Klohn Crippen Berger

Resolution Copper Mining LLC

Resolution Copper Project

DEIS Alternatives Failure Modes

Doc. # CCC.03-81600-EX-REP-00011 - Rev. 0

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Klohn Crippen Berger

January 23, 2019

Resolution Copper Mining LLC
P.O. Box 1944
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85273

Ms. Vicky Peacey
Senior Manager – Permitting and Approvals

Dear Ms. Peacey:

Resolution Copper Project
DEIS Alternatives Failure Modes
Doc. # CCC.03-81600-EX-REP-00011 – Rev. 0

We are pleased to provide this report regarding the Resolution Copper Project's Draft Environmental Impact Statement Tailings Storage Facility Alternatives' review of the failure modes.

Please let me know if you have any questions.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

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Associate, Project Manager

KP:dl

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TABLE OF CONTENTS

List of Figures

List of Appendices

1 INTRODUCTION

The Tonto National Forest (the Forest) is assessing tailings storage facility (TSF) alternatives to be considered and analyzed as part of the Resolution Copper Mine Plan and Land Exchange Environmental Impact Statement (EIS). As part of this undertaking, the Forest is addressing issues raised during public scoping. Specific to the issue of public safety is the completion of a "qualitative assessment of risk of failure of tailings dam and potential impacts downstream in the event of a failure.".

On December 5, 2018 in Spokane, Washington, the following groups met to discuss how to assess risk to public safety:

- The Forest;
- SWCA Environmental Consultants;
- BGC Engineering Ltd. (engineering consultant for the Forest);
- Resolution Copper Mining LLC (RCM);
- Klohn Crippen Berger Ltd. (KCB) (engineering consultant for RCM);
- Golder Associates Inc (Golder - engineering consultant for RCM); and
- Richard Davidson (AECOM) (Independent Technical Review Board member for the Resolution Copper Project tailings facility).

During the meeting it was agreed by the participants that a catastrophic failure of any of the alternatives would have unacceptable consequences due to the potential for impacts to life, environment and property. As such, all alternatives are considered high consequence structures and would be designed with appropriate criteria to manage the potential for a catastrophic failure. For example, ADEQ[1]'s Arizona Mining Guidance Manual BADCT[2] outlines that if there is a potential threat to human life, the maximum design criteria should be employed, including the Maximum Credible Earthquake (MCE) and the Probable Maximum Flood (PMF). The MCE is the largest earthquake that could reasonably be expected to occur at the site from a known seismic source and is estimated by a deterministic seismic hazard assessment. RCM has used the following assessments to define the earthquake and flood design basis:

- URS (2013) and Lettis Consultants (2017) completed a probabilistic seismic hazard assessment (PSHA) to estimate ground motions for a variety of return periods and a deterministic seismic hazard assessment (DSHA) to estimate ground motions for the MCE. The RCM TSF alternatives have been robustly designed to withstand the 10,000-year seismic event in line with international guidelines such as the Canadian Dam Association (CDA; 2007 with 2013 update)

[1] Arizona Department of Environmental Quality
[2] Best Available Demonstrated Control Technology (BADCT)

guidelines. The probabilistic 10,000-year ground motions were higher than the deterministic MCE event.

- Applied Weather Associates has created a Probable Maximum Precipitation (PMP) Evaluation Tool for Arizona, which was used as part of the PMF estimate for the TSF alternatives.

At the request of the Forest, KCB has completed a review of potential failure modes for Alternative 2, 3, 4 and 6 and summarized them in this report. Golder has completed a similar assessment for Alternative 5, Peg Leg.

Tailings dam safety is managed through comprehensive programs, discussed further in Section 2. A failure modes assessment is only one element of an overall dam safety management program that would be implemented for the RCM TSF.

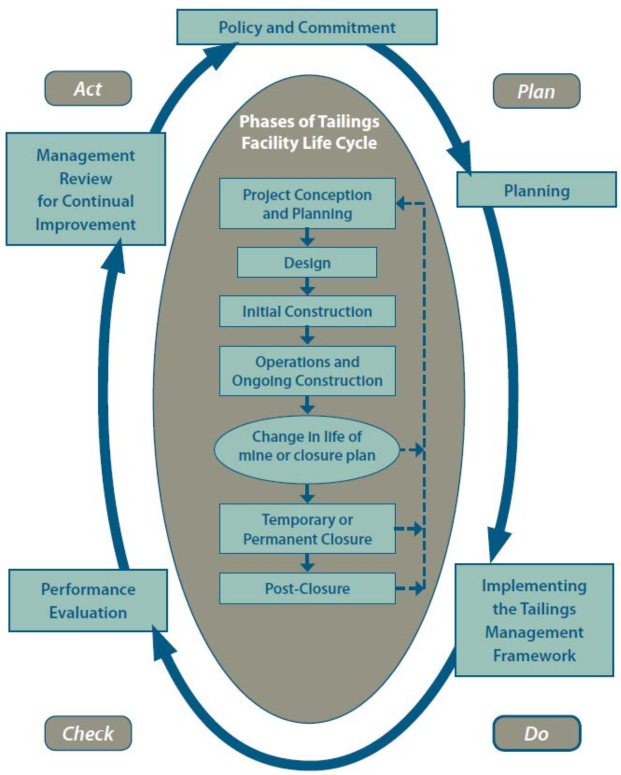
KCB has prepared an overview list of the adopted regulations and international best practices and the TSF design features that address each potential failure mode to demonstrate how the design manages risk, see Section 3.

2 DAM SAFETY MANAGEMENT

2.1 General

Dam safety of tailings facilities should be managed through a comprehensive dam safety and tailings management program implemented by the dam owners. A dam safety and tailings management program or framework should include consideration to and link: design, construction, operation, surveillance, maintenance, change and closure. The Mining Association of Canada (MAC) has produced *A Guide to the Management of Tailings Facilities* that outlines key elements of a tailings management framework, see Figure 2.1. However, there are a number of resources, including internal Rio Tinto guidance documents, that would be used when developing and maintaining a dam safety and tailings management program for the RCM TSF.

Figure 2.1 Elements of the Tailings Management Framework (MAC 2017)



2.2 Elements of Dam Safety Management

The failure mode review presented in this report represents an element of the Project Planning and Design phases of the tailings facility life cycle (see Figure 2.1). This report does not go into detail on all features of a dam safety and tailings management program; however, it is worth noting some of the other elements that would be included in RCM's TSF dam safety and tailings management program, these are introduced in the below sections.

Dam Classification, Design Criteria and TSF design

Several guidance documents are available to determine dam classification and select appropriate design criteria. ADEQ's BADCT guidance manual is used as a minimum for RCM's TSF design in Arizona. However, additional consideration has been given to guidance documents from the Federal Emergency Management Agency (FEMA), United States Army Corps of Engineers (USACE), Canadian Dam Association (CDA), the BC Ministry of Energy and Mines (BCMEM), etc.

Engineer of Record (EoR)

The Rio Tinto D5 standards require a qualified, registered Engineer of Record sign off on the design and construction of a tailings facility. Additional guidelines on the definition of an Engineer of Record and their roles and responsibilities are included in guidance documents from CDA, MAC, BCMEM, etc. Generally, the role of an EoR includes overseeing and signing off on design, construction and operation of a TSF.

Independent Review

The Rio Tinto D5 standards require independent review of the TSF design and operation of the dam for assurance. This would include Independent Technical Review Board (ITRB), third-party review, and quality assurance. Independent review starts early in the design phase and continues through construction, operations, change and closure. Dam Safety Reviews (DSRs) are recommended by CDA and MAC and would be conducted periodically throughout operations and closure.

Construction Standards and Quality Assurance/Quality Control (QA/QC)

ADEQ's BADCT guidance document and the Rio Tinto D5 standards require that there be an appropriate construction standards and a construction Quality Assurance/Quality Control (QA/QC) program. Construction specification would use industry accepted testing and verification procedures through design, investigation and construction, such as ASTM (American Society of Testing and Materials) and/or ANSI (American National Standards Institute) procedures.

Observational Method

Tailings dams differ from water dams because tailings dams are generally constructed from tailings themselves, and over a longer period of time, which may include updates in the design approach and changing conditions on site. As such, special consideration needs to be given to confirming that the TSF construction and operation meets the design assumptions. The TSF will be designed and operated using the Observational Method (Peck 1969). The Observational Method couples an informed, initial understanding of site conditions with quantitative and qualitative information gained during construction and operations to confirm design assumptions or to adjust the design as required. As such, the sensitivity of the design will be assessed based on the plausible bounds of material parameters (e.g. foundation permeability) within this design to identify which issues have the potential to significantly impact the design. Monitoring and contingency strategies will then be identified as the design progresses.

Risk Assessments

The Rio Tinto D5 standards and other guidelines (BCMEM, MAC, CDA) require a risk assessment be completed for a proposed TSF and be maintained/updated on a regular basis throughout construction, operation and closure. Risk assessments are useful to identify potential design changes, preventative controls, mitigative controls and critical controls that would be incorporated into the OMS[3], TARPs[4], EPRP[5] and the Observational Method. The framework for risk assessments is not prescriptive but a Failure Modes and Effects Assessment (FMEA) is a common approach.

Controls and Critical Controls

As part of the Observational Method, risk of failure can be managed through preventative and mitigative controls. Preventative controls are directed towards preventing a situation developing that could lead to a failure mode occurring. Mitigative controls are measures that can be implemented should there be signs that a potential failure mode could be developing or that adverse performance of the structure is developing.

Critical controls are the controls crucial to preventing an event or minimizing the consequence of the event and can be preventative or mitigative. Key indicators for a critical control also include, for example: (1) Would the absence or failure of the control significantly increase the risk despite the existence of other controls? and, (2) Does it address multiple causes or mitigate multiple consequences?

The use of critical controls would be incorporated in the operation and monitoring of a TSF.

The Mount Polley Review Panel (MPC 2015) recommended the use of Quantitative Performance Objectives (QPO). These quantitative measures that confirm the performance of the TSF is in accordance with design (e.g., tailings beach length), and could be considered similar to preventative controls.

Operations, Maintenance and Surveillance (OMS) Manual and Trigger, Action and Response Plans (TARPs)

The Rio Tinto D5 standards and other guidelines (BCMEM, MAC, CDA) require an OMS and TARPs for TSFs. An OMS would outline operational procedures, requirements for maintenance and surveillance (e.g. instrumentation) and action trigger levels associated with instrumentation. The OMS is essentially the tool for conducting the Observational Approach.

The EoR would develop the OMS's surveillance monitoring program for geotechnical stability during the design phase and update it periodically throughout construction, operations and closure. Trigger,

[3] Operations, Maintenance, Surveillance Manual
[4] Trigger, Action, Response Plans
[5] Emergency Preparedness and Response Plan

Action and Response Plans (TARPs) would be incorporated into the OMS for each geotechnical instrument or other means of monitoring.

Emergency Preparedness and Response Plan (EPRP)

The Rio Tinto D5 standards, other guidelines (BCMEM, MAC, CDA) and some jurisdictions require an EPRP. The EPRP is closely linked with the OMS and TARPs. If there is an exceedance in a threshold in the OMS, an evaluation would be completed, potentially leading to mitigation measures or the EPRP being initiated. Considerations for an EPRP include:

- Identify possible emergency situations that could occur during the initial construction, operations and ongoing construction, closure and post-closure phases of the TSF life cycle, and which could pose a risk to populations, infrastructure, and the environment;
- Describe measure to respond to emergency situations and to prevent and mitigate on and off-site environmental and safety impacts associated with emergency situations (MAC 2017); and

EPRPs are typically developed and documented by the EoR, site staff and mine management with regular reviews and updates as necessary.

Operational Plans and Change Management (e.g. tailings deposition plan, water management plan)

The design of TSF is based on a tailings deposition and water management plans and often incorporate QPOs (e.g. pond level or beach length). These should be used during operations. Operational deviations or changes to these plans should be assessed to confirm the changes do not affect the design assumptions. In particular, pond management should be monitored to confirm there is not a net gain in pond volume from year to year, resulting in not meeting storm storage design criteria, which was a recommendation from the Mount Polley Review Panel (MPC 2015).

