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The benefits and opportunities realized through an integrated and transparent closure cost model

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Abstract

Often, a closure strategy and cost estimate are developed to meet a specific purpose, such as regulatory submittal and bonding obligations or to support an Asset Retirement Obligation (ARO). This purpose-based approach may result in an incomplete closure cost to the project, risks to the successful operation and closure of the mine, and reduced accuracy in the resulting cost estimate. Simply stated, a closure plan and cost estimate may not result in a complete understanding of the closure risks (i.e., uncertainties or unknowns), or facilitate the process of identifying a successful closure approach and accurate cost estimate.

By developing a comprehensive closure cost estimate model that can evolve from the conceptual planning through execution, major closure project risks can be clearly communicated and tracked; and plans can be developed to address and mitigate appropriate closure activities. This can be achieved through identifying a suitable work breakdown structure (WBS), developing appropriate activity codes, and using consistent coding of units and unit rates. This also includes developing an end-user interface that is fit for purpose and allows for the simple and transparent means to present and interpret the data. The closure cost model results can then be presented in a manner that is relatable to facilities, activities, quantities, and risk, allowing various stakeholders to identify impacts to the closure plan and costs and identify activities to reduce risk and costs, while realizing efficiencies as the closure project progresses from concept to execution.

This paper presents how incorporating cost codes that represent key elements of the closure plan (i.e., material characterization, contingency, borrow sources, etc.) into a single, comprehensive closure cost estimate model can facilitate and provide additional insight on the cost assumptions and the progression of mine closure planning and costing over time.

Keywords: *closure cost estimate, closure cost model, cost codes, risk, uncertainty*

1 Introduction

Closure cost estimate models are typically simple calculations that are a sum of quantities multiplied by unit rates and can include contingencies and indirect costs as single line items that are applied equally to all or most calculations. More advanced closure cost estimate models may have a WBS that identifies the closure cost estimate by area or facility type (i.e., waste rock dump, tailings facility, or plant site), and a cash flow that schedules the closure cost by year. However, to understand and plan for uncertainties that the closure cost estimate model is based on, the closure cost estimate model must be read in conjunction with the closure plan, which can be difficult.

By developing and incorporating a set of project-specific codes into the closure cost estimate model, assumptions and risks associated with the closure approach and closure plan narrative can be reflected in the model outputs. These cost codes can then be used to graphically present assumptions, risks, and uncertainties to facilitate the overall closure plan development and, most importantly, mitigation of risks and unknowns as the plan progresses.

These project-specific codes were incorporated into the unit rate descriptions and have been referred to in this paper as cost codes.

2 Mine closure plan

To demonstrate how a comprehensive closure cost estimate model can address some of the concerns noted in Section 1, and present some of the features noted previously, a traditional closure cost estimate model was developed based on the mine closure plan for a fictional mine and is presented in this section.

- **Mine:** The open pit will remain in its current condition post-closure, with a fence installed to limit access. The underground mine access portal and ventilation shaft will be backfilled and capped with a concrete plug, covered with 12 inches of growth media, and revegetated via hydroseeding. Historic workings include three adits, five shallow shafts, and ten prospects that will be backfilled, covered with 30 centimetres (cm) of growth media, and revegetated via hydroseeding.
- **Mine waste:** The waste dump and low-grade ore stockpile slopes will be regraded to 3H:1V, following an approximate cut/fill balance. The cover system placed after regrading will consist of finished grade dump crest (flat) surfaces covered with 30 cm of growth media and revegetated via hydroseeding. Finished grade dump slope surfaces will be covered with 30 cm of soil and 30 cm of rock armour.
- **Tailings storage facility:** The top of the tailings will be regraded with a nominal 1% slope to promote positive drainage away from the dam face and diverted into a spillway. The tailings embankment slope will be regraded to 3H:1V, following an approximate cut/fill balance. The cover system placed after regrading will consist of finished grade dump crest (flat) surfaces covered with 30 cm of growth media and revegetated via hydroseeding. Finished grade slope surfaces will be covered with 30 cm of soil and 30 cm of rock armour.
- **Process facilities:** The primary crusher and semi autogenous (SAG) mill will be salvaged and removed from site (salvage value was considered equal to the removal costs). The two mill buildings and other structures will be demolished and disposed of offsite. Any concrete foundations will be broken in place and covered with 30 cm of growth media and revegetated via hydroseeding. The fixed conveyors will be demolished and disposed of offsite. Hazardous materials (either solid or liquid) will be characterized and disposed of offsite prior to the commencement of closure activities.
- **Mine infrastructure:** Buried pipelines for the distribution of fresh water will be drained, capped in place, and the ends will be buried. Process lines, such as the tailings distribution lines, will be drained and disposed of offsite. Freshwater dams and ponds will be breached and regraded, and the area revegetated via hydroseeding. The general footprint of process/contact water ponds are assumed to be impacted soils, will be excavated to a depth of 1.0 metre (m), removed and disposed of offsite, and the area brought back to grade with clean fill. The dam will be breached and regraded, and the area revegetated via hydroseeding. Perimeter fencing will be removed and disposed of offsite. Overhead powerlines, poles, and substations will be decommissioned and disposed of offsite. Groundwater monitoring well decommissioning and abandonment will include the removal of pumps and instrumentation (offsite disposal), perforation of well casing, plugging using grout, removal of the surface completion (offsite disposal), and grading of the surface to conform with the natural topography and revegetation via hydroseeding. Weather stations will be decommissioned and disposed of offsite.
- **Water treatment:** A water treatment plant will be setup onsite for the long-term treatment of contact surface water.

