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COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE ENVIRONMENTAL REMEDIATION INDUSTRIES

AACE INTERNATIONAL

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COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE ENVIRONMENTAL REMEDIATION INDUSTRIES

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. October 5, 2021

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Any terms found in AACE Recommended Practice 10S-90, *Cost Engineering Terminology*, supersede terms defined in other AACE work products, including but not limited to, other recommended practices, the *Total Cost Management Framework*, and *Skills & Knowledge of Cost Engineering*.

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1. PURPOSE

As a recommended practice (RP) of AACE International, the *Cost Estimate Classification System* provides guidelines for applying the general principles of estimate classification to project cost estimates (i.e., cost estimates that are used to evaluate, approve, and/or fund projects). The *Cost Estimate Classification System* maps the phases and stages of environmental remediation project cost estimating together with a generic project scope definition maturity and quality matrix, which can be applied across a wide variety of environmental remediation industries.

This recommended practice provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for environmental remediation industries. It supplements the generic cost estimate classification RP 17R-97 [3] by providing:

- A section that further defines classification concepts as they apply to environmental remediation industries.
- A chart that maps the extent and maturity of estimate input information (project definition deliverables) against the class of estimate.

As with the generic RP, the intent of this document is to provide common terms to improve communications among all the stakeholders involved with preparing, evaluating, and using project cost estimates specifically for the environmental remediation industries.

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The purpose of this recommended practice is to provide the environmental remediation industry with a project definition deliverable maturity matrix in addition to the general information provided in RP 17R-97.

This RP focuses on Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[1] remedial projects and United States Resource Conservation and Recovery Act (RCRA) [2] corrective action projects, as well as decontamination and demolition (D&D), ordnance and explosives cleanups, and other environmental cleanup work. This RP includes estimates for work encompassing the entire environmental remediation life cycle and thus could be applied to cost estimates for closure/post-closure of regulated facilities (e.g., hazardous waste facilities under RCRA); mine reclamation; asbestos abatement prior to demolition of a building. In addition, this legislative framework can be applied towards both local as well as international laws and regulations that follow similar processes for contaminated site characterization, cleanup and closure. [3, 4]

This regulatory framework also provides a general representation of the relationship between specific release site characterization and other design input data and design deliverable maturity to the estimate accuracy and methodology used to produce the cost estimate. The estimate accuracy range is driven by many other variables and risks, so the maturity and quality of the scope definition available at the time of the estimate is not the sole determinate of accuracy; risk analysis is required for that purpose. The project maturity is indicated by percentage completion or the extent and types of input information available that include project scope definition, requirements documents, specifications, project plans, drawings, calculations, learnings from past projects, and other information that must be developed to define the project. The set of deliverables becomes more definitive and complete as the degree of project definition progresses. This is listed in detail in Table 3 (see below).

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating environmental remediation terminology and may classify estimates in other ways. This guideline provides a generic and generally acceptable classification system for the environmental remediation industries that can be used as a basis for comparison. This recommended practice should allow each user to better assess, define, and communicate their own processes and standards in the light of generally-accepted cost engineering practice.

2. INTRODUCTION

For the purposes of this recommended practice, the term *environmental remediation* refers to the process of bringing contaminated properties into environmental compliance under the U.S. Resource Conservation and Recovery Act (RCRA) and the U.S. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Typically, CERCLA addresses cleaning up the release of toxic and hazardous substances from soil, groundwater, and facilities. RCRA is focused on the safe and protective management of wastes from currently operating facilities as well as facilities where hazardous waste is stored. It is also applicable to certain wastes generated by CERCLA cleanups and in some instances serves as the regulatory basis for the entire site cleanup. These U.S. federal acts provide well understood frameworks for environmental remediation, and they can serve as a proxy for other regulations at the state and local level. In addition, this legislative framework can apply towards similar international laws and regulations. RCRA and CERCLA follow very similar site closure processes, which require liability

[1] CERCLA, the United States public law also known as Superfund, which includes improvements and additions provided by the Superfund Amendments and Reauthorization Act of 1986 (SARA).

[2] The Resource Conservation and Recovery Act (RCRA) is the United States public law that creates the framework for the proper management of hazardous and non-hazardous solid waste.