2.3 Company Commitment

Rio Tinto and BHP Billiton are members of the International Council for Mining and Metals (ICMM), which has released a position statement on preventing catastrophic failure of TSFs (2016) that outlines the approach to governance of TSFs that its members have committed to; the six key elements of this TSF governance framework are:

- Accountability, Responsibility and Competency;
- Planning and Resourcing;
- Risk Management;
- Change Management;
- Emergency Preparedness and Response; and
- Review and Assurance.

Dr. Norbert Morgenstern, who is a member of the RCM external Independent Technical Review Board (ITRB), gave the Victor De Mello lecture in Brazil on August 30, 2018. During this lecture he presented his recommended framework: Performance-Based, Risk-Informed Safe Design, Construction, Operation, and Closure (PBRISD). In the accompanying paper, Dr. Morgenstern outlines stages of design, construction, operation and closure and key elements that should be included in each stage. RCM has already incorporated elements of this framework into their tailings framework approach and will continue to use his paper and his external review as guidance.

3 POTENTIAL FAILURE MODES

3.1 Failure Modes

The typical failure modes for tailings facilities that have been reviewed for the TSF alternatives are based on the Canadian Dam Association (CDA) Dam Safety Guidelines (2007, 2013) and are further described in this section.

Failure through Foundation

The most recent examples of foundation failure include Mt. Polley (2014) in Canada, and Aznalcollar (Los Frailes) in Spain (1994). The risk of a foundation failure increases in complex geologic formations, particularly in materials that could include weak clay layers (e.g. glacial geology at Mt. Polley), or weak bedding planes (e.g. claystone layers within the mudstone, sandstone sequences at Aznalcollar). Lightly consolidated clays and desiccated residual clay soils are sensitive to the height of the tailings dam and may become normally consolidated as tailing dams increase beyond 30 m to 40 m high. Soil behavior changes significantly once the past pre-consolidation stress is exceeded, and the soil becomes normally consolidated, exacerbating pore pressure rises and result in the potential for progressive failures**. Note, these conditions have not been encountered at any of the RCM TSF alternative sites.** Loose granular soils are sensitive to static and cyclic liquefaction. Preventative controls include design (e.g. removal or shear keys), site investigations and monitoring (pore pressure and deformations). Mitigative controls include flatter dam slopes and moving the water pond away from the dam.

Slope Failure through Tailings

Slope failures through tailings are often caused by loss of strength in the tailings or the tailings dam. They are often associated with upstream tailings dams with the most recent example of Fundão in Brazil (2015). Failures through the tailings are typically caused by increased pore pressures (above design allowances) within the tailings leading to strength reduction or liquefaction. These could happen during static or seismic conditions. It is also possible to trigger liquefaction through other mechanisms, such as deformation, that can affect the stresses in the tailings. Centerline and downstream dams are normally constructed with QA/QC procedures typical of conventional earth and rockfill dams to confirm density requirements and are less susceptible to this failure mode.

Preventative controls include: design, QA/QC, in situ testing for upstream dams, and pore pressure and deformation monitoring. Mitigative controls include flatter dam slopes or berms, and moving the water pond away from the dam.

Internal Erosion/Piping

Internal erosion or piping is a process by which fine particles are washed out of the facility or its foundation, developing a preferential flow path, and potentially voids, through which fluid (and suspended tailings) can flow at an accelerated rate, potentially destabilizing the structure. The absence of sufficient filters to control movement of particles can lead to failure of the dam. The Omai

(1992) piping failure, in Guyana, occurred when the water pond was against the face of the downstream constructed dam, and the filter between the clay core and the rockfill shell was not sufficient to prevent piping of fines out of the core, and as a result the dam failed.

Piping failure of tailings dams is less common than for conventional water dams as the tailings can play a significant role in reducing the hydraulic gradients (long tailings beaches). Preventative controls include: dam zonation, design of filters and QA/QC of construction. Mitigative controls include: placement of inverted filters over the downstream slope to stop further loss of fine particles. Other controls include movement of the pond away from the dam and reduced spigotting in the areas of potential piping development as measures to reduce hydraulic gradients.

Overtopping

This failure mode occurs when free water accumulates within the pond, and the pond level subsequently rises above the dam crest and begins to flow over the downstream slope. A breach forms as the slope face is progressively eroded, resulting in some fraction of the impoundment contents being released.

Tailings facilities commonly store a design flood event and underestimation of the design conditions or selection of inadequate criteria can lead to overtopping and failure of the dam. Baie Mare (2000) in Romania, is an example of overtopping due to rain on snow event, common in cold temperate climates. Merriespruit (1994), in South Africa, is an example of inadequate freeboard.

Preventative controls: include design (e.g. minimum pond storage requirements, armoring/erosion protection of the downstream slope), water level monitoring and maintenance of storage availability and freeboard. Mitigative controls include: for example, construction of emergency spillways, pumping, emergency dam raising.

Surface Erosion

Surface erosion-related failures of tailings dams are less common than the previous failure modes discussed. Surface erosion could be a contributing factor leading to a breach through slope instability if the erosion is sufficient to oversteepen the slope rather than leading to a breach directly.

Normal operations typically include repair of erosion channels and control of surface water runoff to manage this mechanism. However, under extreme events the rate of erosion may be sufficient to destabilize the dam. The dam could be particularly vulnerable to this mechanism if a surface stream is near the toe of the dam or if the dam materials are highly erodible. Preventative controls include: design and placement of riprap and other erosion protection materials and regular maintenance. Mitigative controls include: emergency repairs of eroded materials.

3.2 RCM Design Controls

RCM has adopted the following controls for the potential failure modes as part of the TSF designs. The review of failure modes for each of the TSF alternatives are included in Appendix I. The alternative Design Basis Memorandums (DBMs), with more details on design criteria and standards, regulations and guidance documents are included in Appendix II.

Failure through Foundation

- Design to meet minimum factor of safety (FOS).
- Site investigations to characterize foundation adequately.
- Minimum downstream dam slopes of the TSF.
- Shear key(s) installed or embankment slopes flattened in areas with potentially weak foundation units.
- Long tailings beaches included in the QPOs.
- Instrumentation installed in the foundation during construction and operations to monitor deformations and phreatic conditions.

Slope Failure through Tailings

- Embankment constructed from compacted cycloned sand or filtered tailings. Liquefaction risk of the cycloned sand will be controlled through both compaction and drainage.
- Well-drained cycloned sand embankment and underdrains reduce pore pressures in the embankment which increases resistant forces in tailings.
- Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.
- Long tailings beaches reduce pore pressures in the embankment. Long beaches may also reduce consequence of slope failure since the embankment would not be breached by the pond.
- Instrumentation installed in the embankment during construction and operations to monitor deformations and pore pressures.

Internal Erosion/Piping

- Long tailings beaches and underdrainage prevent phreatic surface build-up in the embankment.
- Drains to be designed to prevent piping of tailings into drain and filter zones.
- Cycloned sand or filtered tailings in the embankment is internally stable; no embankment drain or filter zones required.
- Visual monitoring and instrumentation installed in the embankment and foundation during construction and operations to monitor seepage and pore pressures.

Overtopping

- Divert as much of the upstream catchment as practical.
- TSF alternatives (Alternative 2, 3, and 6) are designed to store normal operating pond, upset conditions and the Inflow Design Flood (IDF) (72-hour Probable Maximum Flood (PMF)) with adequate freeboard and assuming failure of upstream diversions during operations.
- TSF alternatives (Alternative 2, 3, and 6) are designed to route the IDF through spillways post-closure. Alternative 4 is configured to pass the IDF safely.
- Water level monitoring instruments installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk.

Surface Erosion

- Upstream diversion ditches designed to route the PMF from the upstream non-contact water catchment away from the TSF.
- External slopes progressively reclaimed with adequate covers as soon as practical during operations to minimize erosion.
- Closure spillways and diversions constructed to route water off and away from external slopes.
- Routine visual monitoring or erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.

4 CONCLUSION

A catastrophic failure of any of the alternatives would have unacceptable consequences due to the potential for impacts to life, environment and property. As such, all alternatives are considered high consequence structures and would be designed, constructed, operated and closed to manage the risk. Tailings dam safety risks are managed through comprehensive dam safety and tailings management programs. RCM has adopted regulations and international best practices for the TSF designs and has addressed potential failure modes through design features and would do the same for construction, operations and closure practices.

The failure modes presented in this report will be used by the Forest to help complete the qualitative assessment of risk of failure of tailings dam and potential impacts downstream in the event of a failure.

Design is one element in the dam safety and tailings management program. RCM will incorporate the elements described in Section 2.2 during through the design, construction, operation, change and closure phases to manage the TSF dam safety risks.

5 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Resolution Copper Mining LLC (Client) for the specific application to the Resolution Copper Project. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavored to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

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APPENDIX I

Failures Modes Tables

Table I-1 - Failure Mode Review for Alternative 2 - Near West Modified Proposed Action (Modified Centerline Embankment - "wet")

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					Tailings Storage Facility			
2.01	Slope Failure – Static, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Minimum beach length	**Design features to meet design criteria:** - Shear key(s) installed or embankment slopes flattened in areas with potentially weak foundation units; presence and extent to be confirmed in future site investigations. DEIS design assumes a shear key is required in the entire SE Design Sector. - Modified centerline raised embankment constructed from compacted cycloned sand with 4H:1V exterior slope provides resistance against a global foundation failure. - Well-drained cycloned sand embankment and underdrains reduce pore pressures in the foundation below the exterior slope. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. - Long tailings beaches reduce pore pressures in the foundation below the exterior slope and within the embankment. Long beaches also reduce consequence of slope failure since the embankment would not be breached by the pond. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	PAG tailings to be deposited within NPAG impoundment	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
2.02	Slope Failure – Static, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Minimum beach length	**Design features to meet design criteria:** - Embankment constructed from compacted cycloned sand. Liquefaction risk of the cycloned sand will be controlled through both compaction and drainage. - Well-drained cycloned sand embankment and underdrains reduce pore pressures in the embankment which increases overall stability. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. - Long tailings beaches reduce pore pressures in the embankment. Long beaches may also reduce consequence of slope failure since the embankment would not be breached by the pond. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Measurements may indicate impending instability. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	PAG tailings to be deposited within NPAG impoundment	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
2.03	Slope Failure – Earthquake, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (MDE - 1 in 10,000-year return period) - Minimum beach length	- As Failure Mode 2.01, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Instrumentation and routine monitoring are not capable of monitoring for impending earthquakes.	PAG tailings to be deposited within NPAG impoundment	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
2.04	Slope Failure – Earthquake, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (MCE) - Minimum beach length	- As Failure Mode 2.02, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Instrumentation and routine monitoring are not capable of monitoring for impending earthquakes.	PAG tailings to be deposited within NPAG impoundment	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
2.05	Internal Erosion/Piping	- USACE (2004)	- 1.12 - 1.14	- Minimum beach length - Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Thickening tailings slurry to reduce water entering the impoundment. - Long tailings beaches and underdrainage prevent seepage and pore pressure buildup in the embankment. - Drains to be designed to prevent piping of tailings into drain and filter zones. - Cycloned sand in the embankment is internally stable; no embankment drain or filter zones required. **Operational/monitoring features to confirm design assumptions:** - Visual monitoring and instrumentation installed in the embankment and foundation during construction and operations to monitor seepage and pore pressures. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm if seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	See NPAG	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 8 - Appendix I
2.06	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 1.07 - 1.08 - 1.09 - 1.10 - 1.11 - 1.12	- Pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum beach length	**Design features to meet design criteria:** - Impoundment designed to store normal operating pond, upset conditions and the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. - Impoundment designed to route the IDF through spillways post-closure. - Portions of the foundation with potential underground mine workings (e.g. Bomboy Mine; West Design Sector) or potentially collapsible rock types (e.g. limestone) to be treated to prevent collapse (i.e. excavation/backfill, lining, grouting). **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	See NPAG	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6 - Section 6 - Section 7 - Section 11 - Appendix I - Appendix IV
2.07	Surface Erosion	- BADCT (ADEQ 2005)	-1.18	- Criteria for protecting TSF from flood erosion	**Design features to meet design criteria:** - Upstream diversion ditches designed to route the Probable Maximum Flood (PMF) from the upstream non-contact water catchment away from the TSF. - Embankment slopes progressively reclaimed with adequate covers as soon as practical during operations to minimize erosion. - Closure spillways and diversions constructed to route water off and away from embankment slopes. **Operational/monitoring features to confirm design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.	PAG tailings to be deposited within NPAG impoundment	D - Combination of Design and Operating (A&C) Review Processes	- Section 7 - Section 11 - Appendix I

