected by both the accuracy of the probabilities (that a particular technical solution will be applied) and the costs associated with each potential outcome.

5.4 *Detailed Description of Approaches for Estimation*

5.4.1 *Expected Value*:

5.4.1.1 There are several approaches to calculating an expected value, which is an estimate of the mean value of an unknown quantity that represents a probability-weighted average over the range of all possible values. One method, the decision tree approach, derives an expected value and distribution of potential values through the following steps: (*1*) identify the key issues contributing to the magnitude and timing of event costs, (*2*) develop a decision tree or simulation model of potential event outcomes (including possible allocation scenarios), (*3*) estimate the cost for each potential outcome, (*4*) determine the likelihood of each outcome, and (*5*) calculate the distribution of potential costs and the expected value, which is the probability-weighted cost calculated from items (*2*) through (*4*) above.[8] The information developed from the distribution may be very useful in conveying information about uncertainty, as described below in 5.8.

5.4.1.2 The estimator should be careful to include realistic outcomes with statistically significant probabilities to avoid shifting the expected value through the addition of extreme outcomes with insignificant probabilities of occurrence. Statistical significance will vary depending on the quality of data, the magnitudes of the outcomes, and the presence of outliers.

5.4.1.3 Outcome probabilities should be based, to the extent practicable, on statistical data drawn from comparable events. Where there are a large number of events, statistical approaches to estimating the expected value may be particularly appropriate. It is important to realize statistical approaches can be predictive of aggregate *costs and liabilities*, even if expected values for individual events are at variance from the actual results.

5.4.1.4 Another method for calculating an expected value is an actuarial approach, where historical data are available to estimate the expected value for similar events. Care should be taken when using historical data for estimating costs to assure that the data are applicable to the *event(s)* in question. Care should also be taken when using historical data due to the effects of changes such as technology enhancements, modified laws and/or regulatory policy, the changing application of presumptive remedies, and the application of risk-based corrective action approaches that could significantly alter current and future costs. Considerations should also be given to the potential loss of relevant information through application of statistical means or averages which may not convey information concerning uncertainty.

5.4.1.5 These approaches can be used in combination as appropriate. Other approaches to estimating an expected value may include simulation modeling and Monte Carlo analysis, for example, to estimate cost distributions.

5.4.2 *Most Likely Value (MLV)*—When an expected value approach is not practical or appropriate, a most likely value could be developed using engineering estimates. This MLV captures the cost of the scenario believed to be most likely to occur (for example, a stated preferred remedy). Typically, the estimator exercises a priori judgements (based on experience) about the ranking of likely outcomes, but because of cost or other considerations does not develop a full range of possible outcomes to support an expected value estimate. Care should be exercised in preparing an MLV estimate. For example, the MLV is typically not the mid-point between the high and low cost estimates. The MLV should represent a technical and regulatory scenario that is most likely to occur. The MLV may represent a grouping or cluster of scenarios where the cost outcomes are close in magnitude and the combined probability of the grouping or cluster exceeds the probability of other possible scenarios. The MLV is not useful if no scenario, grouping or cluster of outcomes has a probability of occurrence that is significantly greater than others.

5.4.3 *Range of Values*—When an expected value approach is not practical or appropriate, a range of values (without probabilities) may be developed instead. This approach may also be used in addition to the MLV approach to provide additional information, or instead of the MLV approach if probabilities or rankings for various outcomes cannot be determined. The range of values should cover costs from a low cost estimate to a high cost estimate, based on reasonable assumptions. If some outcomes within the range are more probable than others, this standard recommends the additional estimation of a most likely value or an expected value, when possible.

[8] For additional information on the expected value approach, see, for example: R.V. Kolluru, editor, *Environmental Strategies Handbook: A Guide to Effective Policies & Practices*, New York: McGraw-Hill, Inc., 1994 and G.D. Eppen and F.J. Gould, *Quantitative Concepts for Management: Decision Making without Algorithms*, Englewood Cliffs, NJ: Prentice-Hall, Inc., 1979.

5.4.4 *Known Minimum Value*—When the outcome and cost uncertainties are so great that it is premature to estimate a range of values or a most likely value, then a minimum value including component costs (e.g., contracts entered, initial studies) that are reasonably certain to be incurred should be estimated.