3 Closure cost estimate

For this paper, closure costs were developed for direct contractor costs only (i.e., no ongoing maintenance costs), and have been defined as the sum of the direct contractor costs and contingency. Indirect contractor and owner costs have not been included, and these would include, but not be limited to, such items as engineering, construction management, temporary facilities, surveying, and escalation.

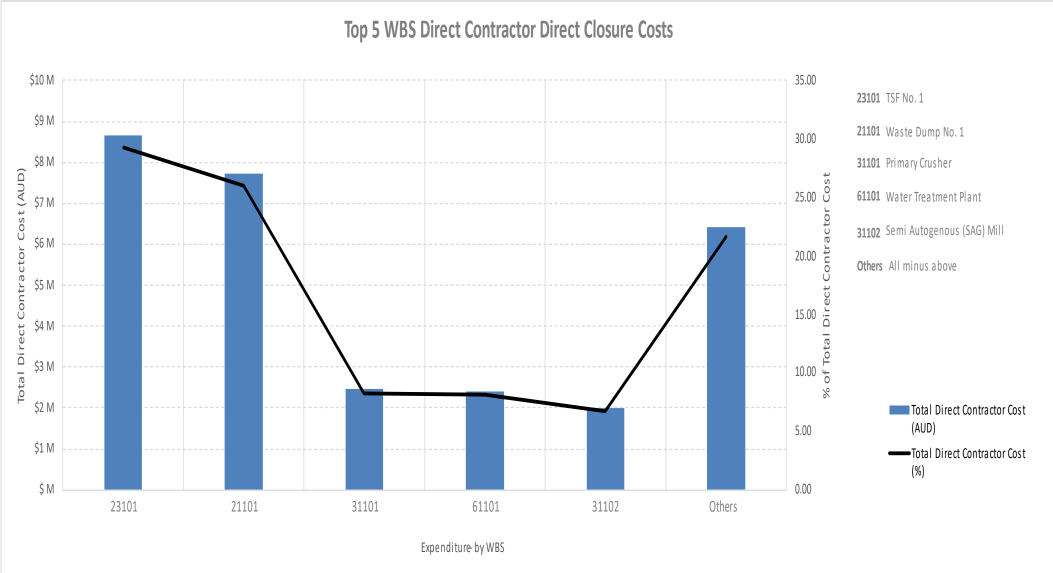
3.1 Traditional closure cost estimate

A traditional closure cost estimate model was developed for the site using the site information and closure approach presented in Section 2, and is presented in Table 1. The closure cost estimate model was developed by generating quantities and multiplying the design quantities by the selected unit rates. The resulting closure cost estimate was $42.9M AUD, including $13.3M AUD as a single line item for.

Table 1 Closure cost estimate

WBS code	Description	Direct contractor cost (AUD)
11101	Pit no. 1	9,000
12101	Shaft no. 1 and ventilation shaft no. 1	155,800
13101	Adits, shafts and prospects	26,700
21101	Waste dump no. 1	7,721,733
22101	Low grade ore stockpile no. 1	579,393
23101	TSF No. 1	8,667,297
24101	Mine buildings	64,815
31101	Primary crusher	2,450,000
31102	Semi autogenous (SAG) mill	2,000,000
32101	Fixed conveyors	2,310
33101	Process Buildings	1,055,556
41201	Primary, secondary and tertiary roads	679,800
42101	Power lines and substations	550,950
43101	Fresh water lines	30,000
44101	Process water dams / ponds	158,509
45101	Laydown areas, yards and parking areas	446,476
46101	Perimeter fencing	45,000
47101	Diversion channels	1,530,000
51101	Monitoring wells and weather station	80,000
61101	Water treatment plant	2,400,000
91101	Contractor mobilization / demobilization	1,000,000
	Subtotal direct contractor costs	**29,653,339**
	Contingency	**13,264,551**
	Closure cost estimate	**42,917,890**

Plotting the direct contractor costs by facility identification (or WBS ID), the five largest closure costs for the project are with TSF No. 1., Waste Dump No. 1, Primary Crusher demolition, Water Treatment Plant, and SAG Mill demolition, respectively. This is presented in Graph 1.



Graph 1 Top five closure costs by WBS

This is typically where a traditional closure plan and cost estimate conclude, with the assumptions and risks associated with the closure approach presented in the closure plan text. This approach makes it difficult to confirm if the assumptions have been correctly incorporated into the closure cost model, the relative impacts these assumptions may have on the closure cost model and options to reduce the risk associated with these assumptions.

3.2 Cost codes

Site-specific closure cost codes were developed for each unit rate that provides searchable details on the assumptions used as basis to develop the unit rates.

