Application to the Representative Policy Board for Approval of the Chemical Improvements at the Lake Whitney Water Treatment Plant Project

South Central Connecticut Regional Water Authority
January 25, 2024

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1. Statement of Application

This application is presented by the South Central Connecticut Regional Water Authority (RWA) to the Representative Policy Board of the South Central Connecticut Regional Water District for approval of the Chemical Improvements at the Lake Whitney Water Treatment Plant Project (WTP). Section 19 of Special Act 77-98, as amended, requires the Representative Policy Board approval before the RWA commences any capital project that will cost more than $2 million. The proposed project will cost approximately $3.1 million.

The Lake Whitney WTP, located in Hamden, Connecticut, was design and constructed in 2004 The treatment plant treats an average 4 million gallons per day (MGD) of water and has a maximum permitted design flow of 15 MGD that is drawn from Lake Whitney. The Lake Whitney WTP is a critical source of water supply and treatment for the New Haven and surrounding areas.

The Lake Whitney WTP utilizes potassium permanganate as an oxidant for pretreatment and sodium hydroxide (caustic) for pH control to prevent corrosion and allow for the efficient use of other treatment chemicals. These systems are necessary to deliver a reliable and quality supply of water to our customers.

The original designed potassium permanganate system is not operational, and a temporary system has been constructed to meet the current manganese demands. Lake Whitney has seen higher manganese levels in the reservoir causing the potassium permanganate feed system to feed higher concentrations and stay online for longer durations than in the past. Improvement is needed to effectively manage the higher manganese levels and maintain compliance with regulatory standards.

The existing caustic system was part of the original treatment plant construction. One of the two bulk storage tanks is currently out of service due to a tank failure. This reduces the amount of chemical inventory storage, which results in partial and increased frequency of chemical deliveries. Hence, higher delivery costs are being borne as well as potential of overfilling the caustic bulk tank during chemical deliveries causes safety concerns. The existing caustic chemical feed lines are PVC and the RWA has standardized to replace them with stainless steel chemical feed lines on all caustic chemical feed systems. Utilizing stainless steel chemical feed lines has mitigated safety hazards for staff and reduced the number of leaks and corresponding repairs.

The goal of this project is to improve the reliability of plant operations and improve safety for plant operations.

Appendix A contains the 30% design drawings for this project.

This application will provide a description of the project, an explanation of why it is necessary, a discussion of the alternatives considered, and the estimated cost. The accuracy and completeness of this document is critical to the RPB's ability to make an informed decision on behalf of the RWA's customers and member communities. The RWA has engaged Tighe & Bond as the consulting engineer for providing engineering design and cost estimation.

2. Description of the Proposed Action

This project will include replacement of the potassium permanganate and caustic chemical feed systems. Each chemical replacement system includes bulk/mix tanks, day tanks, transfer pumps, metering pumps, piping, valves, and instrumentation. The project also includes building modifications necessary to facilitate installation of the new chemical feed systems such as the replacement of the potassium permanganate storage room door, masonry repairs around the door and tank installation efforts, fiberglass platforms and stairs, safety showers, and eye washes for chemical feed systems, chemical resistant coatings for chemical feed system rooms, new electrical lift table and dust collection system for the potassium permanganate system, and miscellaneous plumbing and electrical improvements. Other building improvements wrapped into this project include demolition of the old potassium permanganate system and allowing this room to be used as a future storage room. The original plant made future provision for Aqua Ammonia for disinfection through chloramination (chlorine mixed with ammonia). While chloramination can reduce disinfectant by products, it can elevate lead and copper corrosion as well as degrade natural rubber compounds (as well as create Taste & Odor problems for microbrewers) so there are no plans to implement that technology at any point in the future.

The new caustic system will be installed in the same room as the existing caustic system. To accommodate construction, a temporary chemical feed system for the caustic will be provided to avoid disruption . The potassium permanganate system will be installed in the Future Aqua Ammonia/Storage room which is currently being used for general storage as it will enable additional space for larger mix tanks and easier access for treatment staff. Consequently, no temporary chemical feed system is needed for the potassium permanganate system. This project combines multiple system improvements into one contract thereby increasing system efficiencies across operations, design and construction.

Specifically, the work consists of:

- Demolition of
    - Chemical system bulk tanks, day tanks, concrete pads, containment curb, transfer pumps, metering pumps, re-circulation pumps, weigh scales, supports, piping, and appurtenances.
    - Chemical resistant coating in caustic room.
    - Future Aqua Ammonia Storage room door and frame and miscellaneous equipment (location of the new potassium permanganate system).
    - Existing knockout concrete masonry unit (CMU) walls for new tank installation.
    - Existing Plumbing and emergency eyewash/shower stations.
    - Existing Pump control panels, instrumentation, and all associated conduit and wiring.
- Architectural
    - Installation of new chemical resistant coatings within the secondary containment areas for the caustic room and new potassium permanganate room.
    - Installation of replacement CMU walls and joint sealants for both caustic and new potassium permanganate room, and new door and frame for the new potassium permanganate room.
    - Installation of touch-up and existing potassium permanganate room floor coating.
- Structural
    - Installation of new concrete housekeeping pads for new chemical day tanks and transfer pump.
    - Concrete repairs in existing potassium permanganate room floor.
    - Installation of 4’ wide door and frame for the new potassium permanganate room.
    - Installation of new FRP platforms and stairs around the new potassium permanganate storage.
    - Installation of new FRP mounting table for the potassium permanganate metering pumps

- Mechanical
    - Installation of new chemical bulk tanks, mix tanks, day tanks, transfer pumps, metering pumps, mixers, phosphate dust collection system and lift table, piping, valves, instrumentation, and associated conduit and wiring.
- Plumbing
    - Installation of new miscellaneous piping, backflow preventers, flow switches, and emergency shower and eyewash stations.
- Electrical
    - Installation of new pump control panels, instrumentation, and other miscellaneous electrical modification along with associated conduit and wiring.

3. Need for the Proposed Action

The Lake Whitney WTP is an important component of the RWA's water distribution system as it provides treated water to customers in the New Haven and surrounding areas. Replacing the identified chemical storage and feed systems, along with related building improvements, will improve the reliability and safety of the Lake Whitney WTP and provide consistency with other RWA facilities in line with the mission of the RWA.

Specifically, it has been determined that this project is necessary based on the following reasons:

- Reliability: The caustic and potassium permanganate chemical feed systems, mechanical systems, and electrical systems are at the end of their useful life expectancy. One of the two caustic bulk tanks has failed and needs replacement. This has reduced the available capacity for bulk storage in the caustic system, resulting in more frequent chemical deliveries. In recent years the RWA has increased the dosage of potassium permanganate to address changes in raw water quality. As a result, RWA treatment staff have increased the frequency of potassium permanganate batching, sometimes performing this activity daily. The RWA feels that the increased demand for potassium permanganate will remain the standard operating procedure for the foreseeable future due to water quality issues. The system upgrades, including relocation of the potassium permanganate system into the Aqua Ammonia Storage room (currently used for storage), will increase the bulk storage capacity and as a result reduce the frequency of mixing events.

- Safety: The age and configuration of the existing caustic and potassium permanganate systems increases the likelihood of the RWA treatment staff exposure to hazardous chemicals and increased safety risks. The reduction in bulk storage requires more frequent caustic deliveries. The piping layout around the bulk and day tanks does not meet the RWA's current safety standards. Finally, the aging system is prone to leaks. The existing potassium permanganate room also has several challenges. The existing potassium permanganate room has low overhead clearances, and the existing lighting is not sufficient which contributes to poor working conditions. The current system also lacks a dust collection system which is now an RWA safety standard for mixing dry chemicals. Also, the volume of storage for mixed chemical is insufficient which results in more frequent batching, and the age of the existing potassium permanganate system results in the treatment staff requiring to perform frequent repairs. All of these issues pose concern for the treatment staffs' potential for exposure to these chemicals. The new chemical feed systems will reduce maintenance requirements, provide more chemical storage, improve layouts where possible, and add new alarms and instrumentation to better monitor the systems and implement RWA's safety standards.

- Consistency: Updating and replacing components within the Lake Whitney WTP will result in consistency with other RWA facilities. This will help standardization across all facilities which will contribute to increased efficiencies.