5.5 *Contingencies*—Contingency adjustments may be added to correct for costs that are undefined at the time of the estimate, but that are expected to be incurred. Therefore, care should be taken, when adding contingencies to base unit cost estimates, that the contingencies are reasonable and expected to be incurred.[9]

5.6 *Inflation and Discounting*—Inflation and discounting assumptions should be clearly documented.

5.7 *Allocation*—In estimates where *costs and liabilities* for environmental matters involve multiple parties, it may be necessary to apportion these costs among the parties. Determination of an entity's likely allocated share for an event should be made whenever sufficient information is available, and the allocated share should be factored into the cost estimates developed under 5.2. Private parties and courts have employed a variety of methods to allocate or apportion costs (See Appendix X3). As in the case with cost estimation, the method used to allocate costs is dependent upon the amount of information available and the event facts.

5.8 *Uncertainty Associated with Estimation Approaches*—As outlined in 4.2.1, 5.2.1, 5.2.2, and 5.2.3, estimates for *costs and liabilities* for environmental matters are inherently uncertain until resolution of the event matures to the state where all costs are known with certainty. When possible and appropriate, the estimator should quantify or qualify the level of uncertainty associated with the cost and liability estimates. Numerous measures of uncertainty exist. Users of this standard are encouraged to explore the statistical and risk theory literature for such measurements. The best measure of uncertainty for a given application depends on the information available and the facts surrounding the analysis. The estimator should select that measure which most clearly communicates to the user the nature of the uncertainty being evaluated.

5.8.1 *Uncertainty with Expected Value Approach*—Statistical literature provides numerous examples and methods of measuring uncertainty when using an expected value approach. While the expected value approach may not fall neatly into the statistical realm in all cases, the expected value estimate does provide a basis for developing several simple uncertainty measures. Uncertainty measurement is important as it communicates to the user of the estimate the potential amount of variability and/or the level of confidence in the expected value estimate. In some cases, the potential variability will be so great, or the level of confidence so low, that little value should be attached to the expected value estimate. It is important to those relying on expected value estimates prepared under this standard to be aware of such situations. When providing an uncertainty measure with an expected value estimate, the basis and definition of the uncertainty measure should be included. Following are several uncertainty measurements that should be considered in a communication involving an expected value estimate made using this standard.

5.8.1.1 *Confidence Level*—This measure usually involves estimating the percentiles of the probability distribution underlying the expected value estimate. Selection of a 70 % confidence level estimate, for example, would imply that outcomes with values less than or equal to the 70 % confidence level estimate occur 70 % of the time on average, or equivalently, outcomes exceeding the 70 % confidence level estimate occur no more than 30 % of the time on average.

5.8.1.2 *Confidence Interval*—This measure usually assumes a normal distribution around the expected value estimate and estimates the probability of the actual cost or liability being within a given interval of the expected value. Confidence intervals can also be developed for distributions that are not normal.

5.8.1.3 *Coefficient of Variation*—Equal to the standard deviation divided by the mean, the coefficient of variation (CV) provides a basis for evaluating the amount of statistical variation around the expected value estimate. Opinion polls, for example, often state results inclusive of a plus or minus percentage value. A plus or minus percentage value around the expected value could be based on the CV measurement.

5.8.2 *Uncertainty with Most Likely Value (MLV) Approach*—Significant uncertainty may exist in estimates made using the MLV approach. The most likely outcome may not be very likely overall (even though it is the singular most likely outcome in a portfolio of potential outcomes). In addition, MLV analysis provides very little information to quantify the uncertainty. When available, the probability associated with the most likely outcome provides some information concerning related uncertainties. In addition, identification of the range of potential outcomes provides the user of the cost and liability estimate with bounds on the uncertainty associated with the MLV estimate.

5.8.3 *Uncertainty with Range of Values Approach*—To some extent, the size of the range indicates the breadth of uncertainty associated with these cost estimates. For example, if the range is broad, there may be great uncertainty concerning the ultimate cost. When possible, a most likely outcome value should also be provided. When this is not possible, if there are any cost scenarios of clusters or scenarios within the range that are more likely than others, this information should be provided.

5.8.4 *Uncertainty with Known Minimum Value Approach*—For the known minimum value estimate, the upward uncertainty is unknown. If available, a qualitative description of the potential costs or liabilities may allow a user to roughly assess the extent and likelihood of higher values.