Table I-1 - Failure Mode Review for Alternative 2 - Near West Modified Proposed Action (Modified Centerline Embankment - "wet")

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					Seepage Collection Dams			
2.08	Slope Failure – Static, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Loose alluvium under dam footprint, if present, would be excavated or design would include shear key(s) or embankment slope flattening in areas with potentially weak foundation units. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and lined pond reduces pore pressures in the foundation below dam. - Compacted earthfill dams with 3H:1V side slopes provide resistance against a global foundation failure. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and pore pressures. Monitoring to confirm conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
2.09	Slope Failure – Static, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and lined pond reduces pore pressures in the foundation below dam. - Compacted earthfill dams with 3H:1V side slopes provide resistance against a global slope failure. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
2.10	Slope Failure – Earthquake, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 2.08, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
2.11	Slope Failure – Earthquake, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 2.09, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
2.12	Internal Erosion/Piping	- A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005) - USACE (2004)	- 2.06 - 2.12 - 2.13	- Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Seepage collection ponds are lined, and would include filter zones where required. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor phreatic conditions. Also, seepage will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
2.13	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 2.06 - 2.07 - 2.08 - 2.09 - 2.10 - 2.11	- Normal operating pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum outlet discharge flow rate	**Design features to meet design criteria:** - Sump pumps, including redundancy, used to maintain a minimal pond volume during operations. - Pumps sized to remove floods during duration outlined in design criteria. - Pond designed to store normal operating pond, upset conditions and the Environmental Design Flood (EDF). Spillway to safely pass the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 11 - Appendix I - Appendix III
2.14	Surface Erosion	- A.A.C. R12-15-1216 - BADCT (ADEQ 2005)	- 2.15 - 2.16	- Criteria for protecting dam from flood erosio	**Design features to meet design criteria:** - Erosion protection on upstream and downstream slopes for design flood events. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 8 - Section 10 - Appendix I

Acronyms:

Organizations, Standards and Guidelines

A.A.C. R12-15	Title 12, Chap 15 Arizona Administrative code - Dept of Water Resources
ADEQ	Arizona Department of Environmental Quality
BADCT	Best Available Demonstrated Control Technology
BC MEM	British Columbia Ministry of Energy and Mines
CDA	Canadian Dam Association
EoR	Engineer of Record
ICMM	International Council on Mining and Metals (ICMM)
ICOLD	International Committee on Large Dams (ICOLD)
ITRB	Independent Technical Review Board
MAC	Mining Association of Canada
MEND	Mine Environment Neutral Drainage Program
RT D5	Rio Tinto D5 Standard - Tailings and Water Storage Facilities
USACE	United States Army Corps of Engineers

Environmental

NPAG	Non-potentially Acid Generating
PAG	Potentially Acid Generating

Assurance:

D / P	Design and Permitting
Op	Operations
Close	Closure
Op / Close	Ops & Closure

Assurance Review Processes:

A - Design Review Process:	Review by ITRB, EIS Consultant, Federal Regulatory Agency, State Regulatory Agency & EoR sign off
B - Construction Quality Assurance	Review by independent quality control and assurance contractors
C - Operating Review Process:	Confirmation that the OMS manual remains applicable and is being followed. Accomplished by Owner documentation / records, EoR review of monitoring and operations, and ITRB review.
D - Combination of Design and Operating review (A&C)	A combinations of the above design and operating review processes

Table I-2 - Failure Mode Review for Alternative 3 - Near West Modified Proposed Action (Modified Centerline Embankment - "dry")

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures: NPAG	Defensive Design and Operational Measures: PAG	Assurance Process	DEIS Design Report Section/ Appendix Reference
					Tailings Storage Facility			
3.01	Slope Failure – Static, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Minimum beach length	**Design features to meet design criteria:** - Shear key(s) installed or embankment slopes flattened in areas with potentially weak foundation units, DEIS design assumes a shear key is required in the entire SE Design Sector. - Modified centerline raised embankment constructed from compacted cycloned sand with 4H:1V exterior slope provides resistance against a global foundation failure. - Well-drained cycloned sand embankment and underdrains reduce pore pressures in the foundation below the exterior slope. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. - Long tailings beaches reduce pore pressures in the foundation below the exterior slope and within the embankment. Long beaches also reduce consequence of slope failure since the embankment would not be breached by the pond. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Site investigation results do not indicate that there are any potentially liquefiable or weak layer present in splitter berm area. Shear key(s) or embankment slopes flattened to be included if required. - Pyrite (PAG) cell abutted by scavenger (NPAG) tailings beach, decreasing likelihood of failure through foundation. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Measurements may indicate impending instability. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 7 - Appendix I
3.02	Slope Failure – Static, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Minimum beach length	**Design features to meet design criteria:** - Embankment constructed from compacted cycloned sand. Liquefaction risk of the cycloned sand will be controlled through both compaction and drainage. - Well-drained cycloned sand embankment and underdrains reduce pore pressures in the embankment which increases overall stability. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism . - Long tailings beaches reduce pore pressures in the embankment. Long beaches also may reduce consequence of slope failure since the embankment would not be breached by the pond. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Measurements may indicate impending instability. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Splitter berm constructed from compacted cycloned sand. Liquefaction risk of the cycloned sand will be controlled through both compaction and drainage. Pyrite (PAG) cell splitter berm abutted by scavenger (NPAG) tailings beach. - Raising schedule would limit the height of the splitter berm above the scavenger (NPAG) beach, assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Measurements may indicate impending instability. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 7 - Appendix I
3.03	Slope Failure – Earthquake, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (MDE - 1 in 10,000-year return period) - Minimum beach length	- As Failure Mode 3.01, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Instrumentation and routine monitoring are not capable of monitoring for impending earthquakes.	- As Failure Mode 3.01, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Instrumentation and routine monitoring are not capable of monitoring for impending earthquakes.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 7 - Appendix I
3.04	Slope Failure – Earthquake, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (MCE) - Minimum beach length	- As Failure Mode 3.02, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Instrumentation and routine monitoring are not capable of monitoring for impending earthquakes.	- As Failure Mode 3.02, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Instrumentation and routine monitoring are not capable of monitoring for impending earthquakes.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 7 - Appendix I
3.05	Internal Erosion/Piping	- USACE (2004)	- 1.12 - 1.14	- Minimum beach length - Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Additional thickening of tailings slurry to reduce water entering the impoundment (thickening to 68% removes a significant portion of the water). - Long tailings beaches and underdrainage prevent seepage and pore pressure buildup in the embankment. - Drains designed to prevent piping of tailings into drain and filter zones. - Cycloned sand in the embankment is internally stable; no embankment drain or filter zones. **Operational/monitoring features to confirm design assumptions:** - Visual monitoring and instrumentation installed in the embankment and foundation during construction and operations to monitor phreatic conditions. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm if seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Pyrite (PAG) cell is lined. - Cycloned sand splitter berm is internally stable. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the splitter berm and foundation during construction and operations to monitor phreatic conditions. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm if seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 7 - Section 8 - Appendix I
3.06	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 1.07 - 1.08 - 1.09 - 1.10 - 1.11 - 1.12	- Pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum beach length	**Design features to meet design criteria:** - Impoundment designed to store normal operating pond, upset conditions and the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. - Impoundment designed to route the IDF through spillways post-closure. - Portions of the foundation with potential underground mine workings (e.g. Bomboy Mine; West Design Sector) or potentially collapsible rock types (e.g. limestone) to be treated to prevent collapse resulting in loss of the crest and overtopping. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Pyrite (PAG) tailings cell designed to store normal operating pond, upset conditions and the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance). - Pyrite (PAG) tailings cell encapsulated by scavenger (NPAG) tailings post-closure, surface drains to closure spillway that is designed to route the IDF. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6 - Section 6 - Section 7 - Section 11 - Appendix I - Appendix III
3.07	Surface Erosion	- BADCT (ADEQ 2005)	-1.18	- Criteria for protecting TSF from flood erosion	**Design features to meet design criteria:** - Upstream diversion ditches designed to route the Probable Maximum Flood (PMF) from the upstream non-contact water catchment away from the TSF. - Embankment slopes progressively reclaimed with adequate covers as soon as practical during operations to minimize erosion. - Closure spillways and diversions constructed to route water off and away from embankment slopes. **Operational/monitoring features to confirm design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.	**Design features to meet design criteria:** - Suspended eroded tailings caused by storm events would settle in reclaim pond. - Splitter berms slopes progressively covered by scavenger (NPAG) beach, completely covered post-closure. **Operational/monitoring features to confirm design assumptions:** - Routine visual monitoring or erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns	D - Combination of Design and Operating (A&C) Review Processes	- Section 7 - Section 11 - Appendix I

Table I-2 - Failure Mode Review for Alternative 3 - Near West Modified Proposed Action (Modified Centerline Embankment - "dry")

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					Seepage Collection Dams			
3.08	Slope Failure – Static, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Loose alluvium under dam footprint, if present, would be excavated or design would include shear key(s) or embankment slope flattening in areas with potentially weak foundation units. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and lined pond reduces pore pressures in the foundation below dam. - Compacted earthfill dams with 3H:1V side slopes provide resistance against a global foundation failure. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and pore pressures. Monitoring to confirm conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
3.09	Slope Failure – Static, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and lined pond reduces pore pressures in the foundation below dam. - Compacted earthfill dams with 3H:1V side slopes provide resistance against a global slope failure. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
3.10	Slope Failure – Earthquake, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 3.08, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
3.11	Slope Failure – Earthquake, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 3.09, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
3.12	Internal Erosion/Piping	- A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005) - USACE (2004)	- 2.06 - 2.12 - 2.13	- Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Seepage collection ponds are lined, and would include filter zones where required. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor phreatic conditions. Also, seepage will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
3.13	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 2.06 - 2.07 - 2.08 - 2.09 - 2.10 - 2.11	- Normal operating pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum outlet discharge flow rate	**Design features to meet design criteria:** - Sump pumps, including redundancy, used to maintain a minimal pond volume during operations. - Pumps sized to remove floods during duration outlined in design criteria. - Pond designed to store normal operating pond, upset conditions and the Environmental Design Flood (EDF). Spillway to safely pass the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 7 - Section 11 - Appendix I - Appendix III
3.14	Surface Erosion	- A.A.C. R12-15-1216 - BADCT (ADEQ 2005)	- 2.15 - 2.16	- Criteria for protecting dam from flood erosion	**Design features to meet design criteria:** - Erosion protection on upstream and downstream slopes for design flood events. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 8 - Section 10 - Appendix I

Acronyms:

Organizations, Standards and Guidelines

A.A.C. R12-15 Title 12, Chap 15 Arizona Administrative code - Dept of Water Resources
ADEQ Arizona Department of Environmental Quality
BADCT Best Available Demonstrated Control Technology
BC MEM British Columbia Ministry of Energy and Mines
CDA Canadian Dam Association
EoR Engineer of Record
ICMM International Council on Mining and Metals (ICMM)
ICOLD International Committee on Large Dams (ICOLD)
ITRB Independent Technical Review Board
MAC Mining Association of Canada
MEND Mine Environment Neutral Drainage Program
RT D5 Rio Tinto D5 Standard - Tailings and Water Storage Facilities
USACE United States Army Corps of Engineers