[3] For example, "Kovalick, Walter W., Jr.; Montgomery, Robert H.. 2014. Developing a Program for Contaminated Site Management in Low and Middle Income Countries. Latin America and Caribbean region Environment and Water Resources occasional paper series;. World Bank Group, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/18631 License: CC BY 3.0 IGO." [Taken from the Internet August 24, 2021]

[4] Seek legal counsel in your jurisdiction for specific application of these principles.

owners to assess the extent of environmental contamination and the associated environmental risks, receive public/stakeholder input, and submit preferred alternative proposals to regulatory agencies or a magistrate for approval; and then, upon approval, carry out an executable project(s) to achieve contaminated site closure. Although CERCLA is the predominant legislation for regulating cleanup, if the wastes associated with the cleanup site are listed on the RCRA hazardous waste list then that legislation is applicable.

This recommended practice addresses cost estimate classification solely in environmental remediation projects, programs and portfolios. It is important to note that this RP focuses on environmental remediation in response to the result of the release of toxic and hazardous substance. However, it does not include major capital construction projects such as building a wastewater treatment system for a manufacturing facility.

The cost estimates discussed in this recommended practice are for the full lifecycle costs for a remedial cleanup solution from initial investigations through site closure, including long term surveillance and long-term maintenance (SLTM) (also referred to as *long term surveillance* or *long term stewardship*) that may extend for many years., Although these costs are often easily estimated and high quality estimates can be readily performed, very often there is uncertainty as to how many years these activities will need to be performed, creating uncertainty in the estimated costs for this phase.

Also, this RP does not cover the costs associated with research and development of remedial technology, the costs associated with regulatory or community relations, or the additional liability (e.g., tort) that may be associated with contaminated properties. Also, care must be taken in using this document for accruing environmental liabilities, which are subject to specific financial accounting standards. This is described in detail in a monograph discussing using the TCM Framework for a variety of environmental cost estimates [4]. Cost estimates for accounting and financial reporting of environmental remediation liabilities may be based on engineering cost estimates. However, the user of this RP should be aware that estimates for financial accounting and reporting of environmental liabilities may require the use of different timeframes for operations and maintenance (O&M) and monitoring; assumptions; quantities; unit prices; contingency allowances; time value of money (interest and discount factors); and other variables than would be used in cost estimates for day to day execution of the remediation project.

When applying this RP to cost estimates for environmental remediation that may or will be used for financial accounting and reporting, the estimator should consult with the entity's financial management. Also, the Statement of Federal Financial Accounting Standards (SFFAS) 5, *Accounting for Liabilities of the Federal Government* [5] outlines the specific requirements for stating government liabilities. However, there is guidance available where many of the challenges for the estimates supporting the environmental liabilities can be constructed to be fully aligned with best cost engineering practices [6]. There is also a standard available for state and local governments, Governmental Accounting Standards Board (GASB) Statement 49 [7]. In addition to the aforementioned cost accounting standards the Financial Accounting Standards Board (FASB) Accounting Standards Codification (ASC) Topic 410, Asset Retirement and Environmental Obligations, as well as ASC 410-30 (for corporations): ASC 410-30, "Asset Retirement and Environmental Obligations" [8].

3. COST ESTIMATE CLASSIFICATION MATRIX FOR THE ENVIRONMENTAL REMEDIATION INDUSTRIES

Table 2 provides a summary of the characteristics of the five estimate classes. The maturity level of project definition at the point at which the estimate is being made is the sole determining (i.e., primary) characteristic of class. In Table 2, the maturity is roughly indicated by a percentage of complete definition; however, it is the maturity of the defining deliverables that is the determinant, not the percent. The other characteristics are secondary and are generally correlated with the maturity level of project definition deliverables, as discussed in the generic RP [1]. The specific deliverables, and their maturity or status are provided in Table 4. The post sanction (post funding authorization) classes (Class 1 and 2) are only indirectly covered where new funding is indicated. Again, the characteristics are typical but may vary depending on the circumstances. With minor variations in the definitions, the following phases of the environmental remediation project life-cycle generally apply to all environmental cleanup projects and programs including remediation, decontamination and decommissioning, ordnance and explosive cleanups, and other environmental work.

3.1. Phase 1: Site Investigations - Assess and Inspect Site, and Prepare Site Inspection Reports

In CERCLA, the first step includes the preliminary assessment (PA) and the site inspection (SI). The PA consists of collecting readily available property information, including a site visit to determine if potential contamination exists on the property due to former activities. Once there is information that a potential release has occurred on a property the SI is executed. The SI involves confirming and supplementing PA-phase information through limited environmental sampling to address a relative risk as it relates to human health and the environment.