4. Analysis of the Alternatives to the Proposed Action

In determining the best course of action to replace components within the Lake Whitney WTP, Tighe & Bond evaluated several different alternatives. The alternatives included a no action approach or chemical systems replacement approach.

Alternative 1 – No Action: If the facility was not improved and left online, equipment would potentially fail and there would be possible chemical leaks from aging equipment. A failure can result in water quality issues as well as health and safety risks. Failing equipment, piping, and fittings would eventually require replacement in the future. Replacement parts for outdated items would be more expensive and difficult to find and replace and could result in extended shutdowns of the WTP. Additionally, this option does not address the known issues with limited chemical storage or the current chemical system layouts hazards, including: (1) one of the two sodium hydroxide bulk tanks has a leak so only one bulk talk is available for use; (2) potassium permanganate tanks are undersized so operations staff needs to frequently make new batches; and (3) ceiling height in potassium permanganate room is very low so operations staff can't stand straight up when maintaining system components.

Alternative 2 – Chemical Systems Replacement: Replacing with new chemical feed systems would provide a permanent solution for the facility. This approach would result in a reliable and safe water supply for consumers and mitigate the chance of existing chemical feed system component failure. It will also increase the safety for operators by addressing optimal layouts and providing better storage for the potassium permanganate system.

The alternatives analysis concluded that Alternative No. 2 is most favorable in terms of facility reliability, safety, and quality of outcome. The following items were considered to ensure the chemical system replacements were done in a cost-effective manner:

- Room Selection for Potassium Permanganate: RWA carefully evaluated the room options for the potassium permanganate system. Options included keeping the new system in the existing room or moving to another room. Keeping the system in the existing room presented challenges due to low overhead clearances which would limit the size of the tanks that could be installed. Additionally, the low overhead clearances posed a safety risk to treatment staff and resulted in a less ergonomic layout. Of the possible new rooms, the Aqua Ammonia Storage room was selected because it has twice the head room of the existing Potassium Permanganate Storage room, it also offered the opportunity to install larger chemical tanks to meet the storage needs, provide a more ergonomic layout with the inclusion of an electric lift table, and had the least overhead obstructions. The RWA does not have plans to utilize aqua ammonia at the Lake Whitney WTP, so this room is fully available for Potassium Permanganate storage. Some of the layouts considered are included in Appendix B. Lastly, moving the Potassium Permanganate system to a new room would eliminate the need for a temporary chemical feed system because the existing system could remain online until the new system is completely installed and operating successfully.

- Caustic Room Tank Selection: The RWA carefully evaluated the options for bulk storage and day tank sizing for the caustic system. The dimensions of the existing caustic storage tanks exceed the clearances of the WTP interior hallways. Therefore, replacement in kind is not possible without substantial modifications to existing utilities inside the WTP or removing exterior walls. These options were determined to be prohibitively complicated. Therefore, the RWA selected a bulk storage and day tank option that maximized storage, proved a functional layout for treatment staff, and used tanks that could be transported to the room via the interior halls of the WTP with minimal impact to other utilities inside the building. Some of the layouts considered are included in Appendix B.

This alternative also includes other building improvements such as demolition of the existing potassium permanganate equipment to create a new storage room or possible future temporary chemical feed systems. Performing building improvements under the same contract as the work on the chemical systems improvement project is more cost effective as it results in a single contract development and management and single mobilization for the contractor completing the work. Completing the building improvements at a later date may result in disturbance of maintenance and operations. Also, this type of project consolidation is consistent with past recommendations from the Representative Policy Board.

4.1 Business Case Evaluation

A Business Case Evaluation (BCE) comparing the Alternative 2 to the Status Quo (No Action) Alternative was performed by the RWA to demonstrate the benefits of the alternative, and is included in Appendix E, along with the Business Case Evaluation introductory memo with a definition of terms. The BCE was conducted using the comprehensive Triple Bottom Line (TBL) approach, that evaluates life-cycle costs, cost-benefit ratio, risk and social factors (including environmental) to determine the best long-term solution to a problem. The following summarizes the results of the BCE.

1. Life Cycle Cost Projection (LCCP): the Life Cycle Costs Annuitized Cost Stream is $200,166 for Alternative 2. The life cycle costs over the analysis period (20 years) show a decrease in the present value of annual operating and maintenance costs for Alternative 2 (when compared to the Status Quo).

2. Risk Reduction: The Risk Reduction Effectiveness Factor is 0.95 for Alternative 2. The alternative was found to reduce the Risk Cost from the Status Quo. The Risk Cost (annual basis) of the Status Quo is about $260,000. The overall Residual Risk Cost (annual basis) is about $69,000 for Alternative 2.

3. Benefit/Cost: The Benefit/Cost Ratio is a ratio of the benefit value over the cost value. A higher result demonstrates that the project is more cost effective for the benefits it delivers. This calculation allows for the quantification of factors such as environmental and social impact of a project (both during construction and long-term). The Benefit/Cost Ratio for Alternative 2 is a result of 1.59. Ratios higher than 1.0 demonstrate that an alternative has quantifiably higher benefits than costs.

Based on the results of the BCE, Alternative 2, Chemicals Systems Replacement, was determined to best address all aspects of the need for proposed action while balancing the impact of the work as it relates to the TBL concerns.

5. Statement of the Cost to Be Incurred and/or Saved

5.1 Capital Cost

This project will result in a capital expenditure of $3.1 million, which includes a 20% contingency. A breakdown of the capital cost for this project is presented in Table 1 below, and a detailed breakdown of this cost estimate is contained in Appendix C of this application. The project costs presented are based on 30% complete design drawings, prepared in November of 2023. In accordance with cost estimating principles, the project costs have been adjusted for inflation.

For the construction cost estimate, a 20% contingency is included. This is consistent with the American Association of Cost Engineers (AACE) International Recommended Practices and Standards for a Class 2 estimate, which is included in Appendix D. In a Class 2 estimate, the design of the project is expected to be between 30% to 75% complete and accurate within -15% to +20%. The AACE defines contingency as a specific provision for unforeseeable elements of cost within the defined project scope, particularly where experience has shown that unforeseeable costs are likely to occur. The 20% contingency allowance is included at this design stage for uncertainty in bid prices due to escalation of prices and part/equipment shortages that have occurred as a result of the COVID-19 pandemic and as a means to reduce the risk of possible cost overruns.

TABLE 1
Estimated Project Capital Cost

Description	Estimated Cost
Previous Expenditures (through December 2023)	$64,000
Remaining Design Cost	$60,000
Construction Cost	$1,761,864
Escalation to Midpoint of Construction 5% per year	$110,796
Construction with Inflation	$1,872,660
Contingency 20%	$374,532
Construction Phase Engineering Services	$408,500
RWA Costs *(PM, Temp Systems, SCADA Programming & Department Coordination)*	$280,000
Total	$3,059,692
Rounded Total	$3,100,000

5.2 Operation and Maintenance Cost

The new chemical system and building improvements will require standard, periodic maintenance activities that will be in line with industry standards. The RWA may see some time savings at first, due to the new equipment. In addition, the O&M activities for the facility will be similar to the existing facility, since there is no change in use. Therefore, we do not anticipate a change in overall operation and maintenance cost associated with this project.

5.3 Bonds or Other Obligations the RWA Intends to Issue

As a result, the annual cost of this project to a typical residential customer would be approximately $.90 and to an average residential customer approximately $1.19, assuming a conservative financing assumption of RWA bonds, based on project costs of $3.1 million and existing rates.

However, we expect this project to be funded by a combination of funding sources. The construction portion is anticipated to be funded through the Connecticut Department of Public Health's (CTDPH) Drinking Water State Revolving Fund (DWSRF). By utilizing DWSRF funding, the total financing costs associated with this project will be reduced. Internally generated funds may also be used to fund this project.

6. Preliminary Project Schedule and Permitting

6.1 Schedule

The project schedule is presented below.

1.	Preliminary Design:	November 2023
2.	RPB Submission & Approval	January 2024 – May 2024
3.	Final Design	April 2024
4.	Bidding	May 2024
5.	Award	June 2024
6.	Construction	July 2024 to October 2025
7.	Start-up, Optimization, and Completion	October 2025

Assuming construction is completed while the RWA operates a temporary caustic chemical feed system, we anticipate that active construction on this project will occur from July 2024 until October 2025. With the bidding requirements and lead time issues on equipment, it is anticipated that active construction will begin by January 2025.