The importance of the site-specific cost codes is that they should be based on identifying items of particular interest by the closure cost modeller for the closure project. These cost codes may represent the level of site knowledge available at the time the closure cost model was developed, or conversely, the level of uncertainties or assumptions that were made to develop the closure cost model. These site-specific items can be graphed and tracked to the relative project knowns and unknowns as the closure project advances.

The site-specific closure cost codes developed, and the corresponding abbreviated terms incorporated into the conceptual closure cost model, are described below.

3.2.1 Material

Unit rates were developed that considered each of the materials to be used for each of the closure activities. Examples of the materials used in the closure plan and cost codes include cover soil (C), demolition (D), engineered fill (E), filter material (F), growth media (G), other, soil (O), rock armour (R), tailings (T), unsuitable (U), and waste (W).

3.2.2 Material handling equipment

Unit rates typically include assumptions regarding how the material will be generally transported to its final location. Material handing codes were developed that estimated how the materials may be generally transported or moved onsite, and included the following: dozer (D), highway trucks (H), other (O), scraper (S), mine haul trucks with less than two kilometres (km) haul (Ts), mine haul trucks with greater than two km haul (Tl), and wreckage / demolition (W).

3.2.3 Processing

As part of the unit rate development, assumptions were made for the processing of materials that may be required. These codes identify the material processing requirements and assumptions, or understanding, of materials that may be available from onsite and offsite sources, including imported crushed (Ci), site crushed (Cs), offsite disposal (Do), site disposal (Ds), none/native (N), other (O), imported screened (Si),and site screened (Ss).

3.2.4 Contingency

The Association for the Advancement of Cost Engineering International (AACE International) have developed an accuracy range for five cost estimate levels, noting that the accuracy range should decrease as the level of study increases. For example, AACE International note a +100 to -50 percent accuracy range for a scoping level design that should decrease to -15 to +20 percent for a detailed bid. Contingency can be a general term representing risk or uncertainty associated with such items as the accuracy of the quantity estimates, material suitability, unit pricing development, or other considerations. Contingency should follow the same trend, in which the level of contingency (i.e., uncertainties) assigned to a task or project should decrease as the level of design advances, since the level of site knowledge for such items as borrow source, quantities and unit rates should increase accordingly.

For the comprehensive closure cost model presented in this paper, a contingency cost code was assigned for each of the unit rates to reflect one of the following three contingency (uncertainty) levels selected by the closure cost modeller: high (H), medium (M), or low (L).

3.2.5 Closure activity timing

Concurrent reclamation provides an opportunity for the owner to reduce closure costs by performing certain closure activities during operations using owner staff and equipment.

For this discussion, closure activity timing was defined as being in one of four following stages: concurrent reclamation (operations), or closure activities that can be performed during operations (CO); closure stage 1, or closure activities that can be performed before stage 2 or 3 (Stage 1); closure stage 2, or closure activities that can be performed after stage 1 and are required prior to stage 3 (Stage 2); and closure stage 3 (Stage 3).

3.2.6 Closure element

Like material types, these codes identify the closure cost associated by closure element for each of the unit rates and vary by project. Examples for this project include cover system (C), which is a combination of the soil, growth media, rock armour, and revegetation costs; demolition (D); earthwork (E); surface water management (H); other (O); ripping (R); water treatment (T), and mine workings plugging/abandonment (X).

3.2.7 Borrow characterization

Cost codes were developed to describe the characterization of the borrow sources (which may include considerations such as geotechnical or geochemical characterization) that were assumed, which included onsite characterized (On), offsite characterized (Off), not characterized (N) and not applicable (N/A).

3.2.8 Cost basis

Cost codes were identified to support the basis of the unit rates used to develop closure cost estimate which include the following: engineer's estimate (E), factored (F), other database (O), project experience (P), and quote (Q).

3.3 Unit rates and cost codes

The unit rate descriptions and associated unit rate codes using the abbreviations noted above, are presented in Table 2.

Table 2 Unit rate and cost code table

Unit rate description	Material	Material handling equipment	Processing	Contingency	Closure activity timing	Closure element	Borrow charact.	Cost basis
Unsuitable Foundation Material Excavation and Removal	U	Ts	N	H	Co	E	N	E
Waste Rock (Slope) Recontouring (Dozer Cut to Fill)	W	D	N	M	Co	E	On	E
Waste Rock (Slope) Recontouring (> 2km haul)	W	Tl	N	M	Co	E	On	E
Tailings Surface Recontouring (Scraper)	T	S	N	L	Stage 1	E	On	E
Granular Filter (Import from Offsite)	F	H	Ci	M	Stage 1	E	Off	E
Regrading (Engineered Fill)	E	Ts	N	H	Stage 1	E	N	E
Cover Material – Surface (Growth Media – Scraper)	G	S	N	H	Stage 2	C	On	E
Cover Material – Surface (flat)–(Growth Media (> 2km haul)	G	S	Ss	H	Stage 2	C	On	E
Cover Material (Slope) –Screened Soil (< 2 km haul)	C	S	Ss	H	Stage 1	C	N	E
Cover Material (Slope) –Screened Soil (> 2km haul)	C	Tl	Ss	H	Stage 1	C	N	E
Rock Armour (Slope) (< 2km haul)	R	Ts	Ss	H	Stage 1	C	N	E
Rock Armour (Slope) (> 2km haul)	R	Tl	Ss	H	Stage 1	C	N	E
Revegetation (via dry dispersal)	O	O	O	L	Stage 1	C	N/A	Q
Revegetation (via hydroseeding)	O	O	O	L	Stage 2	C	N/A	Q
Ripping and Regrading	O	O	O	M	Stage 3	R	N/A	E
Diversion Channels	O	O	O	H	Stage 3	H	N/A	E
Spillway	O	O	O	L	Co	E	N/A	F
Mine, Primary, Secondary and Tertiary Roads	O	D	O	L	Stage 3	R	N/A	P
Fence Installation	O	D	O	M	Stage 3	O	N/A	P