In RCRA, work similar to the CERCLA preliminary assessment/site inspection (PA/SI) is performed in the RCRA Facility Assessment (RFA) which is a four-stage process for identifying and gathering information on releases and making preliminary determinations about the need for further investigations and interim actions.

After the site is characterized there are two general types of responses to releases of hazardous substances into the environment:

- Remediation is the study, design, and construction of long-term actions directed toward permanent remedy; and
- Removal actions (known in RCRA as an interim measure [9]) are short-term actions to stop, avoid, minimize, stabilize, alleviate, or eliminate a release or the possibility of a release.

Removal actions can result in significant savings to the cost and schedule for cleanup projects [10] or as permanent or part of permanent solutions [11, 12].

3.2. Phase 2: Conduct Detailed Site Investigation and Characterization

This phase includes risk assessment, characterization and investigations, development and analysis of treatment or remediation options, and treatability studies. In addition, the feasibility of various remedial alternatives are evaluated.

In CERCLA, this is managed through the remedial investigation/feasibility study (RI/FS) process which is used to gather the information and conduct the studies and analysis necessary to select a remedy for the site that will meet the statutory and regulatory requirements for cleanup and satisfy the requirements of the stakeholders. This includes gathering and addressing all of the Applicable or Relevant and Appropriate Requirements (ARARs) that apply to this project, as required by Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 as a part of this detailed investigation and planning phase. A significant factor involves the role of cost in the RI/FS process. In reviewing the selection of alternatives cost-effectiveness of site remediation needs to be considered while ensuring reliable protection of human health and the remediation of the environment [13]. Although the aforementioned reference applies to the RI/FS stage the principles of balancing cost effectiveness to protecting human health and protecting the environment should be considered throughout the life cycle of environmental remediation projects, programs and portfolios. [11, 12, 14]

The feasibility study portion of the RI/FS includes a review of alternatives based on how well they satisfy the compliance criteria, including costs; which is an important first step of environmental cost estimating. The RI/FS is followed by the proposed plan for implementing the preferred alternative. The proposed plan is a key step in the remedy selection process. It summarizes the remedial alternatives evaluated in the FS and specifies the preferred cleanup method. The public is offered the opportunity to comment on the proposed plan prior to a final decision. The final step in the remedial alternative selection process is the record of decision (ROD) approved by the appropriate regulatory authority.

In the case of removal actions, the engineering evaluation/cost analysis (EE/CA) is the analogous document to the RI/FS but it is less comprehensive. The EE/CA report contains a comparative analysis of removal action options for a Superfund hazardous waste site. [12] The goals of the EE/CA are:

1. Satisfy environmental review requirements for removal actions;
2. Satisfy administrative record requirements for improved documentation of removal action selection; and
3. Provide a means for evaluating and selecting alternative technologies.

The EE/CA process is the procedure used by response personnel to develop, evaluate, and select a removal action. This report is the document that records this analytical process. A formal EE/CA report is required for all non-time-critical removal actions/expedited response actions. For other non-time-critical removal actions, site documents can be expanded to provide better documentation of the analysis of removal action options. To the extent possible, such documents should address the major elements of the formal EE/CA, as described in this guidance. [15]

In the RCRA corrective action process, the nature and extent of contamination is evaluated through a RCRA Facility Investigation (RFI), which is followed by a Corrective Measures Study (CMS). The RFI/CMS is analogous to the RI/FS process under CERCLA.

Decision Document:

In CERCLA, following the public comment period (initiated during the proposed plan) the proposed remedy is considered prior to developing the final cleanup remedy. The final remedy is required to be selected from remedies that are protective and address all ARARs. Compliant alternatives are evaluated based on:

1. Long-term effectiveness and permanence;
2. Reduction of toxicity, mobility, or volume through treatment;
3. Short-term effectiveness;
4. Ability to implement; and
5. Cost

RCRA requirements can and often are part of the ARARs. The selected remedy is summarized in the record of decision. The ROD documents all facts, analyses of facts, and site-specific policy determinations considered in the course of selecting a remedial action, and how the remedy selection criteria were used to select the remedial action for a site. It serves as the legal document that certifies the remedy selection process was carried out in accordance with CERCLA and how the selected remedy is protective of human health and the environment. The ROD defines applicable federal and state requirements that are relevant and appropriate to the site; it explains how the remedy eliminates, reduces, or controls exposure. The ROD also defines how the remedy is cost-effective in employing treatment that permanently and significantly reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants. Details concerning the role of cost in the remedy selection process are established in existing law, regulation, and policy with regard to CERCLA (including SARA and related legislation) [11, 13].