5.9 *Recovery/Offsets*—There may be a potential for recovery for, or offsets to, the *costs and liabilities* for environmental matters (e.g., insurance recovery, third-party recovery). Any potential recovery/offsets should be evaluated separately from the original cost and liability estimate, using cost estimation approaches as described in this Section 5. The litigation costs for pursuing such actions also should be estimated separately from these potential recovery/offset estimates.

[9] For additional information on contingencies, see for example F.D. Clark and A.B. Lorenzoni, *Applied Cost Engineering*, NY: Marcel Dekker, 1985, pp. 112-120.

5.10 *Documentation*—Documentation should include the identity of the estimator and a description of their relevant knowledge, training and experience. The estimation documentation should be sufficient for a user to evaluate the estimates. For example, it may be useful to identify the purpose and objective, the estimation approach(es), the major uncertainties considered, and the sources of information used in making estimates of *costs and liabilities* for environmental matters. This documentation may be prepared to cover a single event or multiple events estimated in a similar manner, and may consist solely or in part of existing work papers.

6. Keywords

6.1 cost estimation; environmental; costs; liabilities; expected value; minimum value; most likely value; range of values; uncertainty

APPENDIXES

(Nonmandatory Information)

X1. RELATED DOCUMENTS

E 1369 Standard Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems.

E 1528 Practice for Environmental Site Assessments: Transaction Screen Process.

E 1946 Standard Practice for Measuring Cost Risk of Buildings and Building Systems.

American Institute of Certified Public Accountants (AICPA) Statement of Position 96-1, "Environmental Remediation Liabilities," October 10, 1996.

American Institute of Certified Public Accountants (AICPA) Emerging Insurance Task Force (EITF) Abstract 93-5.

EPA Risk Characterization Program: Policy for Risk Characterization, March 1995; Guidance for Risk Characterization, February 1995; Policy for Use of Probabilistic Analysis in Risk Assessment, May 15, 1997; Guidance on Cumulative Risk Assessment, July 3, 1997.

"Filling the GAAP: An Approach to Improve SEC Disclosure of Environmental Liabilities," *Journal of Environmental Law & Practice*, September/October 1994.

Financial Accounting Standards Bulletin (FASB) Interpretation No. 14, "Reasonable Estimation of the Amount of a Loss and Interpretation of FASB-5."

Financial Accounting Standards Board, Rule No. 5, Accounting for Contingencies, March 1975.

The Presidential/Congressional Commission on Risk Assessment and Risk Management, Final Report, 1997, Volume 1: Framework for Environmental Health Risk Management, Volume 2: Risk Assessment and Risk Management in Regulatory Decision-Making.

Security and Exchange Commission (SEC) Staff Accounting Bulletin No. 92.

SEC Regulation S-K.

Security and Exchange Commission (SEC), Management's Discussion and Analysis of Financial Condition and Results of Operations; Certain Investment Company Disclosures, *Federal Register*, Vol. 54, No.99, May 24, 1989.

U.S. Environmental Protection Agency, *Remedial Action Costing Procedures Manual*, EPA/600/8-87/049, 1987.

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, *Valuing Potential Environmental Liabilities for Managerial Decision-Making: A Review of Available Techniques*. EPA/742/R-96/003, December 1996.

X2. EXAMPLE OF EXPECTED VALUE APPROACH

X2.1 This example provides a simplified overview of how to develop an expected value for *costs and liabilities* associated with a group of contaminated sites. The number of uncertainties contributing to the estimate has been deliberately kept to a minimum for the sake of clarity. In practice, the expected value approach can be applied in the same manner to consider many more uncertainties. Similarly, although only soil contamination is considered in this example, the same approach can be applied to include other sources of *costs and liabilities*.

X2.2 At a hypothetical site, soil contamination has been identified by a limited sampling program. The expected value analysis to estimate the costs associated with the contaminated soil is conducted using the five steps defined in 5.4.1.

X2.2.1 *Step 1.* The key uncertaintainties in this event are associated with three parameters: (*1*) the extent of soil contamination, (*2*) the cleanup level to be applied, and (*3*) the treatment/disposal technology for remediation.

X2.2.2 *Step 2.* The decision tree is constructed to reflect these three uncertainties. By convention, the uncertainties are shown as chance nodes by circles (see Fig. X2.1). In the simplified example, each of the uncertainties results in a factor of two difference in the magnitude of the environmental liability.