Environmental

NPAG Non-potentially Acid Generating
PAG Potentially Acid Generating

Assurance:

D / P Design and Permitting
Op Operations
Close Closure
Op / Close Ops & Closure

Assurance Review Processes:

A - Design Review Process: Review by ITRB, EIS Consultant, Federal Regulatory Agency, State Regulatory Agency & EoR sign off
B - Construction Quality Assurance Review by independent quality control and assurance contractors
C - Operating Review Process: Confirmation that the OMS manual remains applicable and is being followed. Accomplished by Owner documentation / records, EoR review of monitoring and operations, and ITRB review.
D - Combination of Design and Operating review (A&C) A combinations of the above design and operating review processes

Table I-3 - Failure Mode Review for Alternative 4 - Silver King Filtered

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					Tailings Storage Facilities			
4.01	Slope Failure – Static, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.07 - 1.10 - Table 3.1, 6.02	- Steepest allowable slope - Minimum FoS for analysis scenarios - Filter plant target moisture content - Storm water management on slope	**Design features to meet design criteria:** - Shear key(s) or pile slope flattened in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Modified centerline raised structural zone constructed from compacted filtered tailings with 3H:1V exterior slope provides resistance against a global foundation failure. - No permanent ponded water on tailings surface during operations or post-closure reducing the phreatic surface within the tailings and foundation, enhancing stability and reducing consequences of potential failure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the structural zone and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2, 5.3 - Section 6 - Appendix I
4.02	Slope Failure – Static, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.07 - 1.10 - Table 3.1, 6.02	- Steepest allowable slope - Minimum FoS for analysis scenarios - Filter plant target moisture content - Storm water management on slope	**Design features to meet design criteria:** - Shear key(s) or pile slope flattened in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - No permanent ponded water on tailings surface during operations or post-closure reducing the phreatic surface within the tailings, enhancing stability and reducing consequences of potential failure. - Liquefaction risk of the tailings will be controlled through dewatering the tailings and compaction at a 3H:1V exterior slope. - Structural zone sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pile during construction and operations to monitor deformations and phreatic conditions. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2, 5.3 - Section 6 - Appendix I
4.03	Slope Failure – Earthquake, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.07 - 1.10 - Table 3.1, 6.02	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake) - Filter plant target moisture content - Storm water management on slope	- As Failure Mode 4.01, with the following additions or modifications: - Structural zone sized to meet pseudo-static design criteria. - Structural zone sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.		D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2, 5.3 - Section 6 - Appendix I
4.04	Slope Failure – Earthquake, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.07 - 1.10 - Table 3.1, 6.02	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake) - Filter plant target moisture content - Storm water management on slope	- As Failure Mode 4.02, with the following additions or modifications: - Structural zone sized to meet pseudo-static design criteria. - Structural zone sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.		D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2, 5.3 - Section 6 - Appendix I
4.05	Internal Erosion/Piping	- USACE (2004)	- 1.07 - 1.08 - 1.09	- Do not use tailings facilities as water storage - Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Dewatering tailings prior to placement in the impoundment. - No permanent ponded water on tailings surface during operations and post-closure reduces potential for internal erosion and piping. - Filters for underdrains. **Operational/monitoring features to meet design assumptions:** - Visual monitoring and instrumentation installed on tailings surface to monitor pond levels during storm events with backup pumps on the surface. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 5.3 - Section 6 - Section 7 - Appendix I
4.06	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 1.07 - 1.10	- Inflow design flood (IDF) - "Dry" freeboard - Minimum beach length	**Design features to meet design criteria:** - Foundation characterization and design updates to limit potential for dissolution failure leading to loss of the crest and overtopping. - Tailings surface is slopes and designed to route the Inflow Design Flood (IDF) (Probable Maximum Precipitation (PMP)) with adequate freeboard adequate freeboard (including wind and wave runup allowance) safely during operations and closure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed and monitoring on tailings surface to monitor pond levels and volume accumulation not considered in design assumptions during storm events that may lead to overtopping risk. Backup pumps on the surface would also be installed. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Appendix I - Appendix III
4.07	Surface Erosion	- BADCT (ADEQ 2005)	-1.13	- Criteria for protecting TSF from flood erosion	**Design features to meet design criteria:** - Upstream diversion structures (dams, ditches, tunnels) designed to route the Probable Maximum Flood (PMF) from the upstream non-contact water catchment away from the tailings piles. - Tailings piles would be shaped to route precipitation off the surface, but would have a settling pond prior to discharging into collection ditches. - Tailings pile exterior slopes would be progressively reclaimed with adequate covers as soon as practical during operations to minimize erosion. - Potentially require temporary covers or measures for erosion protection. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 8 - Section 10 - Appendix I

Table I-3 - Failure Mode Review for Alternative 4 - Silver King Filtered

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					External Contact Water Collection Dams			
4.08	Slope Failure – Static, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Loose alluvium under dam footprint, if present, would be excavated or design would include shear key(s) or embankment slope flattening in areas with potentially weak foundation units. - Earthfill, downstream constructed dams with 2.5H:1V side slopes provide resistance against a global foundation failure. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and geomembrane lined pond reduces pore pressures in the foundation below dam. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Appendix I
4.09	Slope Failure – Static, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Earthfill, downstream constructed dams with 2.5H:1V side slopes provide resistance against failure through dam. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and geomembraned lined pond enhances stability. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Appendix I
4.10	Slope Failure – Earthquake, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.03 - 2.04 - 2.05 - 2.06	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 4.08, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Appendix I
4.11	Slope Failure – Earthquake, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.03 - 2.04 - 2.05 - 2.06	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 4.09, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Appendix I
4.12	Internal Erosion/Piping	- A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005) - USACE (2004)	- 2.13 - 2.14	- Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Ponds are lined, and would include filter zones where required. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor phreatic conditions. Also, seepage will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
4.13	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007) - USACE (2002)	- 2.07 - 2.08 - 2.09 - 2.10 - 2.11 - 2.12	- Normal operating pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum outlet discharge flow rate	**Design features to meet design criteria:** - Sump pumps, including redundancy, used to maintain a minimal pond volume during operations. - Pumps sized to remove floods during duration outlined in design criteria. - Pond designed to store normal operating pond, upset conditions and the Environmental Design Flood (EDF). Spillway to safely pass the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 10 - Appendix I - Appendix III
4.14	Surface Erosion	- A.A.C. R12-15-1216 - BADCT (ADEQ 2005)	- 2.16 - 2.17	- Criteria for protecting dam from flood erosion	**Design features to meet design criteria:** - Erosion protection on upstream and downstream slopes for design flood events. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 10 - Appendix I

Table I-3 - Failure Mode Review for Alternative 4 - Silver King Filtered

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					Non-contact Water Upstream Diversion Dams			
4.15	Slope Failure – Static, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 3.03 - 3.04 - 3.05	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Loose alluvium under dam footprint, if present, would be excavated shear key(s) or embankment slope flattening in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Earthfill, downstream constructed dams with 2.5H:1V side slopes provide resistance against a global foundation failure. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and geomembraned lined pond reduces pore pressures in the foundation below dam. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
4.16	Slope Failure – Static, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 3.03 - 3.04 - 3.05	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Loose alluvium under dam footprint, if present, would be excavated shear key(s) or embankment slope flattening in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Earthfill, downstream constructed dams with 2.5H:1V side slopes provide resistance against failure through dam. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and geomembraned lined pond enhances stability. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
4.17	Slope Failure – Earthquake, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 3.03 - 3.04 - 3.05 - 3.06	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 6.08, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
4.18	Slope Failure – Earthquake, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 3.03 - 3.04 - 3.05 - 3.06	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 6.09, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
4.19	Internal Erosion/Piping	- A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005) - USACE (2004)	not specified in DBM, would have similar approach to contact water collection ponds	- Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Further site investigations and characterizations to be completed to further design. Design updates may include filter zones, foundation grouting, low permeability blanket upstream of the dam and/or a water management plan updates to limit ponded water near potential dissolution features. **Operational/monitoring features to meet design assumptions:** - Visual monitoring and instrumentation installed in the dam and foundation during construction and operations to monitor phreatic conditions. Also, seepage will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
4.20	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007) - USACE (2002)	- 3.07 - 3.08 - 3.09	- Normal operating pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum outlet discharge flow rate	**Design features to meet design criteria:** - Foundation characterization and design updates to limit potential for dissolution failure leading to loss of the crest and overtopping. - Sump pump used to maintain a minimal pond volume during operations. - Pump sized to remove floods during duration outlined in design criteria. - Pond designed to store normal operating pond, upset conditions and the Environmental Design Flood (EDF). Spillway to safely pass the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 10 - Appendix I
4.21	Surface Erosion	- A.A.C. R12-15-1216 - BADCT (ADEQ 2005)	not specified in DBM, would have similar approach to contact water collection ponds	- Criteria for protecting dam from flood erosion	**Design features to meet design criteria:** - Erosion protection on upstream and downstream slopes for design flood events. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Appendix I

Table I-3 - Failure Mode Review for Alternative 4 - Silver King Filtered

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures (NPAG / PAG)	Assurance Process	DEIS Design Report Section/ Appendix Reference
					Emergency Slurry Tailings Storage Facilities		
4.22	Slope Failure – Static, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	not specified in DBM, would have similar approach to other slurry TSFs (e.g. Alternative 2)	- Steepest allowable slope - Minimum FoS for analysis scenarios - Filter plant target moisture content - Storm water management on slope	**Design features to meet design criteria:** - Excavated shear key(s) or embankment slope flattening in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Earthfill, downstream constructed dams with 2.5H:1V side slopes provide resistance against a global foundation failure. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6
4.23	Slope Failure – Static, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)		- Steepest allowable slope - Minimum FoS for analysis scenarios - Filter plant target moisture content - Storm water management on slope	**Design features to meet design criteria:** - Excavated shear key(s) or embankment slope flattening in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Earthfill, downstream constructed dams with 2.5H:1V side slopes provide resistance against dam failure. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6
4.24	Slope Failure – Earthquake, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)		- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake) - Filter plant target moisture content - Storm water management on slope	- As Failure Mode 4.22, with the following additions or modifications: - Structural zone sized to meet pseudo-static design criteria. - Structural zone sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6
4.25	Slope Failure – Earthquake, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)		- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake) - Filter plant target moisture content - Storm water management on slope	- As Failure Mode 4.23, with the following additions or modifications: - Structural zone sized to meet pseudo-static design criteria. - Structural zone sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6
4.26	Internal Erosion/Piping	- USACE (2004)		- Do not use tailings facilities as water storage - Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Drains to be designed to prevent piping of tailings into drain and filter zones. - No permanent ponded water on tailings surface post-closure reduces potential for internal erosion and piping. **Operational/monitoring features to meet design assumptions:** - Visual monitoring and instrumentation installed on tailings surface to monitor pond levels during storm events with backup pumps on the surface. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6
4.27	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)		- Inflow design flood (IDF) - "Dry" freeboard - Minimum beach length	**Design features to meet design criteria:** - Foundation characterization and design updates to limit potential for dissolution failure leading to loss of the crest and overtopping. - Pond designed to store normal operating pond, upset conditions and the Environmental Design Flood (EDF). Spillway to safely pass the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed and monitoring on tailings pond levels and volume accumulation not considered in design assumptions during storm events that may lead to overtopping risk. Backup pumps on the surface would also be installed. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6
4.28	Surface Erosion	- BADCT (ADEQ 2005)		- Criteria for protecting TSF from flood erosion	**Design features to meet design criteria:** - Erosion protection on upstream and downstream slopes for design flood events. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6

Acronyms:

Organizations, Standards and Guidelines

A.A.C. R12-15 Title 12, Chap 15 Arizona Administrative code - Dept of Water Resources
ADEQ Arizona Department of Environmental Quality
BADCT Best Available Demonstrated Control Technology
BC MEM British Columbia Ministry of Energy and Mines
CDA Canadian Dam Association
EoR Engineer of Record
ICMM International Council on Mining and Metals (ICMM)
ICOLD International Committee on Large Dams (ICOLD)
ITRB Independent Technical Review Board
MAC Mining Association of Canada
MEND Mine Environment Neutral Drainage Program
RT D5 Rio Tinto D5 Standard - Tailings and Water Storage Facilities
USACE United States Army Corps of Engineers

Environmental

NPAG Non-potentially Acid Generating
PAG Potentially Acid Generating

Assurance:

D / P Design and Permitting
Op Operations
Close Closure
Op / Close Ops & Closure

Assurance Review Processes:

A - Design Review Process: Review by ITRB, EIS Consultant, Federal Regulatory Agency, State Regulatory Agency & EoR sign off
B - Construction Quality Assurance Review by independent quality control and assurance contractors
C - Operating Review Process: Confirmation that the OMS manual remains applicable and is being followed. Accomplished by Owner documentation / records, EoR review of monitoring and operations, and ITRB review.
D - Combination of Design and Operating review (A&C) A combinations of the above design and operating review processes

Table I-4 - Failure Mode Review for Alternative 6 - Skunk Camp

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures – NPAG	Defensive Design and Operational Measures – PAG	Assurance Process	DEIS Design Report Section/ Appendix Reference
					Tailings Storage Facility			
6.01	Slope Failure – Static, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Minimum beach length	**Design features to meet design criteria:** - Preliminary stability assessments were completed to estimate potential depth of possible shear keys. Shear key(s) or embankment slopes flattened in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Centerline raised embankment constructed from compacted cycloned sand with 3H:1V exterior slope provides resistance against a global foundation failure. - Well-drained cycloned sand embankment and underdrains reduce pore pressures in the foundation below the exterior slope. - Long tailings beaches reduce pore pressures in the foundation below the exterior slope and within the embankment. Long beaches also would reduce consequence of slope failure since the embankment would not be breached by the pond. - No permanent ponded water on tailings surface post-closure reduces the phreatic surface within the tailings, enhancing stability and reducing consequences of potential failure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Preliminary stability assessments were completed to estimate potential depth of possible shear keys. Shear key(s) or embankment slopes flattened in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Downstream raised embankments constructed from compacted cycloned sand with 2.5H:1V side slopes and scavenger (NPAG) beach abutting the downstream slope provides resistance against a global foundation failure. - Well-drained cycloned sand embankment and underdrains reduce pore pressures in the foundation below the embankment. - PAG embankments are fully covered and supported by scavenger (NPAG) beach by the end of operations (for post-closure). - No permanent ponded water on tailings surface post-closure reduces the phreatic surface within the tailings, enhancing stability and reducing consequences of potential failure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
6.02	Slope Failure – Static, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Minimum beach length	**Design features to meet design criteria:** - Liquefaction risk of the cycloned sand shell will be controlled through both compaction and drainage. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. - Well-drained, compacted cycloned sand embankment and underdrains reduce pore pressures and increase strength in the embankment which increases overall stability. - Long tailings beaches reduce pore pressures in the embankment. Long beaches also would reduce consequence of slope failure since the embankment would not be breached by the pond. - No permanent ponded water on tailings surface post-closure reduces the phreatic surface within the tailings, enhancing stability and reducing consequences of potential failure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Measurements may indicate impending instability. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Liquefaction risk of the cycloned sand shell will be controlled through both compaction and drainage. - Well-drained, compacted cycloned sand embankment and underdrains reduce pore pressures and increase strength in the embankment which increases resistant forces in tailings enhances stability. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism. - PAG embankments and tailings are fully covered and supported by scavenger (NPAG) beach by the end of operations (for post-closure). - No permanent ponded water on tailings surface post-closure reduces the phreatic surface within the tailings, enhancing stability and reducing consequences of potential failure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Measurements may indicate impending instability. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
6.03	Slope Failure – Earthquake, through Foundation	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake) - Minimum beach length	- As Failure Mode 5.01, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.	- As Failure Mode 5.01, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
6.04	Slope Failure – Earthquake, through Tailings	- BADCT (ADEQ 2005) - D5 Rio Tinto (2017) - CDA (2007, 2013) - MEM (2016)	- 1.03 - 1.04 - 1.05 - 1.06 - 1.12	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake) - Minimum beach length	- As Failure Mode 5.02, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.	- As Failure Mode 5.02, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria. - Embankment sized to meet FoS criteria assuming all potentially liquefiable tailings liquefy, regardless of triggering mechanism.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Appendix I
6.05	Internal Erosion/Piping	- USACE (2004)	- 1.12 - 1.14	- Minimum beach length - Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Additional thickening of tailings slurry to reduce water entering the impoundment (thickening to 60% removes a significant portion of the water). - Limited information on foundation conditions (i.e. it is unknown if there are, and location of, dissolution features or potential to develop dissolution features,). Further site investigations and characterizations to be completed to further design. Design updates may include filter zones between the tailings and foundation is required and water management plan updates to limit ponded water near potential dissolution features. - Long tailings beaches and underdrainage prevent seepage and pore pressure buildup in the embankment. - Drains to be designed to prevent piping of tailings into drain and filter zones. - Cycloned sand in the embankment is internally stable; no embankment drain or filter zones. **Operational/monitoring features to meet design assumptions:** - Visual monitoring and instrumentation installed in the embankment and foundation during construction and operations to monitor phreatic conditions. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Further site investigations and characterizations to be completed to further design. Design updates may include filter zones between the tailings and foundation is required and water management plan updates to limit ponded water near potential dissolution features. - Long tailings beaches and underdrainage prevent phreatic surface buildup in the embankment. - Drains to be designed to prevent piping of tailings into drain and filter zones. - Cycloned sand in the embankment is internally stable; no embankment drain or filter zones. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor phreatic conditions. Also, seepage from underdrains will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.2 - Section 6 - Section 7 - Appendix I
6.06	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 1.07 - 1.08 - 1.09 - 1.10 - 1.11 - 1.12	- Pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum beach length	**Design features to meet design criteria:** - Foundation characterization and design updates to limit potential for dissolution failure leading to loss of the crest and overtopping. - Impoundment designed to store normal operating pond, upset conditions and the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. - Impoundment designed to store a potential failure of the pyrite (PAG) cell. - Impoundment designed to route the IDF through spillway post-closure. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	**Design features to meet design criteria:** - Foundation characterization and design updates to limit potential for dissolution failure leading to loss of the crest and overtopping. - Pyrite (PAG) tailings cell designed to store normal operating pond, upset conditions and the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance). - Pyrite (PAG) tailings cell encapsulated by scavenger (NPAG) tailings post-closure, surface drains to closure spillway that is designed to route the IDF. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.	D - Combination of Design and Operating (A&C) Review Processes	- Section 5.6 - Section 10 - Appendix I - Appendix III
6.07	Surface Erosion	- BADCT (ADEQ 2005)	-1.18	- Criteria for protecting TSF from flood erosion	**Design features to meet design criteria:** - Upstream diversion ditches designed to route the 100-year 24-hour storm from the upstream non-contact water catchment away from the TSF. Events greater than this would be stored within TSF impoundment and any eroded tailings would settle in reclaim pond. - Embankment slopes progressively reclaimed with adequate covers as soon as practical during operations to minimize erosion. - Closure spillways and diversions constructed to route water off and away from embankment slopes. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.	**Design features to meet design criteria:** - Upstream diversion ditches designed to route the 100-year 24-hour storm from the upstream non-contact water catchment away from the TSF. Events greater than this would be stored within TSF impoundment and any eroded tailings would settle in reclaim pond. - Embankment slopes progressively covered by scavenger (NPAG) beach, completely covered post-closure. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring or erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.	D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 8 - Section 10 - Appendix I

Table I-4 - Failure Mode Review for Alternative 6 - Skunk Camp

Failure Mode Identifier	Potential Failure Mode	Design Basis Reference (International Standard or Regulatory Criteria)	DBM Item No. (Refer to DBM Attached)	Design Criteria	Defensive Design and Operational Measures		Assurance Process	DEIS Design Report Section/ Appendix Reference
					NPAG	PAG		
					Seepage Collection Pond			
6.08	Slope Failure – Static, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Excavated shear key(s) or embankment slope flattening in areas with potentially weak foundation units would be included in design after more foundation information has been collected. - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and lined pond reduces pore pressures in the foundation below dam. - Compacted earthfill dams with 3H:1V side slopes provide resistance against a global foundation failure. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and pore pressures. Monitoring to confirm conditions assumed in design are met. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
6.09	Slope Failure – Static, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04	- Steepest allowable slope - Minimum FoS for analysis scenarios	**Design features to meet design criteria:** - Low phreatic surface in dam due to sump pump that maintains a minimal operating pond and lined pond reduces pore pressures in the foundation below dam. - Compacted earthfill dams with 3H:1V side slopes provide resistance against a global slope failure. **Operational/monitoring features to confirm design assumptions:** - Instrumentation installed in the embankment and foundation during construction and operations to monitor deformations and phreatic conditions. Monitoring to confirm phreatic conditions assumed in design. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
6.10	Slope Failure – Earthquake, through Foundation	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 5.08, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
6.11	Slope Failure – Earthquake, through Dam	- MEM (2016) - A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005)	- 2.02 - 2.03 - 2.04 - 2.05	- Steepest allowable slope - Minimum FoS for analysis scenarios - Maximum allowable deformations - Design earthquake definition (1:10,000 year return period earthquake)	- As Failure Mode 5.09, with the following additions or modifications: - Embankment sized to meet pseudo-static design criteria.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
6.12	Internal Erosion/Piping	- A.A.C. R12-15-1216 - D5 Rio Tinto (2017) - BADCT (ADEQ 2005) - USACE (2004)	- 2.06 - 2.13	- Filter compatibility guidelines for filters and drains	**Design features to meet design criteria:** - Seepage collection ponds are lined, and would include filter zones where required. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the dam and foundation during construction and operations to monitor phreatic conditions. Also, seepage will be measured and monitored. Monitoring to confirm seepage is being managed in accordance with the design intent. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Appendix I
6.13	Overtopping	- BADCT (ADEQ 2005) - FEMA (2013) - MEM (2016) - D5 Rio Tinto (2017) - CDA (2007, 2013) - USACE (2002)	- 2.06 - 2.07 - 2.08 - 2.09 - 2.10 - 2.11	- Normal operating pond storage capacity - Pond storage volume for operational upset condition - Environmental design flood (EDF) - Inflow design flood (IDF) - "Dry" freeboard - Minimum outlet discharge flow rate	**Design features to meet design criteria:** - Sump pumps, including redundancy, used to maintain a minimal pond volume during operations. - Pumps sized to remove floods during duration outlined in design criteria. - Pond designed to store normal operating pond, upset conditions and the Environmental Design Flood (EDF). Spillway to safely pass the Inflow Design Flood (IDF) (72-hour probable maximum precipitation) with adequate freeboard (including wind and wave runup allowance) and assuming failure of upstream diversions during operations. **Operational/monitoring features to meet design assumptions:** - Instrumentation installed in the pond and routine monitoring to identify potential pond volume accumulation not considered in design assumptions that may lead to an overtopping risk. Monitoring details, frequencies, trigger criteria and lines of communication to be outlined in the OMS manual.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 10 - Appendix III
6.14	Surface Erosion	- A.A.C. R12-15-1216 - BADCT (ADEQ 2005)	- 2.15 - 2.16	- Criteria for protecting dam from flood erosion	**Design features to meet design criteria:** - Erosion protection on upstream and downstream slopes for design flood events. **Operational/monitoring features to meet design assumptions:** - Routine visual monitoring on erosion management structures and erodible areas outlined in the OMS manual to address erosion concerns.		D - Combination of Design and Operating (A&C) Review Processes	- Section 6 - Section 8 - Section 10 - Appendix I