In RCRA, the analogous decision document to a ROD is the statement of basis or the permit modification.

3.3. Phase 3: Remedial Design - Engineering Design and Pre-construction Activities for Treatment or Remediation of the Selected Alternative

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The remedial design phase is used to develop detailed engineering documents for the selected remedy. Continuation of the characterization, modeling, analysis, and treatability studies to help refine the remedial design may also be a part of this phase.

In CERCLA remediation, the remedial action (RA) phase implements the selected remedy method. The RA undertaken is the one specified in the ROD or in the case of interim or non-time critical removal actions the alternative proposed in the EE/CA.

In RCRA, the selected measures are then developed as corrective measures design [19].

3.4. Phase 4: Remedial Action – Initiate Selected Treatment or Remediation Alternatives (May Include Construction)

This phase includes start-up but excludes operations and maintenance.

In CERCLA remediation, the remedial action (RA) phase implements the selected remedy method. The RA undertaken is the one specified in the ROD or in the case of interim actions the alternative proposed in the EE/CA.

In RCRA, the selected measures are then applied as the corrective measures implementation. [9]

3.5. Phase 5: Operations and Maintenance (O&M)

This phase includes all operations and maintenance for the selected treatment or remediation alternatives. This phase ends when clean up or waste treatment goals are met. It should also be noted that some remediation technologies do not require an operations phase. Also, for CERCLA sites, the prescribed 5-year review is required for those sites where hazardous substances remain on site, as a part of this phase. Generally, these 5-year reviews are performed 5 years after start of a CERCLA response action and may continue into Phase 6 (see Table 1 below). Depending on the specific project, these 5-year reviews may take place during this phase and/or during the subsequent Phase 6. O&M 5-year reviews may result in requirements to perform follow-up actions needed to ensure the effective management of the remedy. This may result in additional work that must be included in a revised cost estimate. [16]

3.6. Phase 6: Surveillance and Long-Term Maintenance (SLTM)

This phase, also referred to as long term stewardship, is required once cleanup operations activities are completed or are no longer integral to the selected treatment and/or remediation alternatives. This involves long term site security and maintenance of installed protective measures (i.e., engineered controls) such as installed caps over buried waste sites and physical barriers (e.g., fencing) as well as institutional controls (IC) defined as administrative and legal tools that do not involve construction or physically which protect of human health and the environment at a site [17]. An Institutional Control Implementation and Assurance Plan (ICIAP) often includes long term site security and maintenance of installed protective measures such as annual inspection and maintenance of installed caps over buried waste sites, long term operations of treatment facilities, long term monitoring of sites, fencing, public communications, institutional (land use) controls and other installed environmental protective systems. The ICIAP and corresponding cost estimate must address annual cost and replacement of equipment and other components over the life of the remedy. The ICIAP identifies in detail how the ICs should be implemented and enforced, reporting requirements and reviews. For CERCLA sites, the prescribed 5-year review work is included as a part of this Phase 6 long term surveillance and monitoring. The 5-year reviews are performed until it is determined the site no longer requires SLTM.

Table 1 illustrates the kinds of work and types of documents typically produced at each of the six phases associated with environmental remediation projects, which include remediation of soil, groundwater, contaminated buildings and structures. It is important to note that, by definition, environmental restoration projects require a combination of capital and operations activities which contain both capital project expenditures (capex), as well as the corresponding operational project expenditures (opex). [25]