X2.2.2.1 *Extent of Soil Contamination*—The surface area extent of contamination has been well characterized by shallow soil samples, but the vertical extent is defined only by a very limited number of soil borings. Some of the borings indicate that contamination extends to 1 m in depth and others to 2 m.[10]

X2.2.2.2 *Cleanup Level*—State regulations specify a generic soil cleanup standard for the contaminant of concern, but also allow for determination of a risk-based cleanup goal. A risk-based cleanup goal could be a factor of 10 higher than the generic cleanup standard. Based on the site-specific distribution of contamination at the site, this higher cleanup goal could reduce the contaminated soil volume by a factor of two.

X2.2.2.3 *Treatment/Disposal Technology*—The default approach for the contaminants present at the site would be to excavate and dispose of the soil at an offsite landfill. However, based on the soil conditions and levels of contamination present, a less costly soil venting technology may be feasible.

X2.2.3 *Step 3.* The estimated costs for each potential outcome are determined based on the following assumptions.[11]

X2.2.3.1 Soil volume for deep (2 m) soil contamination

[10] For the purpose of this example, it is assumed that there is a uniform distribution of samples at 1 m and 2 m depths across the site.

[11] These assumptions are given for the purpose of illustration only.

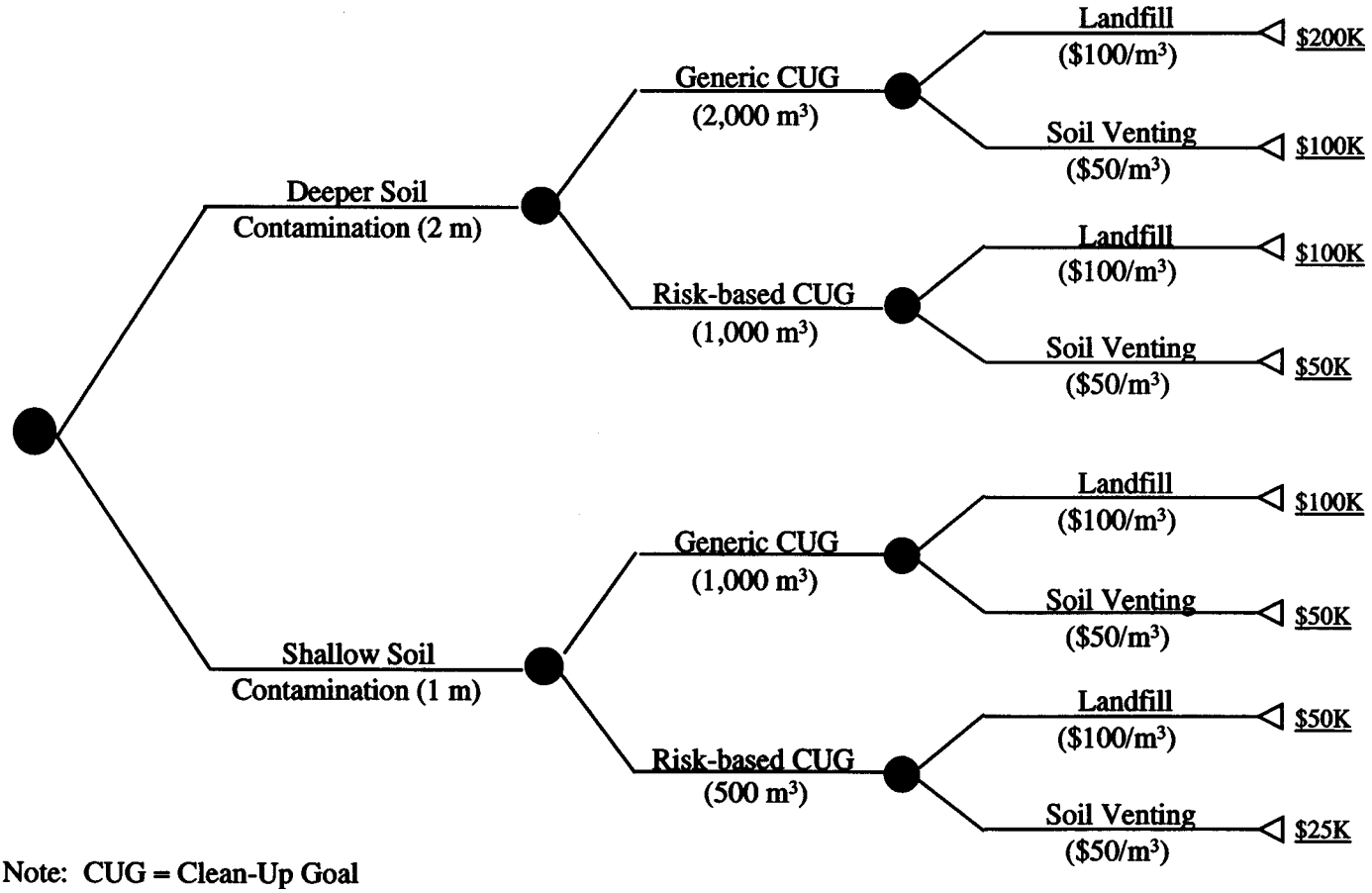

FIG. X2.1 Example Event Tree Uncertainties and Costs

scenario equals 2,000 m^3.

X2.2.3.2 Unit cost for offsite landfill disposal equals \$100 per m^3.

X2.2.3.3 Unit cost for soil venting equals \$50 per m^3.

X2.2.3.4 The costs associated with each potential outcome (represented by a particular path on the decision tree) are shown at the terminal nodes, which are depicted by convention by a triangle as shown in Fig. X2.1. These costs range from a minimum of \$25,000 to a maximum of \$200,000.