Acronyms:

Organizations, Standards and Guidelines

A.A.C. R12-15 Title 12, Chap 15 Arizona Administrative code - Dept of Water Resources
ADEQ Arizona Department of Environmental Quality
BADCT Best Available Demonstrated Control Technology
BC MEM British Columbia Ministry of Energy and Mines
CDA Canadian Dam Association
EoR Engineer of Record
ICMM International Council on Mining and Metals (ICMM)
ICOLD International Committee on Large Dams (ICOLD)
ITRB Independent Technical Review Board
MAC Mining Association of Canada
MEND Mine Environment Neutral Drainage Program
RT D5 Rio Tinto D5 Standard - Tailings and Water Storage Facilities
USACE United States Army Corps of Engineers

Environmental

NPAG Non-potentially Acid Generating
PAG Potentially Acid Generating

Assurance:

D / P Design and Permitting
Op Operations
Close Closure
Op / Close Ops & Closure

Assurance Review Processes:

A - Design Review Process: Review by ITRB, EIS Consultant, Federal Regulatory Agency, State Regulatory Agency & EoR sign off
B - Construction Quality Assurance Review by independent quality control and assurance contractors
C - Operating Review Process: Confirmation that the OMS manual remains applicable and is being followed. Accomplished by Owner documentation / records, EoR review of monitoring and operations, and ITRB review.
D - Combination of Design and Operating review (A&C) A combinations of the above design and operating review processes

APPENDIX II

Design Basis Memorandums (DBM)

DEIS Design for Alternative 3A – Near West Modified Proposed Action (Modified Centerline Embankment – “wet”), DBM

DEIS Design for Alternative 3B – Near West Modified Proposed Action (High Density Thickened NPAG Scavenger and Segregated PAG Pyrite Cell), DBM

DEIS Design for Alternative 4 – Silver King Filtered, DBM

DEIS Design for Alternative 6 – Skunk Camp, DBM

DEIS Design for Alternative 3A – Near West Modified Proposed Action (Modified Centerline Embankment – “wet”), DBM

Resolution Copper Project

DEIS Design for Alternative 3A – Near West Modified Proposed Action (Modified Centerline Embankment – "wet")

Technical Memorandum

Appendix I – Design Basis Memorandum

DISCLAIMER

1 INTRODUCTION

1.1 General

This is the design basis memorandum (DBM) for the design of Alternative 3A – Near West Modified Proposed Action (Modified Centerline Embankment – “wet”) which is one of the tailings storage facility (TSF) design alternatives that Resolution Copper Mining LLC (RC) intends to include in the draft environmental impact statement (DEIS) for the proposed Resolution Copper Project. This TSF is located at the Near West location in Pinal County, Arizona. The DBM outlines the design objective as well as the design criteria and assumptions. This DBM is considered a “live” document that will be reviewed and updated throughout the design process.

1.2 Design Objective

The objective of the TSF is to store the tailings produced by the proposed Resolution Copper Project. The design incorporates findings from alternative studies and site specific data collected from site investigations, where applicable.

The design regulations and guidelines are outlined in Section 1.3, and the design criteria and assumptions are tabulated in Section 2.

The scope of the DEIS design is to provide a basis for comparing impacts from TSF alternatives.

1.3 Design Regulations and Guidelines

The TSF design is governed and guided by the regulations and guidelines listed below. The general approach adopted in this design is to set the design criteria based on the governing regulations, and then to supplement these regulations with guidelines from international practice where the governing regulations are not specific. Where international guidelines are more stringent than the governing regulations, consideration is also given to the additional measures needed to meet the more stringent guidelines.

Governing

<u>Tailings Storage Facility and Seepage Collection Dams</u>

- Arizona State Legislature. 2016. Arizona Administrative Code (A.A.C.).
    - Title 18. Environmental Quality. Chapter 9: Department of Environmental Quality – Water Pollution Control. Chapter 11: Department of Environmental Quality, Article 1: Water Quality Standards.
    - Arizona State Legislature. 2016. Arizona Revised Statues (A.R.S.).
        - Title 49 – The Environment.
- Regulatory agency: Arizona Department of Environmental Quality (ADEQ).
- Environmental Protection Agency (EPA). Clean Water Act (CWA) - 33 U.S.C. §1251 et seq. (1972).
- Rio Tinto. 2017. D5 – Management of Tailings and Water Storage Facilities.

Seepage Collection Dams (only)

In addition to the above governing regulations, the seepage collection dams are regulated by the Arizona Department of Water Resources (ADWR). The additional application Arizona Administrative Code (A.A.C.) is Title 12. Natural Resources. Chapter 15. Department of Water Resources (A.A.C. R12-15).

Guidance

- Arizona Department of Environmental Quality (ADEQ). 2005. Arizona Mining Guidance Manual BADCT (Best Available Demonstrated Control Technology).
- British Columbia Ministry of Energy and Mines (MEM). 2016. *Health, Safety and Reclamation Code for Mines in British Columbia*.
- Canadian Dam Association (CDA). 2007a. *Dam Safety Guidelines (with 2013 revision).*
- Canadian Dam Association (CDA). 2007b. *Technical Bulletin: Hydrotechnical Considerations for Dam Safety*.
- Canadian Dam Association (CDA). 2014. *Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams*.
- Federal Emergency Management Agency (FEMA). 2005. *Federal Guidelines for Dam Safety – Earthquake Analyses and Design of Dams. FEMA-65.*
- Federal Emergency Management Agency (FEMA). 2013. *Selecting and Accommodating Inflow Design Floods for Dams. FEMA-P-94.*
- United States Army Corps of Engineers (USACE). 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).
- United States Army Corp of Engineers (USACE). 2004. *General Design and Construction Considerations for Earth and Rock-Fill Dams. EM 1110-2-2300.*
- United States Army Corp of Engineers (USACE). 2003. *Slope Stability. EM 1110-2-1902.*

1.4 BADCT Approach

The TSF will apply for an Aquifer Protection Permit (APP) with an “individual” Best Available Demonstrated Control Technology (BADCT) approach, which is performance based, and allows the applicant to select from all available Demonstrated Control Technologies (DCTs) that constitute BADCT. This process considers site specific characteristics, operational controls, and other DCTs.

Under the individual BADCT approach, the TSF is considered a “tailings impoundment” and will be designed in accordance with Section 3.5 of the BADCT manual (ADEQ 2005). The seepage dams are considered to be “surface ponds” and will be designed in accordance with Section 3.6 of the BADCT manual (ADEQ 2005) and the regulations pertaining to water dams (A.A.C. R12-15).

2 DESIGN CRITERIA

Table 2.1 Design Criteria

	Item	Design Criteria	Reference
1.0	**Tailings Storage Facility (TSF) Embankment Design**		
1.01a	CDA Consequence Classification	to be confirmed following inundation study	▪ CDA (2007a)
1.01b	Rio Tinto Risk Category	Class IV (considered Class IV until all necessary mitigations have been included in design)	▪ D5 Standard (Rio Tinto 2017)
1.02	Storage capacity	Capacity to store all NPAG scavenger (scavenger) and PAG pyrite (pyrite) tailings production	▪ RC requirement
1.03	Downstream slope	▪ No steeper than 2H:1V	▪ MEM (2016)
1.04	Minimum Factor of Safety	▪ Static (upstream or downstream) – 1.5 (during operation and long term) ▪ Liquefied/post-cyclic – 1.2 ▪ Rapid drawdown – N/A	▪ BADCT (ADEQ 2005) supplemented with MEM (2016) ▪ D5 Rio Tinto (2017) ▪ CDA (2007a) ▪ N/A
1.05	Deformations (seismic or static, e.g. settlement)	▪ For cases with no liquefiable materials, horizontal seismic coefficient for pseudo-static analysis = 0.6 x Peak ground acceleration (PGA). This seismic coefficient is selected to maintain consistency with the requirements of the seepage collection dams, as per A.A.C R12-15-1216. ▪ For elements of the TSF sensitive to deformation, a simplified deformation analysis is required. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not reduce freeboard sufficiently to lead to an uncontrolled release of fluid tailings, does not impact the functionality of the drains, etc.).	▪ BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
1.06	Seismicity	▪ Maximum Credible Earthquake (MCE). Earthquake design ground motions will be selected in future design stages for appropriate return period events.	▪ BADCT (ADEQ 2005) supplemented with MEM (2016), CDA (2014), D5 Rio Tinto (2017) and industry practice
1.07	Pond Storage Capacity	See Figure 2.1 Storage capacity = minimum operating volume + maximum average seasonal volume + volume required for operational upset + volume for critical duration storm event including sediment (Environmental Design Flood and Inflow Design Flood) + volume required for “dry” freeboard (Table 2.1, Item 1.11)	▪ BADCT (ADEQ 2005)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.08	Storage Volume for Operational Upset Conditions	RC to confirm after RC internal risk audit and to be updated in next stage of design.	
1.09	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. Design will assume 200-year 24 hr; EDF will be confirmed through water balance and water quality modeling.	▪ BADCT (ADEQ 2005)
1.10	Inflow Design Flood (IDF) For Dam Safety	<u>Return Period:</u> Probable Maximum Flood (PMF) <u>Duration:</u> For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to contain the design flood volume. Therefore, the duration will be confirmed during the flood routing and water balance calculations: ▪ with a spillway: spillway sized for the critical duration of 6 hr to 72 hr; and ▪ without a spillway: minimum of 72 hr (to be confirmed based inflows and discharge rates).	▪ BADCT (ADEQ 2005) ▪ FEMA (2013) ▪ MEM (2016) ▪ D5 Rio Tinto (2017)
1.11	“Dry” Freeboard	▪ Wind and wave run-up + 2 ft ▪ Wind event annual exceedance probability = 2-year ▪ Wave height and run-up to be calculated using industry standard methods ▪ Earthquake-induced settlements of the embankment crest to be assessed and included in minimum freeboard determination	▪ BADCT (ADEQ 2005) ▪ CDA (2007b) ▪ USACE (2002)
1.12	Beach length	Will become part of the Quantitative Performance Objectives (QPO) ▪ Sufficient to achieve seepage and hydraulic gradient criteria during normal operations and periods of flood storage. ▪ Sufficient to provide a secondary defense against loss of fluid tailings in the event of downstream slope displacement.	
1.13	Seepage	Water quality requirements at the point of compliance are to be assessed.	▪ BADCT (ADEQ 2005), Clean Water Act (EPA) and Arizona State Legislature (A.A.C. R18-11)
1.14	Drains	▪ Provide drains/filters satisfying USACE (2004) guidelines to mitigate potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	▪ USACE (2004)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.15	Construction and Operations	▪ Quantifiable performance objectives to be defined prior to construction. ▪ All construction and borrow materials with contingency to be defined prior to construction.	▪ MEM (2016)
1.16	Closure	Planned closure landscape is to be a physically stable landform without a permanent water pond that meets point of compliance criteria.	▪ D5 Rio Tinto (2017)
1.17	Closure Surface Diversions	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment.	▪ BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
1.18	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact to structural zones, containment, other structures or the environment. BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.	▪ BADCT (ADEQ 2005)
2.0	**Seepage Collection Dams**		
2.01	Assumed downstream hazard classification	High (will be reviewed for each individual seepage dam in future design stages)	▪ A.A.C R12-15-1216
2.02	Downstream slope	As per Table 2.1, item 1.03	
2.03	Stability Factor of Safety (FOS)	▪ End of construction – Static (upstream or downstream) – 1.3 (≤ 50 ft high), 1.4 (> 50 ft high) ▪ Steady state seepage – Static – 1.5 ▪ Rapid drawdown – 1.2	▪ A.A.C R12-15-1216 ▪ D5 Rio Tinto (2017)
2.04	Deformations (seismic or static, e.g. settlement)	▪ Pseudo-static – FOS = 1.0 with horizontal seismic coefficient = 0.6 x Peak ground acceleration. ▪ As per Table 2.1, item 1.05, where elements are sensitive to deformations, a simplified deformation analysis will be conducted to identify the potential displacements for comparison with allowable deformations for that element. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not impact the integrity of the dam core or the spillway, etc.)	▪ A.A.C R12-15-1216 and BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
2.05	Seismicity	▪ MCE, assumed to be mean 1:10,000 year return period: ♦ Sensitivity to 95th percentile to be considered	▪ A.A.C R12-15-1216 supplemented with MEM (2016) and CDA (2007a) ▪ D5 Rio Tinto (2017)
2.06	Pond Storage Capacity	See Table 2.1, item 1.07	
2.07	Storage Volume for Operational Upset Conditions	One week of average seepage and precipitation to account for a period of pump shut-down	