6.2 Permitting

This project involves replacement of the existing chemical systems. In addition, the building improvements involve replacement and repairs to existing systems. This project will not result in any process changes to the Lake Whitney Water Treatment Plant. For these reasons, we do not believe this project will require permit approvals from the Connecticut Department of Public Health and will only require building permits/approvals from local authorities.

7. Statement of the Facts on Which the Board Is Expected to Rely in Granting the Authorization Sought

- Improves reliability and safety by replacing aging chemical feed system and building equipment/components.
- Improves consistency with other RWA facilities.
- Improves safety for RWA Treatment staff.
- Maintains operations and operating capacity of the Lake Whitney Water Treatment Plant facility, a critical source of potable water for New Haven and surrounding areas.

8. Explanation of Unusual Circumstances Involved in the Application

There were no unusual circumstances involved in this application.

9. Conclusion

The Lake Whitney Water Treatment Plant is a critical source of water supply for New Haven, CT and surrounding areas. The proposed chemical systems replacement and building improvements is a priority project for the RWA and is needed to improve the safety, reliability, and long-term viability of this important water supply treatment source. Further, these improvements will ultimately need to be performed, and delaying the project will likely result in higher future costs as the building systems continue to degrade.

At $3.1 million, the project maximizes the cost and non-cost benefits for the RWA. As such, the RWA has concluded that the proposed action is consistent with and advances the policies and goals of the South Central Connecticut Regional Water Authority.

Appendix C

Engineer's Opinion of Probable Cost for the Chemical Improvements at the Lake Whitney Water Treatment Plant Project

ENGINEER'S CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST Tighe&Bond

Project: **Chemical Improvements at the Lake Whitney Water Treatment Plant (Potassium Permanganate and Caustic Systems)**
Location: **Hamden, CT**

Estimate Type:
- ☐ Conceptual
- ☐ Preliminary Design
- ☑ Design Development
- ☐ Construction
- ☐ Change Order
- 30 % Complete

Prepared By: RRB
Date Prepared: 12/15/2023
T&B Project No.: S1889-A46

Spec. Section	Item No.	Description	Qty	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
DIVISION 1 - GENERAL CONDITIONS			(Costs included in unit prices in other Divisions)						
	1	10% of Construction Subtotal	1	LS	$133,480	$133,480		$0	$133,480
SUBTOTAL - DIVISION 1						**$133,480**		**$0**	**$133,480**
DIVISION 2 - SITE WORK									
02225	1	Selective Demolition							
	a	Permanganate Room Equipment	1	LS	$7,500	$7,500		$0	$7,500
	b	Caustic Room Equipment	1	LS	$40,000	$40,000		$0	$40,000
	c	Storage Room 114 Equipment	1	LS	$5,000	$5,000		$0	$5,000
	d	Knockout CMU and Relocate Utilities	1	LS	$25,000	$25,000			$25,000
	e	Residual Chemical Disposal	1	LS	$10,000	$10,000		$0	$10,000
	f	Permanganate Room Curb and Pad	1	LS	$6,000	$6,000		$0	$6,000
	g	Electrical Demolition	1	LS	$20,000	$20,000		$0	$20,000
SUBTOTAL - DIVISION 2						**$113,500**		**$0**	**$113,500**
DIVISION 3 - CONCRETE									
03300	1	Cast in Place Concrete							
	a	Housekeeping Pads - Chemical day tanks	1	LS	$3,600	$3,600		$0	$3,600
	b	Housekeeping Pads - Transfer Pumps	1	LS	$1,200	$1,200		$0	$1,200
	c	Concrete Entry into Caustic Room	1	LS	$4,800	$4,800			$4,800
	2	Concrete Repair (e.g. Perm. Room Floor)	1	LS	$12,000	$12,000		$0	$12,000
SUBTOTAL - DIVISION 3						**$21,600**		**$0**	**$21,600**
DIVISION 4 - MASONRY									
04810	1	Unit Masonry Assembly							
	a	Permanganate Room Door Masonry Repairs	20	SF	$75	$1,500		$0	$1,500
	b	Caustic Room Knock-Out Wall	144	SF	$100	$14,400		$0	$14,400
	c	Permanganate Room Knock-Out Wall	36	SF	$100	$3,600		$0	$3,600
SUBTOTAL - DIVISION 4						**$19,500**		**$0**	**$19,500**
DIVISION 5 - METALS									
05500	1	Miscellaneous Metals - 4' Wide Single Door Lintel	1	LS	$1,000	$1,000		$0	$1,000
	2	Miscellaneous Metals - Miscellaneous Items	1	LS	$2,000	$2,000		$0	$2,000
SUBTOTAL - DIVISION 5						**$3,000**		**$0**	**$3,000**
DIVISION 6 - WOOD & PLASTICS									
06600	1	Fiberglass Products							
	a	FRP Platform and Stair into New Perm. Room and FRP Platform to Mix Tanks	1	EA	$42,000	$42,000	$16,800	$16,800	$58,800
	b	FRP Permanganate Metering Pump Tables	2	EA	$2,000	$4,000	$800	$1,600	$5,600
SUBTOTAL - DIVISION 6						**$46,000**		**$18,400**	**$64,400**
DIVISION 7 - THERMAL & MOISTURE PROTECTION									
07920	1	Joint Sealants	1	LS	$7,500	$7,500		$0	$7,500
SUBTOTAL - DIVISION 7						**$7,500**		**$0**	**$7,500**
DIVISION 8 - DOORS & WINDOWS									
08200	1	Metal Doors & Frames							
	a	4' Wide Door & Hardware - Perm. Room	1	EA	$8,000	$8,000		$0	$8,000
SUBTOTAL - DIVISION 8						**$8,000**		**$0**	**$8,000**
DIVISION 9 - FINISHES									
09900	1	Painting							
	a	Touch-Up/Misc Painting	1	LS	$10,000	$10,000		$0	$10,000
	b	New Perm. Room Painting at Door Masonry	1	LS	$500	$500		$0	$500
09960	2	Chemical Resistant Floor Coating							
	a	Sodium Hydroxide Area	1,080	SF	$75	$81,000		$0	$81,000
	b	Existing Perm. Room Floor	200	SF	$75	$15,000		$0	$15,000
SUBTOTAL - DIVISION 9						**$106,500**		**$0**	**$106,500**
DIVISION 10 - SPECIALTIES									
10440	1	Signage	1	LS	$200	$200		$0	$200
SUBTOTAL - DIVISION 10						**$200**		**$0**	**$200**

ENGINEER'S CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST Tighe&Bond

Project: **Chemical Improvements at the Lake Whitney Water Treatment Plant (Potassium Permanganate and Caustic Systems)**
Location: **Hamden, CT**

Estimate Type: ☐ Conceptual ☐ Construction Prepared By: RRB
☐ Preliminary Design ☐ Change Order Date Prepared: 12/15/2023
☑ Design Development 30 % Complete T&B Project No.: S1889-A46