Unit rate description	Material	Material handling equipment	Processing	Contingency	Closure activity timing	Closure element	Borrow charact.	Cost basis
Water Treatment Plant	O	O	O	L	Stage 3	T	N/A	P
Well Abandonment and Surface Reclamation	O	O	O	M	Stage 3	O	N/A	S
Overhead Powerline Removal	D	W	Do	L	Stage 3	D	N/A	S
Substation Demolition and Removal	D	W	Do	L	Stage 3	D	N/A	F
Weather Station Demolition	D	W	Do	L	Stage 3	D	N/A	F
Shaft Backfill and Plug	O	O	Ss	M	Stage 3	X	On	S
Shaft Backfill	O	O	Ss	L	Stage 3	X	On	S
Adit and Prospect Backfill	O	O	Ss	L	Co	X	On	S
Plug and Cap Freshwater Pipes	O	O	O	L	Co	X	N/A	P
Geomembrane Removal and General Grading	O	O	Do	H	Stage 3	O	N/A	P
Fence Demolition	D	W	Ds	L	Stage 3	D	N/A	P
Hazardous Material Abatement	D	W	Do	L	Stage 1	D	Off	P
Building Demolition One and Two Story	D	W	Do	L	Stage 1	D	N/A	F
Primary Crusher Demolition	D	W	Do	L	Stage 1	D	N/A	F
Semi Autogenous (SAG) Mill Demolition	D	W	Do	L	Stage 1	D	N/A	F
Fixed Conveyor Demolition	D	W	Do	L	Stage 1	D	N/A	F
Piping Removal	O	O	Do	M	Stage 1	O	N/A	S
Pond Dam Breach and Recontouring	O	O	O	M	Stage 2	O	N/A	F
Impacted Soil Excavation and Removal (Onsite Disposal)	U	Tl	Ds	M	Stage 2	R	N/A	E
Mobilization and Demobilization	O	O	O	M	Co	O	N/A	P

The cost codes from each unit rate can then be used to describe or represent the assumptions made in developing the conceptual closure plan and approach. For example:

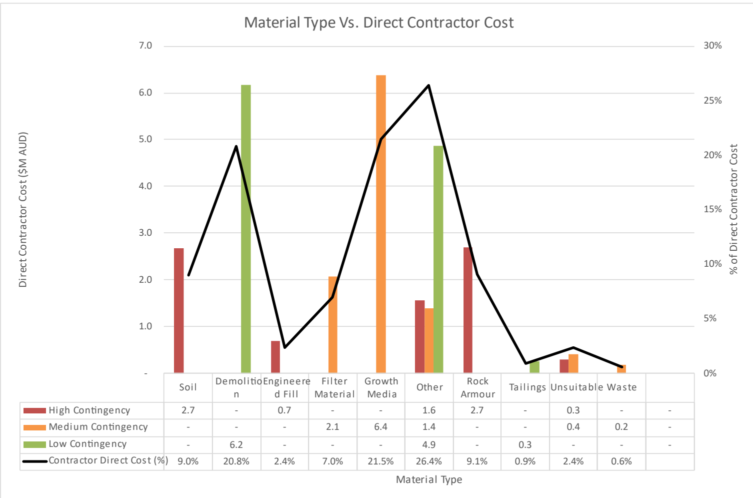
- The cost codes for the tailings surface recontouring identify tailings as the material type, dozers to be the equipment type, no processing required, earthworks as the element type, a low contingency level (either because the unit rates are considered well estimated and/or the quantity estimate is considered to be relatively accurate), the material is an onsite material that has been characterized, and the closure activity would be performed during Stage 1 of closure.
- The borrow source for the Soil to be used for cover (C) material on the tailings slopes was noted by the cost modeller as not being sufficiently characterized (N) and was assigned a high contingency (H) allowance. This identifies that a geotechnical investigation to characterize the borrow source quantity and quality should be performed to reduce the continency allowance. Conversely, the growth media (G) for the cover system was noted by the cost modeller as being from an onsite borrow source that has been characterized, and was assigned a medium (M) contingency.

4 Results

The following plots were developed within the closure cost model for the closure approach presented in Section 2 and the cost codes discussed in Section 3.2.

4.1 Material type versus direct contractor cost

Graph 2 presents the ten types of materials identified for the project by direct contractor cost and contingency level. **Graph 2** identifies that the two soil types (soil and rock armour) represents approximately 18% of the direct contractor cost and have the highest contingency allowance, as defined by the closure cost modeller.