General Phases in the Environmental Cleanup Process and Description		**CERCLA Documentation**	**RCRA Documentation**
Phase 1	Conduct site surveys and investigations: • Assess conditions and identify contaminated areas that may require remedial actions	• Preliminary assessment/site inspection (PA/SI) report	• RCRA facility assessment (RFA) report
Phase 2	In depth investigations and development and selection of remedial alternatives: • Alternative analysis • Selection of preferred alternative • Summary schedule • Life cycle cost estimate ranges of alternatives • Identify the preferred alternative	• Remedial investigation (RI) report • Feasibility study (FS) report, including estimates associated with screening and detailed analysis of the alternatives • FS: treatability studies **<u>Remedy Selection:</u>** • Proposed plan • Draft record of decision • Final record of decision (ROD)	• RCRA facility investigation (RFI) report • Corrective measures study (CMS) report **<u>Remedy Selection:</u>** • Corrective action plan
Phase 3	• Detailed design, plans and specifications for the selected remedy • Detailed implementation plans for selected alternative • Detailed schedule	• Remedial design • Remedial action implementation plan • Waste management plan • Cost estimates and detailed schedules	• Final RCRA permit modification • RCRA corrective measures design • RCRA corrective measures implementation plan • Associated detailed schedule and cost estimates
Phase 4	• Physical construction activities • Implementation of actual cleanup	• Execution of the remedial design – installation of equipment, excavation, etc. • Detailed execution schedules and cost estimates	• Corrective measures implementation • Detailed execution schedules and cost estimates
Phase 5	• Operations and maintenance (if any) associated with the cleanup • At the end of phase 5 - decontamination and decommissioning of facilities dedicated to the cleanup • The site is removed from the National Priority List	• Operations and maintenance plan and manual (if needed) • Operations and maintenance (if any) reports associated with the remedial action e.g. operation of a pump and treat facility.	• Operations and maintenance plan and manual (if needed) • Operations and maintenance (if any) reports associated with the corrective measures
Phase 6	• Routine monitoring • Enforcing any long-term site restrictions	• Site surveillance and/or maintenance reports • CERCLA 5-year review report	• Site surveillance and/or maintenance reports

Table 1 – Phases of Environmental Cleanup Relating to Specific Environmental Regulatory Framework

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	Primary Characteristic	***Secondary Characteristic***		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges at an 80% confidence interval
Class 5	0% to 2%	(Phase 1) Early investigations and preliminary planning; preliminary assessment/site inspection (PA/SI) report; RCRA facility assessment (RFA) report and federal facility compliance agreement.	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +175%
Class 4	1% to 15%	(Phase 1 and/or 2) In depth investigations, evaluation of remedial alternatives and remedy selection; remedial investigation/feasibility study (RI/FS) facility investigation (RFI) and corrective measures study (CMS)	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	(Phase 2 and/or 3) Preliminary planning and design of selected remedy; record of decision; preliminary remedial design Initial estimates for O&M and LTM	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +45%
Class 2	30% to 75%	(Phase 3, 4, 5 and/or 6) Intermediate remedial design refined estimates for O&M and LTM final remedial action/remedial action implementation plan (RA/RAIP); corrective measure implementation plan (CMIP); construction and remedial action	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	(Phase 4, 5 and/or 6) Pre-final/final remedial design Detailed/remedial action, operations and maintenance and long term monitoring plans and cost estimates	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 2 – Cost Estimate Classification Matrix for the Environmental Remediation Industries [14, 18, 23, 24]

Note (1): Although the ranges in table 2 are primarily derived from the capital elements of projects (e.g. the type of technology, its size, capacity, etc.) these costs include operations activities as required. For those applicable technologies that have an operating phase, (e.g., pump and treat, air sparging, waste characterization, waste transportation and disposal, soil vapor extraction, etc.) the operating costs of that selected technology are directly tied to its requirements and are dependent on specific project parameters (e.g., its size, maintenance requirements, utility usage, operating cycle, etc.)

Note (2): Although long term monitoring cost can be estimated with high accuracy at the end of phase 4, the specific number of years required to support cleanup is highly variable and difficult to predict. Therefore, although the annual costs may be estimated precisely it is difficult to do the same for the life cycle of a specific project.

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This matrix (Table 2) and guideline outline an estimate classification system that is specific to environmental remediation work. Refer to Recommended Practice 17R-97 [3] for a general matrix that is non-industry specific, or to other cost estimate classification RPs for guidelines that will provide more detailed information for application in other specific industries. These will provide additional information, particularly the *Estimate Input Checklist and Maturity Matrix* which determines the class in those industries. See Professional Guidance Document 01, *Guide to Cost Estimate Classification.* [26]