Spec. Section	Item No.	Description	Qty	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
DIVISION 11 - EQUIPMENT									
11010	1	Maintenance Equipment							
	a	Lift Table in New Permanganate Room	1	EA	$13,000	$13,000	$5,200	$5,200	$18,200
11240	2	Metering Pumps							
	a	Permanganate Metering Pumps	2	EA	$10,678	$21,355	$10,678	$21,355	$42,710
	b	Pre Caustic Metering Pumps	3	EA	$7,350	$22,050	$7,350	$22,050	$44,100
	c	Post Caustic Metering Pumps	3	EA	$7,978	$23,935	$7,978	$23,935	$47,870
	d	Post Caustic Metering Pump (low flow)	1	EA	$6,850	$6,850	$6,850	$6,850	$13,700
	e	Metering Pump Control Panels	3	EA	$20,000	$60,000	$20,000	$60,000	$120,000
11242	3	Transfer Pumps, Mixers, & Dust Collection System							
	a	Permanganate Transfer Pump	1	EA	$1,260	$1,260	$1,260	$1,260	$2,520
	b	Caustic Transfer Pump	1	EA	$1,260	$1,260	$1,260	$1,260	$2,520
	c	Transfer Pump Control Panel	2	EA	$4,000	$8,000	$2,000	$4,000	$12,000
	d	Pump Accessories							
		SS back pressure valves	7	EA	$1,800	$12,600	$720	$5,040	$17,640
		SS pressure relief valves	7	EA	$1,800	$12,600	$720	$5,040	$17,640
		SS pulsation dampener	7	EA	$600	$4,200	$240	$1,680	$5,880
		CPVC/PVC back pressure valves	2	EA	$500	$1,000	$200	$400	$1,400
		CPVC/PVC pressure relief valves	2	EA	$600	$1,200	$240	$480	$1,680
		CPVC/PVC pulsation dampener	2	EA	$600	$1,200	$240	$480	$1,680
		Clear PVC calibration columns	9	EA	$150	$1,350	$60	$540	$1,890
		Pressure gauges	9	EA	$300	$2,700	$120	$1,080	$3,780
		PVC y-strainers	9	EA	$500	$4,500	$200	$1,800	$6,300
	e	Permanganate Mix Tank Mixer and Stand	2	EA	$5,500	$11,000	$2,200	$4,400	$15,400
	f	Permanganate Room Dust Collector	1	EA	$25,000	$25,000	$10,000	$10,000	$35,000
SUBTOTAL - DIVISION 11						**$235,060**		**$176,850**	**$411,910**
DIVISION 13 - SPECIAL CONSTRUCTION									
13210	1	Polyethylene Tanks:							
	a	Permanganate Mix Tank - 960 gal	2	EA	$10,900	$21,800	$4,360	$8,720	$30,520
	b	Permanganate Day Tank - 545 gal IMFO	1	EA	$6,600	$6,600	$2,640	$2,640	$9,240
	c	Caustic Bulk Tanks - 3,000 gal IMFO	2	EA	$16,300	$32,600	$6,520	$13,040	$45,640
	d	Caustic Day Tank - 1,250 gal IMFO	1	EA	$11,800	$11,800	$4,720	$4,720	$16,520
	e	Freight Delivery	1	EA	$11,500	$11,500	$4,600	$4,600	$16,100
13420	2	Instrumentation							
	a	Mix/Bulk Tank Level Transmitters	4	EA	$3,000	$12,000	$1,200	$4,800	$16,800
	b	Day Tank Level Transmitters	2	EA	$3,000	$6,000	$1,200	$2,400	$8,400
	c	Day Tank Pressure Transmitters	2	EA	$4,100	$8,200	$1,640	$3,280	$11,480
	d	High Level Switches	6	EA	$1,200	$7,200	$480	$2,880	$10,080
	e	Flood Switches	2	LS	$600	$1,200	$240	$480	$1,680
	f	Emergency Shower Flow Switch	2	EA	$1,000	$2,000	$400	$800	$2,800
SUBTOTAL - DIVISION 13						**$120,900**		**$48,360**	**$169,260**
DIVISION 15 - MECHANICAL									
15050	1	Seals and Sleeves for Piping Between Walls	1	LS	$5,000	$5,000		$0	$5,000
15060	1	Hangers and Supports	1	LS	$20,000	$20,000		$0	$20,000
15104	2	PVC Piping							
	a	1.5" PVC Permangate Pump Discharge Piping	100	LF	$100	$10,000		$0	$10,000
	b	0.5" to 2" PVC Permangate Room Piping	100	LF	$100	$10,000		$0	$10,000
	c	8" PVC Permangate Mix Tank Vent to Dust Coll.	20	LF	$200	$4,000		$0	$4,000
	d	0.5" to 2" PVC Caustic Room Piping	100	LF	$100	$10,000		$0	$10,000
	e	6" PVC Caustic Vent Piping	100	LF	$200	$20,000		$0	$20,000
15105	3	SS Pipe and fittings	300	LF	$250	$75,000	$100	$30,000	$105,000
15109	4	Flexible hose and fittings	1	LS	$1,000	$1,000	$400	$400	$1,400
15110	5	Valves							
	a	0.5" to 2" PVC Valves - Perm. System	25	EA	$250	$6,250	$100	$2,500	$8,750
	b	PVC Motor Operator Valves - Perm System	2	EA	$1,500	$3,000	$600	$1,200	$4,200
	c	0.5" to 2" SS Valves - Caustic System	75	EA	$500	$37,500	$200	$15,000	$52,500
	d	Ductbill Check Valves - Caustic System	2	EA	$200	$400	$80	$160	$560
	e	SS Motor Operator Valves - Caustic System	2	EA	$5,000	$10,000	$2,000	$4,000	$14,000
15120	6	Piping Specialties	1	LS	$20,000	$20,000	$8,000	$8,000	$28,000
	a	3/4" SOV - Perm. Mix Tank Fill	2	EA	$1,000	$2,000	$400	$800	$2,800
15110	7	Plumbing Valves							
	a	Hose Bibbs	2	EA	$100	$200	$60	$120	$320
15140	8	Domestic Piping and Fittings							
	a	Process CW, 2" CU, Perm. Mix Tank Fill	50	FT	$100	$5,000		$0	$5,000

ENGINEER'S CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST Tighe&Bond

Project: **Chemical Improvements at the Lake Whitney Water Treatment Plant (Potassium Permanganate and Caustic Systems)**
Location: **Hamden, CT**

Estimate Type: ☐ Conceptual ☐ Preliminary Design ☑ Design Development ☐ Construction ☐ Change Order 30 % Complete

Prepared By: RRB
Date Prepared: 12/15/2023
T&B Project No.: S1889-A46

Spec. Section	Item No.	Description	Qty	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
	b	Domestic CW, 1-1/2" CU	100	FT	$75	$7,500		$0	$7,500
	c	Backflow Preventer	4	EA	$1,400	$5,600	$560	$2,240	$7,840
15080	9	Insulation for Above, Armacell	150	FT	$10	$1,500		$0	$1,500
15411	10	Emergency Plumbing Fixtures							
	a	Emergency Shower w/ Eyewash (interior)	2	EA	$2,500	$5,000	$750	$1,500	$6,500
SUBTOTAL - DIVISION 15						**$258,950**		**$65,920**	**$324,870**
DIVISION 16 - ELECTRICAL									
16050	1	General Electrical Work - Demo and Mobilization	1	EA	$15,000	$15,000	$0	$0	$15,000
16120	1	Electrical Conduit and Wire	1	EA	$68,000	$69,500	$0	$0	$69,500
16140	1	Wiring Devices	1	EA	$27,600	$27,600	$0	$0	$27,600
16490	1	Control Panels and Accessories	1	EA	$23,000	$23,000	$0	$0	$23,000
16500	1	Luminaires and Accessories	1	EA	$19,000	$19,000	$0	$0	$19,000
SUBTOTAL - DIVISION 16						**$84,500**		**$0**	**$84,500**

SUB-TOTAL				$1,468,220
CONTRACTOR OH&P	@	20%		$293,644
SUB-TOTAL with Contractor OH&P				$1,761,864
Escalation to Mid Point of Construction (Anticipated March 2025) 1.25 Years at 5% per Year (Assumed Notice to Proceed Issued June, 2024)				$1,872,660
CONTINGENCY	@	20%		$293,644
CONSTRUCTION TOTAL				**$2,166,304**
			SAY	**$2,200,000**
ENGINEERING - DESIGN PHASE AND BIDDING				$108,500
ENGINEERING - CONSTRUCTION PHASE				$300,000
PROJECT TOTAL				**$2,574,804**
				$2,600,000

Appendix D

American Association of Cost Engineers (AACE) ***Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries*****, August 2020**

AACE INTERNATIONAL RECOMMENDED PRACTICE

18R-97

COST ESTIMATE CLASSIFICATION SYSTEM - AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

AACE INTERNATIONAL

AACE INTERNATIONAL

AACE International Recommended Practice No. 18R-97

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

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. August 7, 2020

Note: As AACE International Recommended Practices evolve over time, please refer to web.aacei.org for the latest revisions.

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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Disclaimer: The content provided by the contributors to this recommended practice is their own and does not necessarily reflect that of their employers, unless otherwise stated.