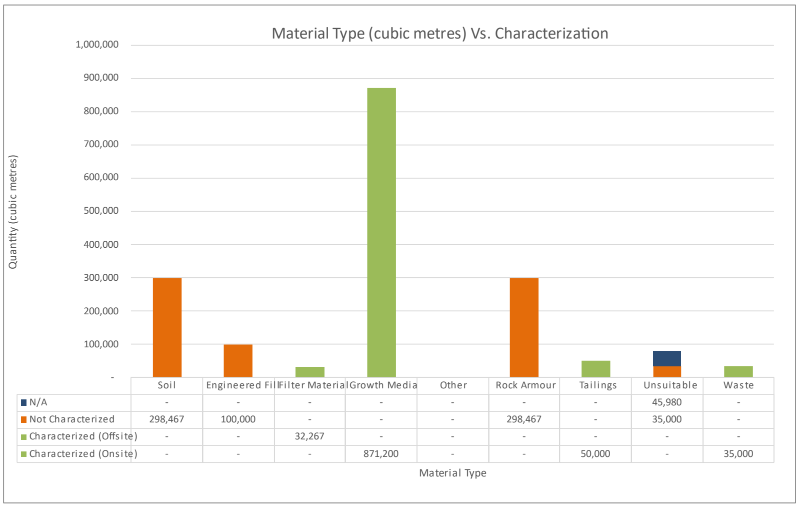
	Soil	Demolition	Engineered Fill	Filter Material	Growth Media	Other	Rock Armour	Tailings	Unsuitable	Waste	
High Contingency	2.7	-	0.7	-	-	1.6	2.7	-	0.3	-	-
Medium Contingency	-	-	-	2.1	6.4	1.4	-	-	0.4	0.2	-
Low Contingency	-	6.2	-	-	-	4.9	-	0.3	-	-	-
Contractor Direct Cost (%)	9.0%	20.8%	2.4%	7.0%	21.5%	26.4%	9.1%	0.9%	2.4%	0.6%	

Graph 2 Material type versus direct contractor cost

4.2 Material type vs. quantity

A traditional closure cost estimate model presents individual construction quantities by pay item, and it can be difficult to understand the total construction quantity of each material. **Graph 3** presents the total quantities estimated for each of the nine types of materials used for the project and identifies the three largest quantities as growth media, soil, and rock armour, all of which are associated with the cover design. Based on this graph, should the soil thickness in the cover system increase from 30 cm to 60 cm, for example, it is relatively easy to estimate that this will increase the volume of soil material in the cover system from approximately 300,000 cubic metres (m^3) to approximately 600,000 m^3. This graph also presents the level of characterization for each material, as understood and defined by the closure cost modeller. As presented in

Graph 3, Growth Media is approximately 49% of the total closure material estimate and was noted to be from an onsite source that has been adequately characterized. The Soil material represents approximately 17% of the total closure material estimate, and has been noted as not having adequate characterization, either due to geotechnical, geochemical or borrow source reasons. This lack of soil characterization will also support the high contingency for the soil material in Graph 2.

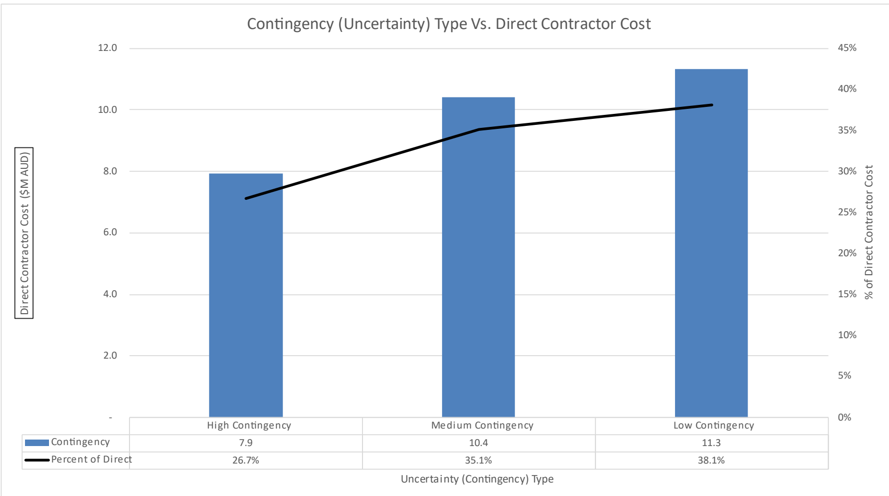


Graph 3 Material type vs. quantity

4.3 Contingency level (uncertainty) vs. direct contractor cost

Contingency is a broad term that refers to cost allowance that is assigned to the closure approach, quantities, and unit rates. From a quantity perspective, the contingency can be related to the level of confidence in the closure layouts, grading plans, and geotechnical conditions (i.e., unsuitable material that may need to be excavated or stable slope requirements). The contingency associated with the unit rates can be related to such items as haul distances, cycle times and borrow source locations, equipment types, treatment strategies, and estimating labour and equipment rates in the future.

Graph 4 presents that the closure cost modeller assigned approximately 27% of the direct contractor costs with a high contingency (+ 50%). This suggests that the closure cost model has a significant number of unknowns, and additional detail regarding the assumptions in quantities and unit rates that should be reviewed and confirmed. These results should facilitate discussions between the various contributors to the closure cost estimate as to why the level of uncertainty is as high as was selected.