X2.2.4 *Step 4.* The likelihood of each outcome is determined as shown in Fig. X2.2.

X2.2.4.1 Approximately half of the soil borings collected at the site show that contamination extends to a depth of 2 m, and the other half show contamination extending to 1 m. Based on this information, a 50 % probability is assigned to each depth scenario.

X2.2.4.2 Historical experience with the relevant state agency suggests a reasonable likelihood that a site-specific risk assessment will be accepted. Accordingly, a 60 % probability is assigned to the higher risk-based cleanup goal, and a 40% probability is assigned to the default generic cleanup goal. (Note that the probabilities must add to 100 %.)

X2.2.4.3 Historical experience with the soil type present at the site and the level of contamination suggests a high likelihood of soil venting being technically feasible. Therefore, a probability of 80 % is assigned to soil venting, and a 20 % probability is assigned to offsite landfill disposal.

X2.2.5 The expected value is then calculated by summing the probability-weighted costs for each pathway on the decision tree. Using the assumed probabilities and unit cost data, the expected value is calculated at \$63,000 (See calculation in Fig. X2.2). The probability of each individual outcome, as represented by a pathway on the decision tree, is calculated by multiplying the probabilities along that pathway. Thus, the maximum cost of \$200,000 has a 4 % likelihood (50 % × 40 % × 20 %) and the minimum cost of \$25,000 has a 24 % likelihood (50 % × 60 % × 80 %). The most likely outcome of \$50,000 has a probability of 46 % (by summing the three \$50,000 outcomes with probabilities of 24 %, 16 %, and 6 %).