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AACE® International Recommended Practice No. 18R-97

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

TCM Framework: 7.3 – Cost Estimating and Budgeting

August 7, 2020

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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 project cost estimating together with a generic project scope definition maturity and quality matrix, which can be applied across a wide variety of industries and scope content.

This recommended practice provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for the process industries. It supplements the generic cost estimate classification RP 17R-97[1] by providing:

- A section that further defines classification concepts as they apply to the process 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 improve communications among all the stakeholders involved with preparing, evaluating, and using project cost estimates specifically for the process industries.

The overall purpose of this recommended practice is to provide the process industry with a project definition deliverable maturity matrix that is not provided in 17R-97. It also provides an approximate representation of the relationship of specific 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.

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating processes, terminology, and may classify estimates in other ways. This guideline provides a generic and generally acceptable classification system for the process industries that can be used as a basis to compare against. 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 document, the term *process industries* is assumed to include firms involved with the manufacturing and production of chemicals, petrochemicals, and hydrocarbon processing. The common thread among these industries (for the purpose of estimate classification) is their reliance on process flow diagrams (PFDs), piping and instrument diagrams (P&IDs), and electrical one-line drawings as primary scope defining documents. These documents are key deliverables in determining the degree of project definition, and thus the extent and maturity of estimate input information. This RP applies to a variety of project delivery methods such as traditional design-bid-build (DBB), design-build (DB), construction management for fee (CM-fee), construction management at risk (CM-at risk), and private-public partnerships (PPP) contracting methods.

Estimates for process facilities center on mechanical and chemical process equipment, and they have significant amounts of piping, instrumentation, and process controls involved. As such, this recommended practice may apply to portions of other industries, such as pharmaceutical, utility, water treatment, metallurgical, converting, and similar industries.

Most plants also have significant electrical power equipment (e.g., transformers, switchgear, etc.) associated with them. As such, this RP also applies to electrical substation projects, either associated with the process plant, as part of power transmission or distribution infrastructure, or supporting the power needs of other facilities. This RP excludes power generating facilities and high-voltage transmission.

This RP specifically does not address cost estimate classification in non-process industries such as commercial building construction, environmental remediation, transportation infrastructure, hydropower, "dry" processes such as assembly and manufacturing, "soft asset" production such as software development, and similar industries. It also does not specifically address estimates for the exploration, production, or transportation of mining or hydrocarbon materials, although it may apply to some of the intermediate processing steps in these systems.

The cost estimates covered by this RP are for engineering, procurement, and construction (EPC) work only. It does not cover estimates for the products manufactured by the process facilities, or for research and development work in support of the process industries. This guideline does not cover the significant building construction that may be a part of process plants.

This guideline reflects generally-accepted cost engineering practices. This recommended practice was based upon the practices of a wide range of companies in the process industries from around the world, as well as published references and standards. Company and public standards were solicited and reviewed, and the practices were found to have significant commonalities. [4,5,6,7] These classifications are also supported by empirical process industry research of systemic risks and their correlation with cost growth and schedule slip [8].

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3. COST ESTIMATE CLASSIFICATION MATRIX FOR THE PROCESS INDUSTRIES

A purpose of cost estimate classification is to align the estimating process with project stage-gate scope development and decision-making processes.

Table 1 provides a summary of the characteristics of the five estimate classes. The maturity level of project definition is the sole determining (i.e., primary) characteristic of class. In Table 1, 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 3. 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.

	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%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1 – Cost Estimate Classification Matrix for Process Industries

This matrix and guideline outline an estimate classification system that is specific to the process industries. Refer to Recommended Practice 17R-97 [1] 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.* [16]

Table 1 illustrates typical ranges of accuracy ranges that are associated with the process 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 1. 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 1. [17]

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

- Level of familiarity with technology.
- Unique/remote nature of project locations and conditions and the availability of reference data for those.
- Complexity of the project and its execution.
- 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.
- Market and pricing conditions.
- Currency exchange.
- The accuracy of the composition of the input and output process streams.

Systemic risks such as these are often the primary driver of accuracy, especially during the early stages of project definition. 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 a process industry project may have an accuracy range as broad as -50% to +100%, or as narrow as -20% to +30%. 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 1 for the accuracy ranges conceptually illustrated in Figure 1. [18]

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, similar accuracy ranges may occur if the Class 5 estimate of one project that is based on a repeat project with good cost history and data and, whereas the Class 3 estimate for another is for a project involving new technology. It is for this reason that Table 1 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. [19]

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 range of ranges identified in Table 1. As previously mentioned, research indicates that for weak project systems, and/or complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 1.

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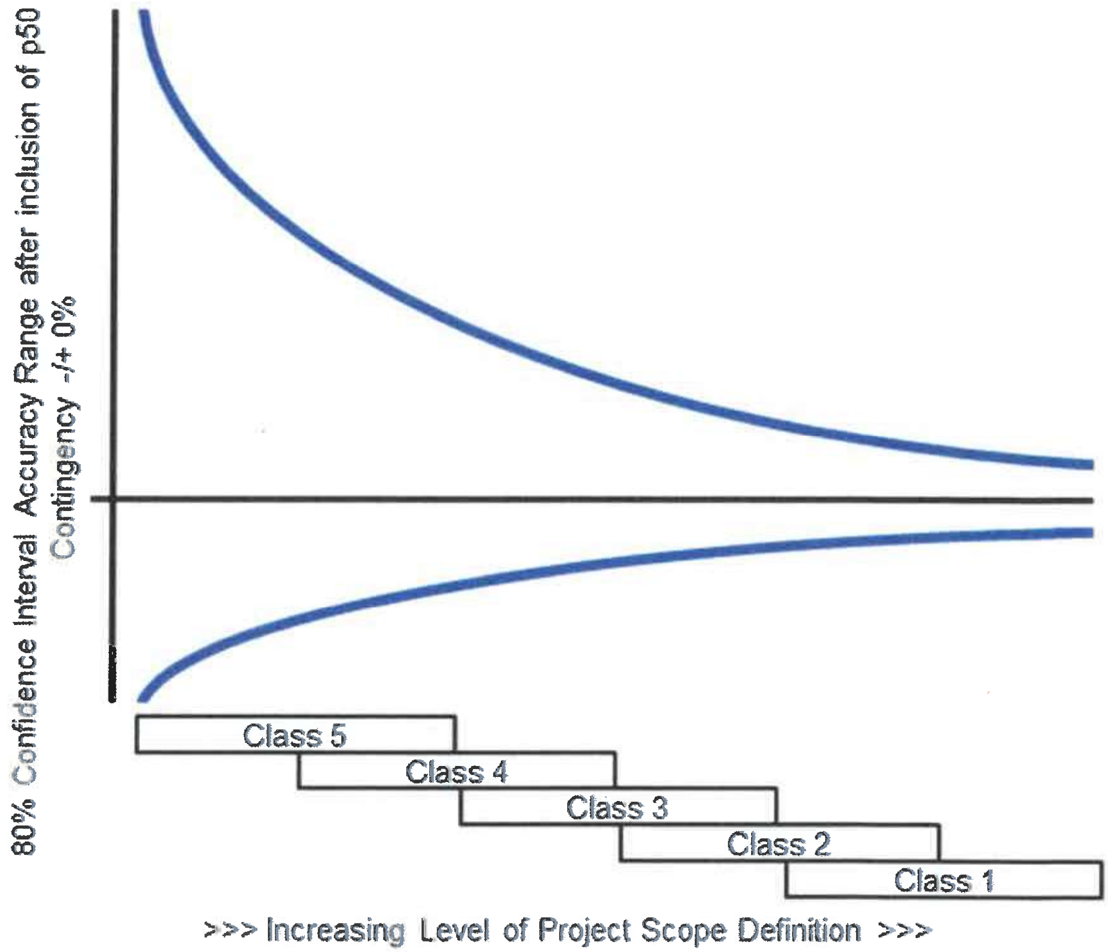

Figure 1 – Illustration of the Variability in Accuracy Ranges for Process Industry Estimates

4. DETERMINATION OF THE COST ESTIMATE CLASS

For a given project, the determination of the estimate class is based upon the maturity level of project definition based on the status of specific key planning and design deliverables. The percent design completion may be correlated with the status, but the percentage should not be used as the class determinate. While the determination of the status (and hence the estimate class) is somewhat subjective, having standards for the design input data, completeness and quality of the design deliverables will serve to make the determination more objective.