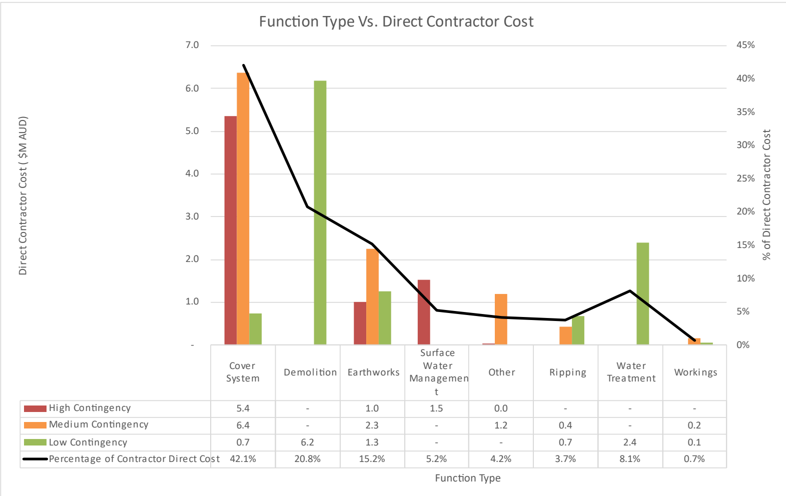


Graph 4 Contingency (uncertainty) vs. direct contractor cost

4.4 Element type vs. direct contractor cost

Graph 5 presents the eight closure elements identified for the project by direct contractor cost and level of contingency. This graph illustrates that the cover system represents approximately 42% of the direct contractor cost. It also shows that $5.4M of cover system has a high contingency (50%) assigned, $6.4M has a medium contingency (35%) assigned, and only $0.7M of the cover system has a low contingency (15%) assigned.

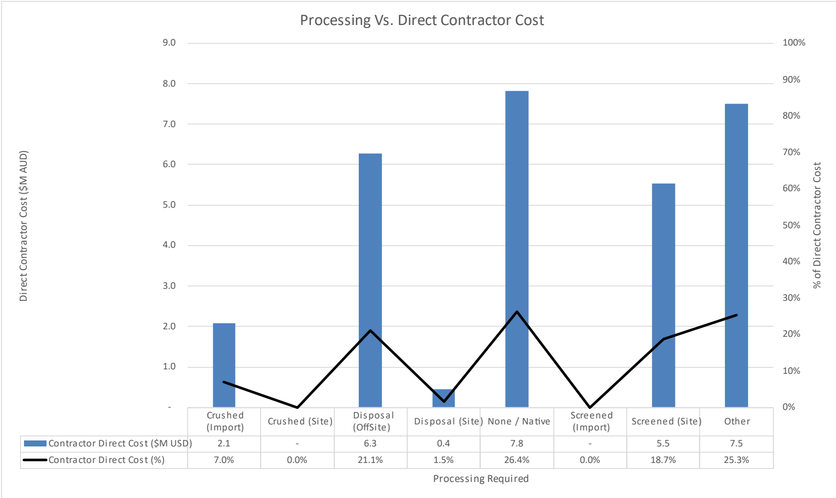
These results present three observations. The first is that the cover system is the element type with the largest direct contractor cost. The second observation is that because the cover system is mainly comprised of the growth medium, soil, and rock armour, changing the thickness of these materials (i.e., either an increase or decrease), or changing borrow source locations (i.e., haul distances) for the cover system can have a significant impact on the closure cost estimate. The third observation is that the cover system has the highest contingency applied. Similar to Section 4.4, this suggests that the cover system has a significant number of unknowns, and additional detail regarding the assumptions in quantities and unit rates that should be reviewed and confirmed. These results should facilitate discussions between the various contributors as to why the level of uncertainty is as high as was selected.



Graph 5 **Element type vs. direct contractor cost**

4.5 Processing and disposal required vs. direct contractor cost

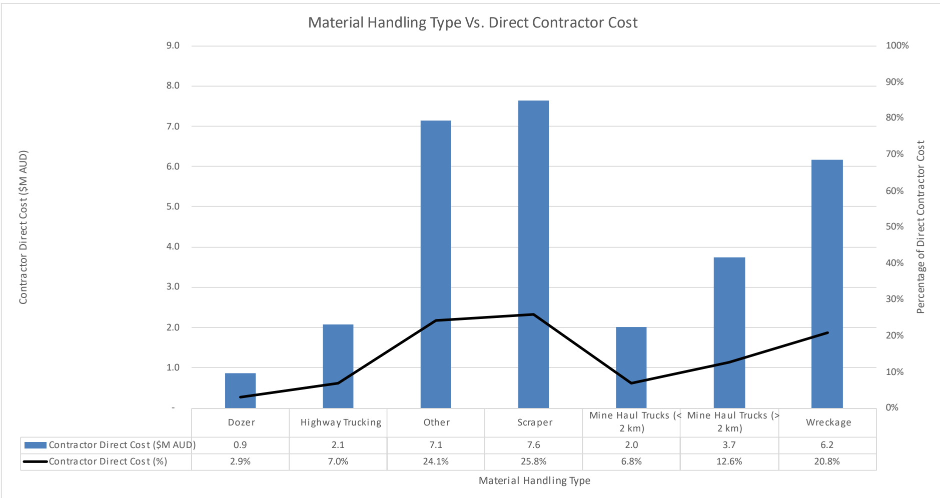
Graph 6 presents the processing and disposal costs for the various closure elements. This graph presents that approximately 26% of the direct contractor costs is native material that require no processing, approximately 19% of the direct contractor costs are based on the onsite material needing to be screened, and approximately 7% of the direct contractor costs is associated with the import of crushed material. This suggests that identifying a suitable onsite rock quarry can present a cost savings, but it would be expected to have a relatively minor impact to the closure cost model.