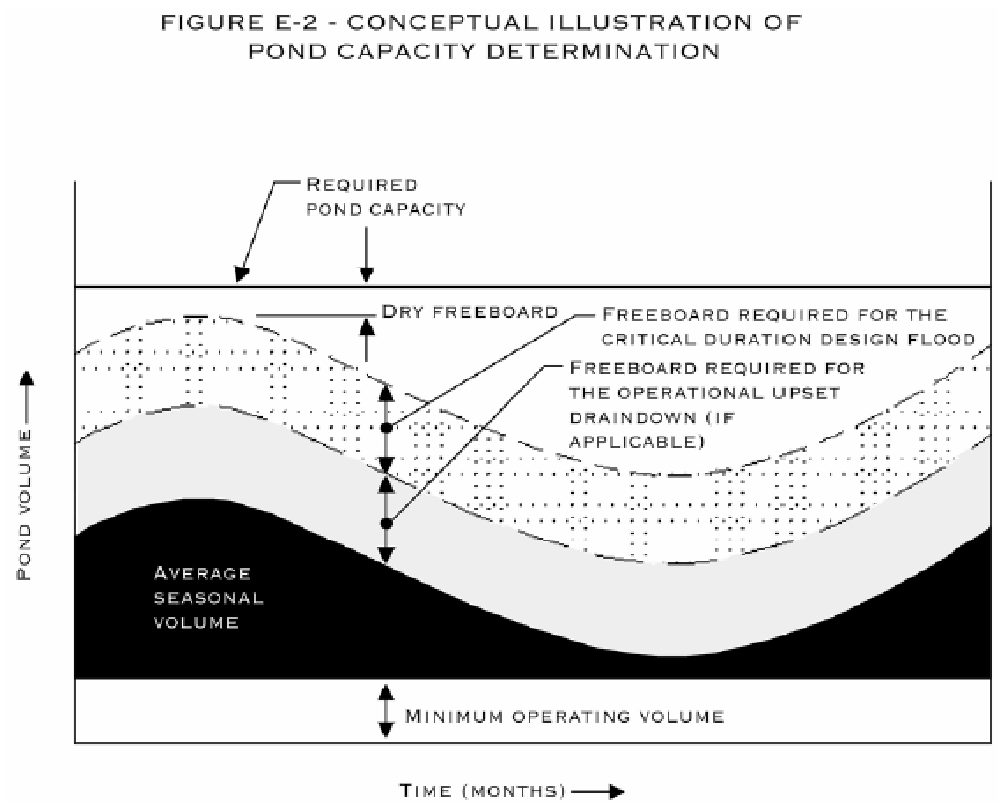
Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.08	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. TSF design will assume 200-year 24 hr; EDF will be confirmed through water balance and water quality modeling.	▪ BADCT (ADEQ 2005)
2.09	Inflow Design Flood (IDF) For Dam Safety	Storm to be routed through spillway - Probable Maximum Flood (PMF) BADCT: Return Period: if failure of dam would pose an imminent risk to human life and/or high downstream incremental consequences the PMF should be used. Duration: For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to route the design flood volume. The range of storm duration to be considered are 6 hr to 72 hr. A.A.C R12-15-1216: For a high hazard potential dam, the applicant shall design the dam to withstand an inflow design flood that varies from .5 PMF to the full PMF, with size increasing based on persons at risk and potential for downstream damage. The applicant shall consider foreseeable future conditions. FEMA (2013): PMF for a dam classified as high hazard.	▪ BADCT (ADEQ 2005) ▪ A.A.C R12-15-1216 ▪ D5 Rio Tinto (2017) ▪ FEMA (2013)
2.10	Freeboard	Largest of: ▪ IDF + wave run up with a critical wind annual exceedance probability of the 1 in 2 year event ▪ IDF + 3 ft ▪ 5 ft	▪ A.A.C R12-15-1216 with consideration from CDA (2007b)
2.11	Low level outlet (or discharge - pump)	Can discharge 90% of storage volume within 30 days (minimum capacity).	▪ A.A.C R12-15-1216
2.12	Seepage	See Table 2.1, item 1.13	
2.13	Drains	▪ Provide core and drains/filters satisfying USACE (2004) guidelines to limit potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	▪ BADCT (ADEQ 2005), USACE (2004) and A.A.C R12-15-1216
2.14	Crest width	Minimum of dam height (centerline) divided by 5, plus 5 ft. Minimum crest width = 12 ft, maximum crest width = 25 ft.	▪ A.A.C R12-15-1216

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.15	Erosion protection	Well graded, durable riprap, sized to withstand wave action, placed on a well graded pervious sand and gravel bedding or geotextile with filtering capacity suitable for the site.	▪ A.A.C R12-15-1216
2.16	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment. (BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.)	▪ BADCT (ADEQ 2005)

Figure 2.1 Pond Capacity Determination (ADEQ 2005)



3 DESIGN BASIS

Table 3.1 Design Assumptions, Constraints & Data Sources

	Item	Design Basis	Comments
1.0	**General Design Basis**		
1.01	TSF location	▪ Near West site, Pinal County, Arizona (USFS land) ▪ Coordinates (Arizona State Plane Central NAD83): 920,000' E, 880,000' N	
1.02	Mine Flow Sheet	Selective	
1.03	Mine life	41 years	Received from RC
1.04	TSF operating life	41 years	Received from RC
1.05	Tailings types	Two types of tailings are produced: ▪ scavenger tailings (84% of total weight); and ▪ pyrite tailings (16% of total weight).	Received from RC
1.06	Tailings technology	Thickened slurry (scavenger and pyrite tailings).	
1.07	Tailings delivery	See process schematic (Figure 3.1)	
1.08	Total tailings production	1.37 billion short tons	Received from RC
1.09	Ore and tailings production schedule	Table 3.2	
1.10	Units	U.S. Customary	
1.11	Embankment raise methodology	Hydraulically placed cycloned sand modified centerline (see Figure 3.2)	KCB (2017a)
1.12	Cycloned sand availability	Cycloned Sand Recovery: 45% Cyclone uptime: 50% (Year 1-2); 70% (Year 3-5); 80% (Year 6-41) Cycloned sand retention in hydraulic cells: 90%	Lower bound recovery from Krebs simulations (KCB 2018) To account for reduced efficiency at the start of operations; communicated by RC
2.0	**Topography**		
2.01	Projection	Arizona State Plane Central	
2.02	Datum	NAD83	
2.03	Unit of measurement	U.S. Customary	
2.04	Survey	2013 LiDAR survey received from RC on June 5/6, 2013.	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
3.0	**Seismicity**		
3.01	Ground Motions	Not considered in analysis at this stage of design (refer to Table 3.1, Item 8.02).	
4.0	**Climate and Hydrology**		
4.01	Average precipitation (in inches)	J: 2.0; F: 2.0; M: 2.0; A: 0.8; M: 0.3; J: 0.3; J: 1.9; A: 2.8; S: 1.5; O: 1.2; N: 1.4; D: 2.1; Total: 18.2	Data collected at the Superior climate station (ID: 028348) with gaps filled using data from the regional climate stations.
4.02	Wet and dry year precipitations	Consideration to wet and dry years for the water balance will not be made at this stage of design.	
4.03	Average annual pan evaporation	96.5 in	Pan evaporation data collected at the Roosevelt 1 WNW climate station (ID: 027281). Free water surface evaporation determined using the Evaporation Atlas for the Contiguous 48 United States (NOAA 1982).
4.04	Evapotranspiration for reference surface/crop (in inches)	J: 2.9; F: 3.4; M: 5.0; A: 6.6; M: 8.5; J: 9.2; J: 9.0; A: 8.0; S: 7.0; O: 5.8; N: 3.8; D: 3.1; Total: 72.3	Calculated using the Penman-Monteith combined equation in Hydrus1D based on the generated Superior climate data set and reference vegetation parameters.
4.05	Natural catchment runoff coefficient	0.15	Calculated by dividing the average annual runoff from the nearby USGS hydromet station by the average annual precipitation at site (KCB 2014).
4.06	Probable Maximum Precipitation (PMP)	PMP Depth (inches) – General Winter: 6 hour Duration 4.9, 24 hour Duration 9.0, 72 hour Duration 13.3; Tropical: 12.4, 16.3, 20.4; Local: 12.1, -, -	Applied Weather Associates PMP Evaluation Tool. Determined as the critical storm for design. For the Near West site catchment.
4.07	Runoff coefficient during storm events	1.0	To account for high antecedent moisture conditions and the predominantly exposed rock in the catchment
4.08	Extreme point precipitation depths	See Table 3.3	From NOAA Atlas 14 (NOAA 2018).

Item 4.01 – Average precipitation (in inches):

J	F	M	A	M	J	J	A	S	O	N	D	Total
2.0	2.0	2.0	0.8	0.3	0.3	1.9	2.8	1.5	1.2	1.4	2.1	18.2

Item 4.04 – Evapotranspiration for reference surface/crop (in inches):

J	F	M	A	M	J	J	A	S	O	N	D	Total
2.9	3.4	5.0	6.6	8.5	9.2	9.0	8.0	7.0	5.8	3.8	3.1	72.3

Item 4.06 – Probable Maximum Precipitation (PMP):

Storm Type	PMP Depth (inches)		
	6 hour Duration	24 hour Duration	72 hour Duration
General Winter	4.9	9.0	13.3
Tropical	12.4	16.3	20.4
Local	12.1	-	-

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.0	**Tailings Characteristics and Deposition**			
		Scavenger Tailings	**Pyrite Tailings**	
5.01	Target gradation produced at mill	*"Total" Tailings:* Target P80 = 160 microns 50% fines (<74 microns) <10% clay (<2 microns)	Target P80 = 75 to 80 microns 80% fines (<74 microns) <20% clay (<2 microns)	Scavenger "Total" Tailings: Provided by RC. Pyrite Tailings: Provided by RC. Clay content assumed from previous test work on cleaner tailings. See Figure 3.3.
5.02	Target gradation produced by cyclones	*Cycloned Sand (Underflow)*: Target P80 = 200 microns <20 % fines (<74 microns) 0% clay (<2 microns) *Cyclone Overflow:* Target P80 = 60 microns 90% fines (<74 microns) 15% clay (<2 microns)	N/A	Provided by RC. See Figure 3.3. Target fines content for cycloned sand to be less than 20%, based on seepage performance and constructability from other cycloned sand embankment case histories.
5.03	Specific gravity	2.78	3.87	Average values from KCB laboratory testing programs on scavenger "total" tailings and cleaner tailings.
5.04	Solids content pumped from the mill	65%	50%	Provided by RC
5.05	Cyclone solids content	*Cyclone Feed:* 35% *Cyclone Overflow:* 25% *Cycloned Sand:* 70%	N/A	From most recent Krebs simulations (KCB 2018).
5.06	Solids content discharged into TSF	*"Total" Tailings:* 65% *Cyclone Overflow:* 50% to 60% *Cycloned Sand:* 60%	50%	Cycloned sand solids content based on case history data and construction performance at other large cycloned sand embankments that use hydraulic cell construction.
5.07	Liquefaction assumption	All potentially liquefiable tailings will liquefy at the TSF, regardless of triggering mechanism.		
5.08	Pyrite tailings management	N/A	Subaqueous deposition	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.09	Tailings beach slopes (above water)	1% within 1,500 ft of discharge point, 0.5% thereafter	N/A	Scavenger Tailings - Based on topography and bathymetry surveys from two large, cycloned sand impoundment beaches and slopes below water. These facilities have long exposed beaches, up to five miles. Pyrite Tailings - Based on topography and bathymetry surveys of subaqueous disposal of high-pyrite tailings from floating barges.
5.10	Tailings beach slopes (below water)	2.5% within 1,000 ft of water's edge; 1.0% thereafter	10% within 100 ft of discharge point; 0.5% thereafter	
5.11	Dry beach runoff coefficient	0.15	N/A	Estimated based on Hydrus1D infiltration modeling
5.12	Dry density for staging assessment	*Interlayered "Total" Tailings and Cyclone Overflow (Composite Beach):* 75 pcf (first 5 years of operations); 81 pcf (remaining years of operations) *Cycloned Sand (compacted):* 113 pcf	106 pcf	KCB (2018)
6.0	**Cyclone Plant Design**			
6.01	No. of Clusters	2		
6.02	Feed Tonnage	5,040 dry stph		
6.03	Feed Flow	45,267 USGPM		
6.04	Solids Content of Feed, Overflow, Underflow	see Table 3.1, Item 5.05		
6.05	Pressure Drop	15 psi		
6.06	Target No. of Spare Cyclones per Cluster	2		
6.07	Target No. of Spare Ports per Cluster	1		