5. CHARACTERISTICS OF THE ESTIMATE CLASSES

The following tables (2a through 2e) provide detailed descriptions of the five estimate classifications as applied in the process industries. They are presented in the order of least-defined estimates to the most-defined estimates. These descriptions include brief discussions of each of the estimate characteristics that define an estimate class.

For each table, the following information is provided:

- **Description:** A short description of the class of estimate, including a brief listing of the expected estimate inputs based on the maturity level of project definition deliverables.

- **Maturity Level of Project Definition Deliverables (Primary Characteristic):** Describes a particularly key deliverable and a typical target status in stage-gate decision processes, plus an indication of approximate percent of full definition of project and technical deliverables. Typically, but not always, maturity level correlates with the percent of engineering and design complete.

- **End Usage (Secondary Characteristic):** A short discussion of the possible end usage of this class of estimate.

- **Estimating Methodology (Secondary Characteristic):** A listing of the possible estimating methods that may be employed to develop an estimate of this class.

- **Expected Accuracy Range (Secondary Characteristic):** Typical variation in low and high ranges after the application of contingency (determined at a 50% level of confidence). Typically, this represents about 80% confidence that the actual cost will fall within the bounds of the low and high ranges if contingency appropriately forecasts uncertainty and risks.

- **Alternate Estimate Names, Terms, Expressions, Synonyms:** This section provides other commonly used names that an estimate of this class might be known by. These alternate names are not endorsed by this recommended practice. The user is cautioned that an alternative name may not always be correlated with the class of estimate as identified in Tables 2a-2e.

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CLASS 5 ESTIMATE	
Description: Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Block flow diagram agreed by key stakeholders. List of key design basis assumptions. 0% to 2% of full project definition. **End Usage:** Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	**Estimating Methodology:** Class 5 estimates generally use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

Table 2a – Class 5 Estimate

CLASS 4 ESTIMATE	
Description: Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Process flow diagrams (PFDs) issued for design. 1% to 15% of full project definition. **End Usage:** Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	**Estimating Methodology:** Class 4 estimates generally use factored estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Screening, top-down, feasibility (pre-feasibility for metals processes), authorization, factored, pre-design, pre-study.

Table 2b – Class 4 Estimate

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CLASS 3 ESTIMATE	
Description: Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineered process and utility equipment lists. Remedial action plan resulting from HAZOPs is identified. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Piping and instrumentation diagrams (P&IDs) issued for design. 10% to 40% of full project definition. **End Usage:** Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase control estimates against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate is often the last estimate required and could very well form the only basis for cost/schedule control.	**Estimating Methodology:** Class 3 estimates generally involve more deterministic estimating methods than conceptual methods. They usually involve predominant use of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring methods may be used to estimate less-significant areas of the project. **Expected Accuracy Range:** Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, feasibility (for metals processes) development, basic engineering phase estimate, target estimate.

Table 2c – Class 3 Estimate

CLASS 2 ESTIMATE	
Description: Class 2 estimates are generally prepared to form a detailed contractor control baseline (and update the owner control baseline) against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the bid estimate to establish contract value. Typically, engineering is from 30% to 75% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, piping and instrument diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: All specifications and datasheets complete including for instrumentation. 30% to 75% of full project definition. **End Usage:** Class 2 estimates are typically prepared as the detailed contractor control baseline (and update to the owner control baseline) against which all actual costs and resources will now be monitored for variations to the budget, and form a part of the change management program. Some organizations may choose to make funding decisions based on a Class 2 estimate.	**Estimating Methodology:** Class 2 estimates generally involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detail takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods. **Expected Accuracy Range:** Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Detailed control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.

Table 2d – Class 2 Estimate

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CLASS 1 ESTIMATE	
Description: Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, overall engineering is from 65% to 100% complete (some parts or packages may be complete and others not), and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: All deliverables in the maturity matrix complete. 65% to 100% of full project definition. **End Usage:** Generally, owners and EPC contractors use Class 1 estimates to support their change management process. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution. Construction contractors may prepare Class 1 estimates to support their bidding and to act as their final control baseline against which all actual costs and resources will now be monitored for variations to their bid. During construction, Class 1 estimates may be prepared to support change management.	**Estimating Methodology:** Class 1 estimates generally involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities. **Expected Accuracy Range:** Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Table 2e – Class 1 Estimate

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6. ESTIMATE INPUT CHECKLIST AND MATURITY MATRIX

Table 3 maps the extent and maturity of estimate input information (deliverables) against the five estimate classification levels. This is a checklist of basic deliverables found in common practice in the process industries. The maturity level is an approximation of the completion status of the deliverable. The completion is indicated by the following descriptors:

General Project Data:

- **Not Required (NR):** May not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.

- **Preliminary (P):** Project definition has begun and progressed to at least an intermediate level of completion. Review and approvals for its current status has occurred.

- **Defined (D):** Project definition is advanced, and reviews have been conducted. Development may be near completion with the exception of final approvals.

Technical Deliverables:

- **Not Required (NR):** Deliverable may not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.

- **Started (S):** Work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion.

- **Preliminary (P):** Work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals.

- **Complete (C):** The deliverable has been reviewed and approved as appropriate.

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
GENERAL PROJECT DATA:					
A. SCOPE:					
Non-Process Facilities (Infrastructure, Ports, Pipeline, Power Transmission, etc.)	P	P	D	D	D
Project Scope of Work Description	P	P	D	D	D
Byproduct and Waste Disposal	NR	P	D	D	D
Site Infrastructure (Access, Construction Power, Camp etc.)	NR	P	D	D	D
B. CAPACITY:					
Plant Production / Facility (includes power facilities)	P	P	D	D	D
Electrical Power Requirements (when not the primary capacity driver)	NR	P	D	D	D

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MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
C. PROJECT LOCATION:					
Plant and Associated Facilities	P	P	D	D	D
D. REQUIREMENTS:					
Codes and/or Standards	NR	P	D	D	D
Communication Systems	NR	P	D	D	D
Fire Protection and Life Safety	NR	P	D	D	D
Environmental Monitoring	NR	NR	P	P	D
E. TECHNOLOGY SELECTION:					
Process Technology	P	P	D	D	D
F. STRATEGY:					
Contracting / Sourcing	NR	P	D	D	D
Escalation	NR	P	D	D	D
G. PLANNING:					
Logistics Plan	P	P	P	D	D
Integrated Project Plan[1]	NR	P	D	D	D
Project Code of Accounts	NR	P	D	D	D
Project Master Schedule	NR	P	D	D	D
Regulatory Approval & Permitting	NR	P	D	D	D
Risk Register	NR	P	D	D	D
Stakeholder Consultation / Engagement / Management Plan	NR	P	D	D	D
Work Breakdown Structure	NR	P	D	D	D
Startup and Commissioning Plan	NR	P	P/D	D	D
H. STUDIES:					
Environmental Impact / Sustainability Assessment	NR	P	D	D	D
Environmental / Existing Conditions	NR	P	D	D	D
Soils and Hydrology	NR	P	D	D	D
TECHNICAL DELIVERABLES:					
Block Flow Diagrams	S/P	C	C	C	C
Equipment Datasheets	NR/S	P	C	C	C
Equipment Lists: Electrical	NR/S	P	C	C	C

[1] The integrated project plan (IPP), project execution plan (PEP), project management plan (PMP), or more broadly the project plan, is a high-level management guide to the means, methods and tools that will be used by the team to manage the project. The term integration emphasizes a project life cycle view (the term execution implying post-sanction) and the need for alignment. The IPP covers all functions (or phases) including engineering, procurement, contracting strategy, fabrication, construction, commissioning and startup within the scope of work. However, it also includes stakeholder management, safety, quality, project controls, risk, information, communication and other supporting functions. In respect to estimate classification, to be rated as *defined*, the IPP must cover all the relevant phases/functions in an integrated manner aligned with the project charter (i.e., objectives and strategies); anything less is *preliminary*. The overall IPP cannot be rated as *defined* unless all individual elements are defined and integrated.