Graph 6 **Processing required vs. direct contractor cost**

4.6 Material handling type vs. direct contractor cost

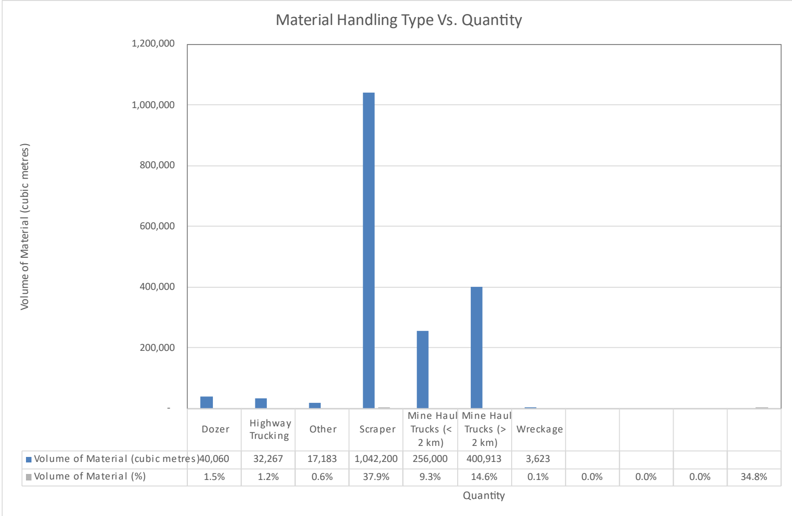
Graph 7 presents the material handling requirements for the various materials required. This graph presents that approximately 26% of the direct contractor costs assumes scrapers will be used to transport and place material, while approximately 13% of the direct contractor costs assume mine haul trucks transporting material for a distance greater than 2 km. **Graph 7** also shows that approximately 7% of the direct contractor costs would be transported using highway trucks, which corresponds to the approximately 7% of the direct contractor costs of crushed material from an offsite source.



Graph 7 **Material handling type vs. direct contractor cost**

4.7 Material handling type vs. quantity

Graph 8 presents the quantity of materials by handling type or equipment utilized. This graph presents that approximately 1 million m^3 of material is being moved via scraper, while approximately 32,000 m^3 of material are being moved via highway class trucks. These results suggest that a relatively close borrow source is available as scrapers were assumed in the closure cost model. Should the borrow source location change to be further away, scrapers may not be an efficient or feasible means of transporting material and could require mine haul trucks (an ancillary equipment, such as loaders and dozers) to transport material, which could have a significant increase in closure costs and a higher carbon footprint.

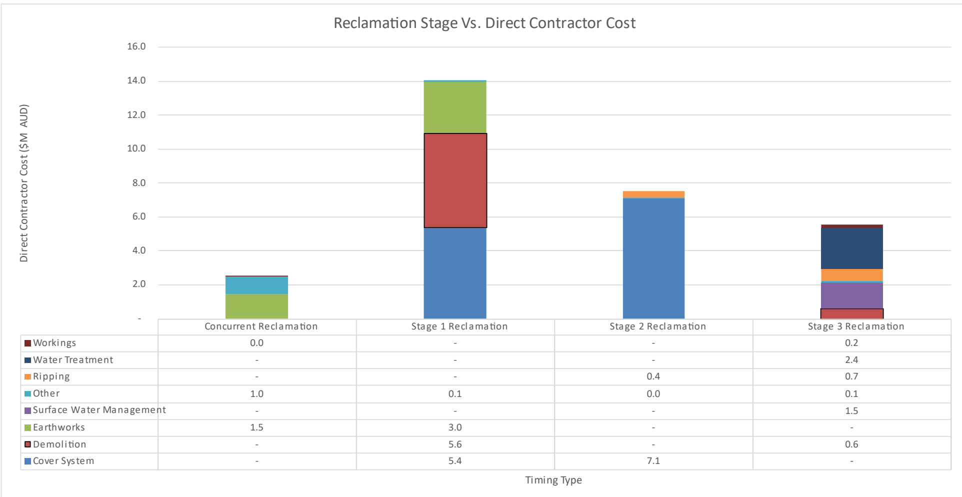


Graph 8 Material handling type vs. quantity

4.8 Closure stage vs. direct contractor cost

Graph 9 presents an estimate of the closure cost for the stages of closure defined. This suggests that there is approximately $2.5M of concurrent closure activities that can potentially be performed by the owner during operations. This does not mean that the owner can save $2.5M, rather it suggests an opportunity to (1) accelerate the closure schedule somewhat if this work was performed during operations, and (2) reduce these costs by using owner equipment during operations versus contractor equipment during reclamation.