Table 2 illustrates typical ranges of accuracy ranges that are associated with environmental remediation industries. The +/- value represents typical percentage variation at an 80% confidence interval of actual costs from the cost estimate after application of appropriate contingency (typically to achieve a 50% probability of project cost overrun versus underrun) for given scope. Depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall into the ranges identified. However, this does not preclude a specific actual project result from falling outside of the indicated range of ranges identified in Table 2. In fact, research indicates that for weak project systems and complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 2. [33] Notably, environmental remediation projects are known for a high level of uncertainty due to the limitations of site characterization and cleanup technology effectiveness in different situations. [10] Environmental projects are under the scrutiny of a wide variety of stakeholders, including state and federal regulatory agencies, the environmental consultant, the construction manager, and the local citizen action groups who review and approve the activities and oversee the work; therefore, delays in the approval of the submittals may occur or work restrictions may be enacted at the site. [11, 21]

In addition to the degree of project definition, estimate accuracy is also driven by other systemic risks [22] such as:

- Level of non-familiar technology in the project.
- Complexity of the project.
- Quality of reference cost estimating data.
- Quality of assumptions used in preparing the estimate.
- Experience and skill level of the estimator.
- Estimating techniques employed.
- Time and level of effort budgeted to prepare the estimate.
- Unique/remote nature of project locations and the lack of reference data for these locations.
- Limitations in groundwater and soil characterization technology.
- Wide variability (heterogeneity) in subsurface conditions (e.g., hydraulic conductivity).
- Extent of political, regulatory, or community engagement.
- Accuracy of records concerning site process history.

Systemic risks such as these are often the primary driver of accuracy, especially during the early stages of project definition. It should be noted that many of these systemic risks can and should be adjusted to reflect the specific qualities of the projects and programs at a given cleanup site. As project definition progresses, project-specific risks (e.g. risk events and conditions) become more prevalent and also drive the accuracy range. Another concern in estimates is potential organizational pressure for a predetermined value that may result in a biased estimate. The goal should be to have an unbiased and objective estimate both for the base cost and for contingency. The stated estimate ranges are dependent on this premise and a realistic view of the project. Failure to appropriately address systemic risks (e.g. technical complexity) during the risk analysis process, impacts the resulting probability distribution of the estimated costs, and therefore the interpretation of estimate accuracy.

Figure 1 illustrates the general relationship trend between estimate accuracy and the estimate classes (corresponding with the maturity level of project definition). Depending upon the technical complexity of the project, the availability of appropriate cost reference information, the degree of project definition, and the inclusion of appropriate contingency determination, a typical Class 5 estimate for an environmental remediation industry project may have an accuracy range as broad as -50% to +175%, or as narrow as -20% to +30%. This includes capital project estimate (capex), as well as, the corresponding operational project estimate (opex). However, note that this is dependent upon the contingency included in the estimate appropriately quantifying the uncertainty and risks associated with the cost estimate. Refer to Table 2 for the accuracy ranges conceptually illustrated in Figure 1. [34]

Figure 1 also illustrates that the estimating accuracy ranges overlap the estimate classes. There are cases where a Class 5 estimate for a particular project may be as accurate as a Class 3 estimate for a different project. For example, if the Class 5 estimate of a project that is based on a repeat project with parallel scope, good cost history and performance data can be comparable to the Class 3 estimate for another unique project which lacks the previous project's advantageous cost history but is reliant on a new technology. It is for this reason that Table 2 provides ranges of accuracy values. This allows consideration of the specific circumstances inherent in a project and an industry sector to provide realistic estimate class accuracy range percentages. While a target range may be expected for a particular estimate, the accuracy range should always be determined through risk analysis of the specific project and should never be pre-determined. AACE has recommended practices that address contingency determination and risk analysis methods. [27]

If contingency has been addressed appropriately approximately 80% of projects should fall within the ranges shown in Figure 1. However, this does not preclude a specific actual project result from falling inside or outside of the indicated accuracy ranges identified in Table 2. As previously mentioned, research indicates that for weak project systems, and/or complex or otherwise risky projects, the high ranges may be significantly higher than the high range indicated in Table 2.

Lastly, cost estimates for the O&M and SLTM stages are initially and importantly defined during the feasibility study and refined sequentially during the remediation design (RD) phase. Typically cost estimates for O&M and monitoring at the pre-final or final RD stages are Class 3 or Class 2. During the remedial action construction phase, the contractor finalizes the O&M plan/manual and then updates the O&M estimate (typically to a more accurate Class 2 or Class 1 estimate).