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MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Equipment Lists: Process / Utility / Mechanical	NR/S	P	C	C	C
Heat & Material Balances	NR	C	C	C	C
Process Flow Diagrams (PFDs)	NR	C	C	C	C
Utility Flow Diagrams (UFDs)	NR	C	C	C	C
Design Specifications	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S/P	C	C	C
Instrument List	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Plot Plans / Facility Layouts	NR	S/P	C	C	C
Construction Permits	NR	S/P	P/C	C	C
Civil / Site / Structural / Architectural Discipline Drawings	NR	S/P	P	C	C
Demolition Plan and Drawings	NR	S/P	P	C	C
Erosion Control Plan and Drawings	NR	S/P	P	C	C
Fire Protection and Life Safety Drawings and Details	NR	S/P	P	C	C
Electrical Schedules	NR	NR/S	P	P/C	C
Instrument and Control Schedules	NR	NR/S	P	P/C	C
Instrument Datasheets	NR	NR/S	P	P/C	C
Piping Schedules	NR	NR/S	P	P/C	C
Piping Discipline Drawings	NR	NR/S	S/P	C	C
Spare Parts Listings	NR	NR	P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Facility Emergency Communication Plan and Drawings	NR	NR	S/P	P/C	C
Information Systems / Telecommunication Drawings	NR	NR	S/P	P/C	C
Instrumentation / Control System Discipline Drawings	NR	NR	S/P	P/C	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C

Table 3 – Estimate Input Checklist and Maturity Matrix (Primary Classification Determinate)

7. BASIS OF ESTIMATE DOCUMENTATION

The basis of estimate (BOE) typically accompanies the cost estimate. The basis of estimate is a document that describes how an estimate is prepared and defines the information used in support of development. A basis document commonly includes, but is not limited to, a description of the scope included, methodologies used, references and defining deliverables used, assumptions and exclusions made, clarifications, adjustments, and some indication of the level of uncertainty.

The BOE is, in some ways, just as important as the estimate since it documents the scope and assumptions; and provides a level of confidence to the estimate. The estimate is incomplete without a well-documented basis of estimate. See AACE Recommended Practice 34R-05 *Basis of Estimate* for more information [12].

8. PROJECT DEFINITION RATING SYSTEM

An additional step in documenting the maturity level of project definition is to develop a project definition rating system. This is another tool for measuring the completeness of project scope definition. Such a system typically provides a checklist of scope definition elements and a scoring rubric to measure maturity or completeness for each element. A better project definition rating score is typically associated with a better probability of achieving project success.

Such a tool should be used in conjunction with the AACE estimate classification system; it does not replace estimate classification. A key difference is that a project definition rating measures overall maturity across a broad set of project definition elements, but it usually does not ensure completeness of the key project definition deliverables required to meet a specific class of estimate. For example, a good project definition rating may sometimes be achieved by progressing on additional project definition deliverables, but without achieving signoff or completion of a key deliverable.

AACE estimate classification is based on ensuring that key project deliverables have been completed or met the required level of maturity. If a key deliverable that is indicated as needing to be complete for Class 3 (as an example) has not actually been completed, then the estimate cannot be regarded as Class 3 regardless of the maturity or progress on other project definition elements.

An example of a project definition rating system is the *Project Definition Rating Index* developed by the Construction Industry Institute. It has developed several indices for specific industries, such as IR113-2 [13] for the process industry and IR115-2 [14] for the building industry. Similar systems have been developed by the US Department of Energy [15].

9. CLASSIFICATION FOR LONG-TERM PLANNING AND ASSET LIFE CYCLE COST ESTIMATES

As stated in the Purpose section, classification maps the phases and stages of project cost estimating. Typically, in a phase-gate project system, scope definition and capital cost estimating activities flow from framing a business opportunity through to a capital investment decision and eventual project completion in a more-or-less steady, short-term (e.g., several years) project life-cycle process.

Cost estimates are also prepared to support long-range (e.g., perhaps several decades) capital budgeting and/or asset life cycle planning. Asset life cycle estimates are also prepared to support net present value (e.g., estimates for initial capital project, sustaining capital, and decommissioning projects), value engineering and other cost or economic studies. These estimates are necessary to address sustainability as well. Typically, these long-range estimates are based on minimal scope definition as defined for *Class 5*. However, these asset life cycle "conceptual" estimates are prepared so far in advance that it is virtually assured that the scope will change from even the minimal level of definition assumed at the time of the estimate. Therefore, the expected estimate accuracy values reported in Table 1 (percent that actual cost will be over or under the estimate including contingency) are not meaningful because the Table 1 accuracy values explicitly *exclude scope change*. For long-term estimates, one of the following two classification approaches is recommended:

- If the long-range estimate is to be updated or maintained periodically in a controlled, documented life cycle process that addresses scope and technology changes in estimates over time (e.g., nuclear or other licensing may require that future decommissioning estimates be periodically updated), the estimate is rated as *Class 5* and the Table 1 accuracy ranges are assumed to apply for the specific scope included in the estimate at the time of estimate preparation. Scope changes are explicitly excluded from the accuracy range.

- If the long-range estimate is performed as part of a process or analysis where scope and technology change is not expected to be addressed in routine estimate updates over time, the estimate is rated as *Unclassified* or as *Class 10* (if a class designation is required to meet organizational procedures), and the Table 1 accuracy ranges cannot be assumed to apply. The term *Class 10* is specifically used to distinguish these long-range estimates from the relatively short time-frame *Class 5* through *Class 1* capital cost estimates identified in Table 1 and this RP; and to indicate the order-of-magnitude difference in potential expected estimate accuracy due to the infrequent updates for scope and technology. Unclassified (or Class 10) estimates are not associated with indicated expected accuracy ranges.

In all cases, a *Basis of Estimate* should be documented so that the estimate is clearly understood by those reviewing and/or relying on them later. Also, the estimating methods and other characteristics of Class 5 estimates generally apply. In other words, an *Unclassified* or *Class 10* designation must not be used as an excuse for unprofessional estimating practice.

REFERENCES

1. AACE International, Recommended Practice 17R-97, *Cost Estimate Classification System*, AACE International, Morgantown, WV, (latest revision).
2. Stephenson, H. Lance, CCP, Editor, *Total Cost Management Framework: An Integrated Approach to Portfolio, Program and Project Management*, AACE International, Morgantown, WV (latest revision).
3. AACE International, Recommended Practice 10S-90, *Cost Engineering Terminology*, AACE International, Morgantown, WV (latest revision).
4. John R. Heizelman, *Estimating Factors for Process Plants*, 1988 AACE Transactions, V.3, AACE International, Morgantown, WV, 1988.
5. K.T. Yeo, The Cost Engineer Journal, UK Vol. 27, No. 6, 1989.
6. Stevens, G. and T. Davis, How Accurate are Capital Cost Estimates?, 1988 AACE Transactions, B.4, AACE International. Morgantown, WV, 1988. (* Class 3 is inferred)
7. Behrenbruch, Peter, article in Journal of Petroleum Technology, Vol. 45, No. 8, Society of Petroleum Engineers, August 1993.
8. AACE International, Recommended Practice 42R-08, *Risk Analysis and Contingency Determination Using Parametric Estimating*, AACE International, Morgantown, WV (latest revision).
9. AACE International, Recommended Practice 40R-08, *Contingency Estimating - General Principles*, AACE International, Morgantown, WV (latest revision).
10. AACE International, Recommended Practice 41R-08, *Risk Analysis and Contingency Determination Using Range Estimating*, AACE International, Morgantown, WV (latest revision).
11. AACE International, Recommended Practice 44R-08, *Risk Analysis and Contingency Determination Using Expected Value*, AACE International, Morgantown, WV (latest revision).
12. AACE International, Recommended Practice 34R-05, Basis of Estimate, AACE International, Morgantown, WV (latest revision).
13. Construction Industry Institute (CII), PDRI: Project Definition Rating Index – Building Projects, Version 3.2 (115-2), Austin, TX, December 1, 2009.
14. Construction Industry Institute (CII), PDRI: Project Definition Rating Index – Industrial Projects, Version 3.2 (113-2), Austin, TX, December 1, 2009.