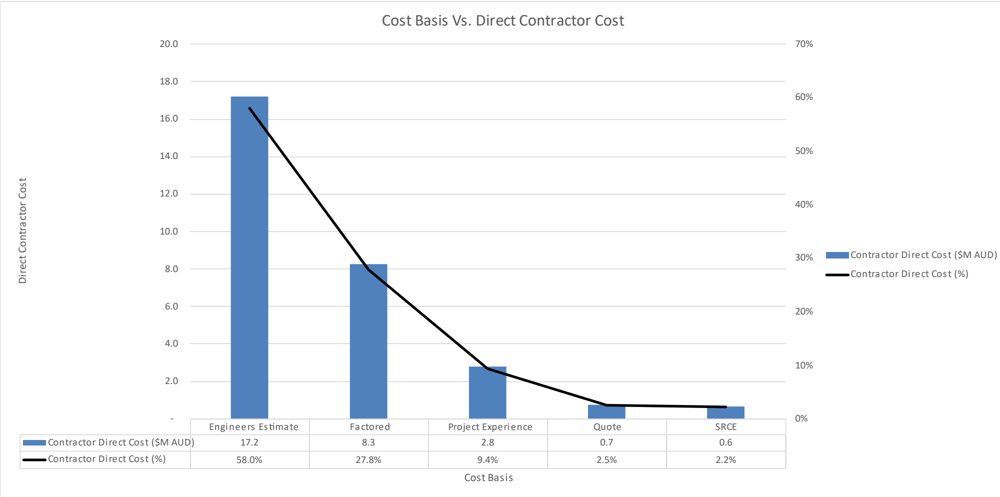
Graph 9 also identified the types of closure elements (i.e., cover placement, earthworks regrading, etc.) that were scheduled to occur at each stage in the closure plan. For example, approximately $1.5M of earthworks could be performed near the end of operations (concurrent reclamation), and the activities would be associated with the regrading of the tailings embankment slope in preparation of the overall tailings closure. As a check, these activities seem reasonable because the operator would not be able to reclaim the impoundment area of the tailings impoundment since there would be active deposition during operations.



Graph 9 Closure staging vs. direct contractor cost

4.9 Cost basis vs. direct contractor cost / % of direct contractor cost

AACE International have identified five cost estimate classifications, with corresponding methodology to support these classifications. For example, an AACE International Class 5 cost estimate is performed at a concept or screening level, and the unit rates can be based on assumptions, judgement, or similar project, while a Class 2 cost estimate is performed to support a detailed design and is based on contractor quotes. As presented in Graph 10, approximately 3% of the costs were based on quotes, while 58% was based on an engineer's estimate. This graph reinforces that the cost estimate can be used to support an AACE International Class 5 cost estimate but will not justify this same data being used to support a Class 2 or Class 3 cost estimate.



Graph 10 Cost basis vs. direct contractor cost

4.10 Summary

Both the traditional closure cost estimate and the comprehensive closure cost model presented in this paper estimated a closure cost of $42.9M, which includes $29.7M of direct contractor costs and $13.3M of contingency.

However, the comprehensive closure cost model with site-specific cost codes has identified that (1) two soil types (soil and rock armour) have the highest contingency allowance, and additional investigations should be done to reduce the contingency allowance assigned; (2) the cover materials represent the largest quantities and largest corresponding project cost, but also were assigned the highest contingency allowance, suggesting additional investigations and characterizations should be done to reduce the contingency assigned; (3) approximately 1 million m^3 of material is being moved via scraper, suggesting that relatively close borrow sources are available; (4) should the borrow source location change to be further away, scrapers may not be an efficient means of transporting material and could require mine haul trucks (in additional to an ancillary equipment, such as loaders and dozers) to transport material, which could have a significant increase in closure costs and project carbon footprint; (5) approximately 7% of the direct contractor costs are related to transporting crushed rock from an offsite source via highway trucks, which suggests the vast majority of material needed for closure has been identified as coming from an onsite borrow; and (6) there is an opportunity to perform a limited amount of concurrent reclamation activities.

5 Conclusion

It can be difficult and time consuming to (1) confirm that the narrative assumptions in the closure plan match the numerical assumptions made in a closure cost estimate, (2) review that practical construction methods and phasing have been developed in the closure plan, and (3) correlate the uncertainty in the closure plan with contingency in the closure cost model. However, by incorporating site-specific cost codes for each unit rate, additional detail on the closure cost estimate model can be developed to help the owner more quickly and simply evaluate and validate alignment with the overall closure plan approach and objectives. The presentation of the site-specific cost codes also helps identify trends or options to reduce costs or uncertainty, promote discussions between the various stakeholders, and facilitate future studies and investigations to reduce contingency (uncertainty). All of these factors ultimately contribute to an increased confidence that the closure costs are in alignment with the closure plan.

References

Association for the Advancement of Cost Engineering International (AACE International), 2021. '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.