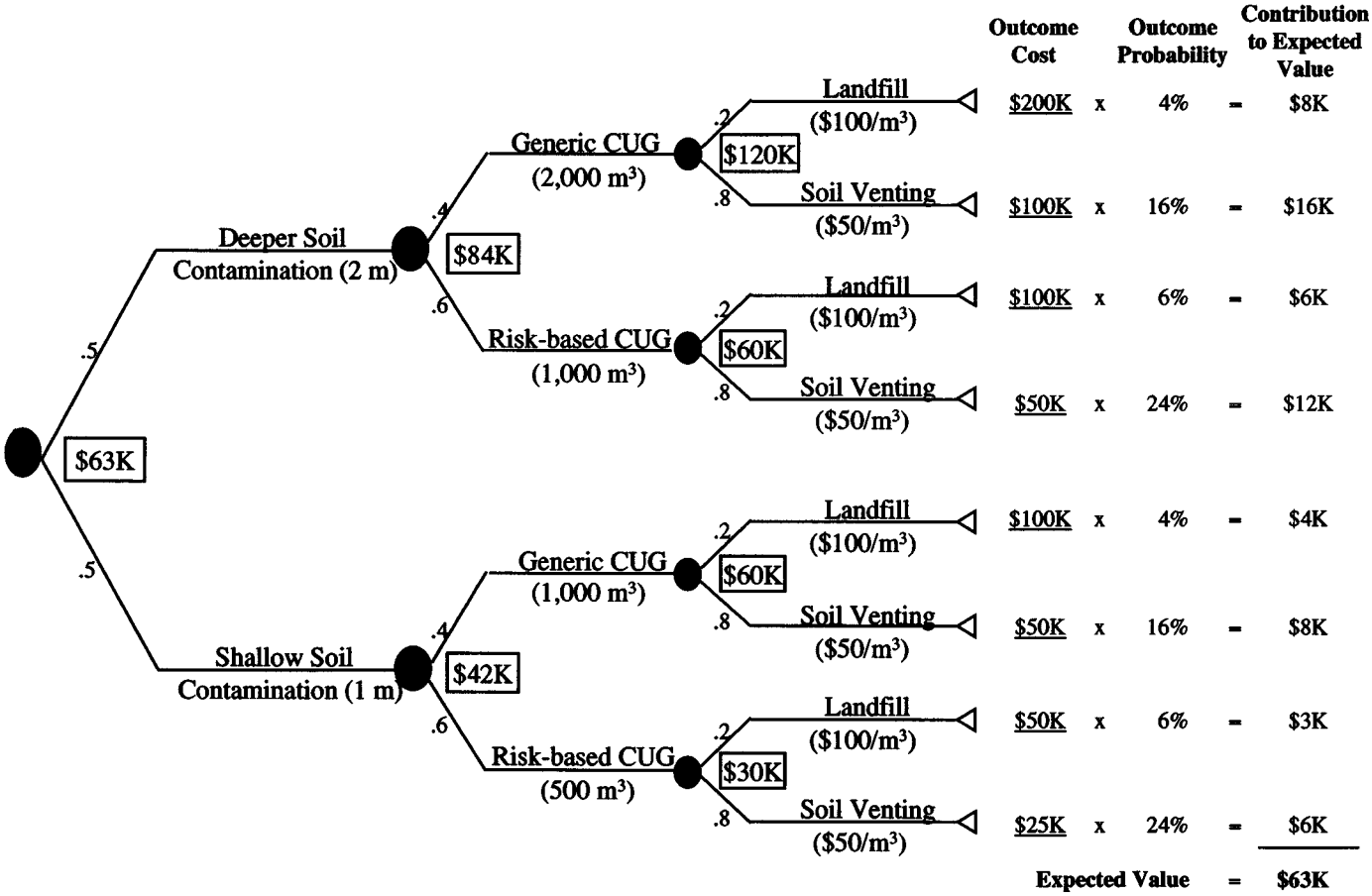

FIG. X2.2 Example Event Tree Expected Value

X3. POTENTIAL ALLOCATION CONSIDERATIONS

X3.1 The courts, PRP groups, and other parties have considered numerous issues in deriving allocations for CERCLA and non-CERCLA events. CERCLA states that "[In] resolving contribution claims, the court may allocate response costs among the liable parties using such equitable factors as the court determines are appropriate." Having pointed to "equitable factors," CERCLA is then silent as to what those factors might be. Factors that may be considered include, but are not limited to:

X3.1.1 The ability of the parties to demonstrate that their contribution to a discharge, release or disposal of a hazardous waste can be distinguished;

X3.1.2 The amount of the hazardous waste involved;

X3.1.3 The degree of toxicity of the hazardous waste involved;

X3.1.4 The degree of involvement by the parties in the generation, transportation, treatment, storage or disposal of the hazardous waste;

X3.1.5 The degree of care exercised by the parties with respect to the hazardous waste concerned, taking into account the characteristics of such hazardous waste; and

X3.1.6 The degree of cooperation by the parties with federal, state, or local officials to prevent any harm to the public health or the environment.

X3.1.7 Existing contracts between parties on the question of liability, such as indemnity agreements;

X3.1.8 Relative fault of the parties (e.g., cost causation, stand-alone costs);

X3.1.9 The owner's acquiescence in the operator's activities and manner of operation;

X3.1.10 The degree to which each party made efforts to prevent and/or contain any known release of hazardous wastes at the site, at the time the releases occurred;

X3.1.11 Relative economic benefits across the classes of PRPs; and

X3.1.12 Benefit to the current owner, if any, of the cleanup.

X3.2 If it is possible that other PRPs will not pay their full share, adjustments may be included to reallocate such orphan shares.