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15. U.S. Department of Energy (DOE), *Project Definition Rating Index Guide for Traditional Nuclear and Non-Nuclear Construction Projects*, DOE G 413.3-12, July 22, 2010.
16. AACE International, Professional Guidance Document PGD 01, *Guide to Cost Estimate Classification*, AACE International, Morgantown, WV (latest revision).
17. J. K. Hollmann, Project Risk Quantification, Sugarland, TX: Probabilistic Publishing, 2016.
18. AACE International Recommended Practice No. 104R-19, Understanding Estimate Accuracy, Morgantown, WV: AACE International, Latest revision.
19. AACE International, Professional Guidance Document (PGD) 02, Guide to Quantitative Risk Analysis, Morgantown, WV: AACE International, Latest revision.

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APPENDIX: UNDERSTANDING ESTIMATE CLASS AND COST ESTIMATE ACCURACY

Despite the verbiage included in the RP, often, there are still misunderstandings that the class of estimate, as defined in the RP above, defines an expected accuracy range for each estimate class. This is incorrect. The RP clearly states that "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 predetermined." Table 1 and Figure 1 in the RP are intended to illustrate only the general relationship between estimate accuracy and the level of project definition. For the process industries, typical estimate ranges described in RP 18R-97 above are shown as a range of ranges:

- Class 5 Estimate:
  - High range typically ranges from +30% to +100%
  - Low range typically ranges from -20% to -50%
- Class 4 Estimate:
  - High range typically ranges from +20% to +50%
  - Low range typically ranges from -15% to -30%
- Class 3 Estimate:
  - High range typically ranges from +10% to +30%
  - Low range typically ranges from -10% to -20%
- Class 2 Estimate:
  - High range typically ranges from +5% to +20%
  - Low range typically ranges from -5% to -15%
- Class 1 Estimate:
  - High range typically ranges from +3% to +15%
  - Low range typically ranges from -3% to -10%

As indicated in the RP, these +/- percentage members associated with an estimate class are intended as rough indicators of the accuracy relationship. They are merely a useful simplification given the reality that every individual estimate will be associated with a unique probability distribution correlated with its specific level of uncertainty. As indicated in the RP, estimate accuracy should be determined through a risk analysis for each estimate.

It should also be noted that there is no indication in the RP of contingency determination being based on the class of estimate. AACE has recommended practices that address contingency determination and risk analysis methods (for example RP 40R-08, *Contingency Estimating – General Principles* [9]). Furthermore, the level of contingency required for an estimate is not the same as the upper limits of estimate accuracy (as determined by a risk analysis).

The results of the estimating process are often conveyed as a single value of cost or time. However, since estimates are predications of an uncertain future, it is recommended that all estimate results should be presented as a probabilistic distribution of possible outcomes in consideration of risk.

Every estimate is a prediction of the expected final cost or duration of a proposed project or effort (for a given scope of work). By its nature, an estimate involves assumptions and uncertainties. Performing the work is also subject to risk conditions and events that are often difficult to identify and quantify. Therefore, every estimate presented as a single value of cost or duration will likely deviate from the final outcome (i.e., statistical error). In simple terms, this means that every point estimate value will likely prove to be wrong. Optimally, the estimator will analyze the uncertainty and risks and produce a probabilistic estimate that provides decision makers with the probabilities of over-running or under-running any particular cost or duration value. Given this probabilistic nature of an estimate, an estimate should not be regarded as a single point cost or duration. Instead, an estimate actually reflects a range of potential outcomes, with each value within this range associated with a probability of occurrence.

Individual estimates should always have their accuracy ranges determined by a quantitative risk analysis study that results in an estimate probability distribution. The estimate probability distribution is typically skewed. Research shows the skew is typically to the right (positive skewness with a longer tail to the right side of the distribution) for large and complex projects. In part, this is because the impact of risk is often unbounded on the high side.

High side skewness implies that there is potential for the high range of the estimate to exceed the median value of the probability distribution by a higher absolute value than the difference between the low range of the estimate and the median value of the distribution.

Figure A1 shows a positively skewed distribution for a sample cost estimate risk analysis that has a point base estimate (the value before adding contingency) of $89.5. In this example, a contingency of $4.5 (approximately 5%) is required to achieve a 50% probability of underrun, which increases the final estimate value after consideration of risk to $93. Note that this example is intended to describe the concepts but not to recommend specific confidence levels for funding contingency or management reserves of particular projects; that depends on the stakeholder risk attitude and tolerance.

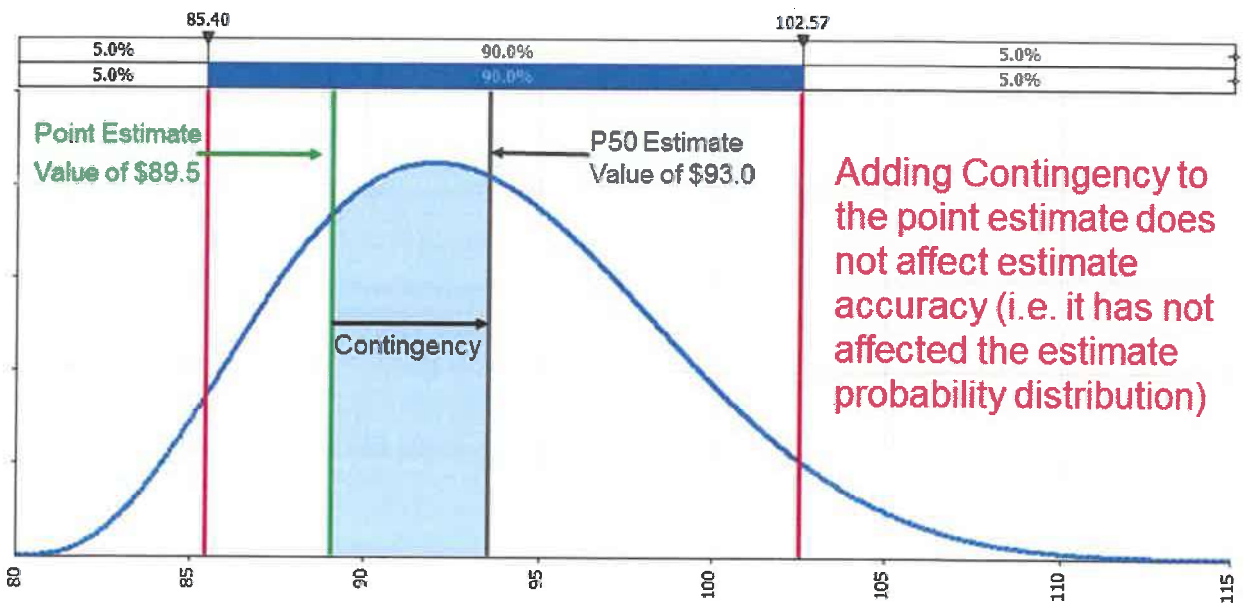

Figure – A1: Example of an Estimate Probability Distribution at a 90% Confidence Interval

Note that adding contingency to the base point estimate does not affect estimate accuracy in absolute terms as it has not affected the estimate probability distribution (i.e., high and low values are the same). Adding contingency simply increases the probability of underrunning the final estimate value and decreases the probability of overrunning the final estimate value. In this example, the estimate range with a 90% confidence interval remains between approximately $85 and $103 regardless of the contingency value.

As indicated in the RP, expected estimate accuracy tends to improve (i.e., the range of probable values narrows) as the level of project scope definition improves. In terms of the AACE International estimate classifications, increasing levels of project definition are associated with moving from Class 5 estimates (lowest level of scope definition) to Class 1 estimates (highest level of scope definition), as shown in Figure 1 of the RP. Keeping in mind that accuracy is an expression of an estimate's predicted closeness to the final actual value; anything included in that final actual cost, be it the result of general uncertainty, risk conditions and events, price escalation, currency or anything else within the project scope, is something that estimate accuracy measures must communicate in some manner. With that in mind, it should be clear why standard accuracy range values are not applicable to individual estimates.

The level of project definition reflected in the estimate is a key risk driver and hence is at the heart of estimate classification, but it is not the only driver of estimate risk and uncertainty. Given all the potential sources of risk and uncertainty that will vary for each specific estimate, it is simply not possible to define a range of estimate accuracy solely based on the level of project definition or class of estimate.