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
6.08	Selected Cyclone Model	gMAX15U	
6.09	Selected Cyclone Vortex	6.75 inches	
6.10	Selected Cyclone Apex	3 inches	
6.11	Selected Cyclone Diameter	15 inches	
6.12	Selected Operating Cyclones per Cluster	24	
6.13	Selected No. of Spare Cyclones per Cluster	2	
6.14	Selected No. of Cyclones Installed per Cluster	26	
6.15	Selected No. of Spare Ports per Cluster	2	
7.0	**Thickener Design**		
7.01	Thickener Type	High-Density	
7.02	No. of Thickeners	2	
7.03	Design Tonnage	144,000 tpd ore	
7.04	Diluted Feed %solids	20%	
7.05	Underflow %solids (Cyclone Overflow Feed)	50%	
7.06	Underflow %solids (Scavenger Total Tailings Feed)	n/a	
7.07	Unit Settling Rate	0.98 ft^2/tpd	
7.08	Sizing Design Allowance	15%	
7.09	Thickener Diameter	250 ft	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
8.0	**Tailings Storage Facility (TSF) Impoundment Design**		
8.01	Design criteria	As per Table 2.1.	
8.02	Stability	Embankment section (Figure 3.2) assumed to meet design stability criteria for DEIS	Based on preliminary stability analyses reported in KCB (2017a) and typical assumed foundation conditions at the Near West site (KCB 2017b)
8.03	Perimeter Embankment Crest width	100 ft	Sufficient to accommodate 2-way vehicle traffic, pipelines and any other equipment required to be on the crest (e.g. cyclones).
8.04	Perimeter Embankment Downstream Slope	4H:1V (see Figure 3.2)	For ease of progressive reclamation. A trade-off assessing the impacts to steepening to 3H:1V has been completed (Appendix III).
8.05	Perimeter Embankment Upstream Slope	1.5H:1V (see Figure 3.2)	Assumed based on preliminary stability analysis reported in KCB (2017a)
8.06	Liner	Engineered low-permeability liner[2] in the pyrite starter cell; selective engineered liner placement over permeable portions of the foundation	
8.07	Drainage	Sand and gravel drainage blanket in the embankment footprint; gravel/rockfill finger drains in existing drainage channels in the embankment footprint	
8.08	Closure	TSF Surfaces: slope, cover and revegetate to shed water, limit infiltration, limit erosion and return the landscape to a similar condition prior to mining. Pyrite management: limit oxygen ingress through subaqueous deposition, cover and encourage saturation of the pyrite tailings in the long term (i.e. after removal of the pond).	Approach agreed by RC
9.0		**Pond Management**	
9.01	Pond Management	▪ Permanent water pond located on the tailings surface. Tailings strategically deposited to keep pond cover over pyrite tailings.	D5 Rio Tinto (2017)
9.02	Minimum operating pond volume	▪ Minimum amount to keep pyrite tailings saturated and provide operating pond depth.	

[2] The engineered low-permeability liner could be comprised of one or more of the following: compacted fine tailings, geomembrane liner, asphalt, slurry bentonite, and/or cemented paste tailings

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

<table>
<tr><th></th><th>Item</th><th>Design Basis</th><th>Comments</th></tr>
<tr><td>9.03</td><td>Minimum operating pond depth</td><td>
Seepage Collection Dams: 10 ft for reclaim pump (could be accounted for by a sump or other means).
TSF Reclaim Pond:
<table>
<tr><th>Pond</th><th>Years of Operation</th><th>Minimum Operating Depth (ft)</th><th>Minimum Water Cover above Maximum Tailings El. (ft)</th></tr>
<tr><td>Scavenger</td><td>1 to 9</td><td>20</td><td>n/a[2]</td></tr>
<tr><td>Pyrite</td><td>1 to 9</td><td>n/a[1]</td><td>10</td></tr>
<tr><td>Combined Pyrite and Scavenger</td><td>10 to 41</td><td>n/a[1]</td><td>5</td></tr>
</table>
No minimum depth. Water cover is determined based on the minimum height above the maximum tailings elevation.
No minimum water cover. Minimum water depth is based on minimum depth in the lowest part of the pond (where the reclaim barge will be positioned).
</td><td></td></tr>
</table>

Table 3.2 Mine and Tailings Production Schedule

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Care and Maintenance	2017	-	1	-	-	-
Care and Maintenance	2018	-	2	-	-	-
Care and Maintenance	2019	-	3	-	-	-
Care and Maintenance	2020	-	4	-	-	-
Construction	2021	-	5	-	-	-
Construction	2022	-	6	-	-	-
Construction	2023	-	7	-	-	-
Construction	2024	-	8	-	-	-
Construction	2025	-	9	-	-	-
Construction	2026	-	10	-	-	-
Construction	2027	-	11	-	-	-
First Ore	2028	1	12	5,346,486	766,631	6,113,118
Ramp up	2029	2	13	7,187,504	991,640	8,179,144
Ramp up	2030	3	14	7,897,945	1,014,556	8,912,501
Ramp up	2031	4	15	15,085,826	2,110,526	17,196,352
Ramp up	2032	5	16	21,902,288	3,328,288	25,230,577
Ramp up	2033	6	17	28,780,765	4,569,518	33,350,283
Ramp up	2034	7	18	34,178,734	5,793,075	39,971,810
Full Production	2035	8	19	37,849,588	7,340,459	45,190,047
Full Production	2036	9	20	37,128,274	8,184,034	45,312,308
Full Production	2037	10	21	36,749,978	8,772,867	45,522,845
Full Production	2038	11	22	37,121,210	8,792,910	45,914,120
Full Production	2039	12	23	38,040,923	8,019,027	46,059,950
Full Production	2040	13	24	37,486,298	6,800,935	44,287,232
Full Production	2041	14	25	39,582,789	6,518,836	46,101,626
Full Production	2042	15	26	39,666,729	6,589,905	46,256,634
Full Production	2043	16	27	39,211,923	6,919,174	46,131,097
Full Production	2044	17	28	38,679,739	7,360,739	46,040,478
Full Production	2045	18	29	38,273,841	7,838,027	46,111,868

Table 3.2 Mine and Tailings Production Schedule (cont'd)

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Full Production	2046	19	30	38,130,733	8,150,877	46,281,610
Full Production	2047	20	31	38,448,597	7,968,471	46,417,068
Full Production	2048	21	32	38,926,908	7,537,946	46,464,854
Full Production	2049	22	33	39,028,952	7,382,565	46,411,517
Full Production	2050	23	34	39,006,219	7,367,901	46,374,120
Full Production	2051	24	35	38,564,309	7,824,341	46,388,650
Full Production	2052	25	36	38,008,651	8,406,901	46,415,552
Full Production	2053	26	37	37,822,090	8,629,862	46,451,952
Full Production	2054	27	38	38,599,981	7,902,469	46,502,450
Full Production	2055	28	39	39,472,443	6,988,070	46,460,513
Full Production	2056	29	40	39,579,974	6,796,869	46,376,843
Full Production	2057	30	41	39,595,841	6,786,681	46,382,522
Full Production	2058	31	42	39,503,382	6,740,343	46,243,725
Ramp Down	2059	32	43	31,481,866	5,391,484	36,873,350
Ramp Down	2060	33	44	24,576,943	4,320,111	28,897,054
Ramp Down	2061	34	45	18,707,166	3,478,519	22,185,685
Ramp Down	2062	35	46	13,146,108	2,643,079	15,789,186
Ramp Down	2063	36	47	9,566,562	1,952,428	11,518,989
Ramp Down	2064	37	48	4,993,554	1,079,281	6,072,835
Ramp Down	2065	38	49	2,121,484	545,241	2,666,725
Ramp Down	2066	39	50	928,110	274,819	1,202,929
Ramp Down	2067	40	51	326,877	99,724	426,602
Ramp Down	2068	41	52	19,505	4,936	24,440
Closure	2069	-	53	-	-	-
			TOTAL TAILINGS	**1,150,727,095**	**219,984,066**	**1,370,711,161**

Notes: Tailings production schedule supplied by Resolution Copper.
Mine plan descriptions, mine years and modeling years supplied by Resolution Copper.

Table 3.3 Precipitation Depth-Duration-Frequency Estimates for the TSF

Average Recurrence Interval (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr	2 day	3 day	4 day	7 day	10 day	20 day	30 day	45 day	60 day
Precipitation in inches																			
1	0.2	0.4	0.4	0.6	0.7	0.9	0.9	1.1	1.3	1.6	1.8	2.0	2.1	2.4	2.7	3.3	4.0	4.7	5.5
2	0.3	0.5	0.6	0.8	1.0	1.1	1.2	1.4	1.7	2.0	2.3	2.5	2.7	3.0	3.4	4.2	5.1	6.0	6.9
5	0.4	0.6	0.8	1.1	1.3	1.5	1.5	1.8	2.1	2.6	2.9	3.2	3.5	3.9	4.3	5.4	6.5	7.7	8.7
10	0.5	0.8	0.9	1.3	1.6	1.7	1.8	2.1	2.4	3.0	3.5	3.8	4.1	4.7	5.1	6.4	7.6	8.9	10.1
25	0.6	0.9	1.1	1.5	1.9	2.1	2.2	2.5	2.8	3.6	4.2	4.6	5.0	5.8	6.2	7.7	9.1	10.6	11.9
50	0.7	1.0	1.3	1.7	2.2	2.4	2.5	2.8	3.2	4.1	4.7	5.2	5.7	6.7	7.2	8.7	10.3	12.0	13.3
100	0.8	1.2	1.5	2.0	2.4	2.7	2.8	3.1	3.5	4.6	5.3	5.9	6.5	7.6	8.2	9.8	11.6	13.3	14.7
200	0.9	1.3	1.6	2.2	2.7	3.0	3.1	3.4	3.9	5.1	5.9	6.6	7.4	8.7	9.2	10.9	12.9	14.6	16.1
500	1.0	1.5	1.8	2.4	3.0	3.4	3.6	3.9	4.4	5.8	6.8	7.7	8.5	10.2	10.7	12.4	14.7	16.5	17.9
1000	1.1	1.6	2.0	2.7	3.3	3.7	3.9	4.2	4.7	6.4	7.4	8.5	9.5	11.4	12.0	13.6	16.1	17.9	19.3

Note: From NOAA Atlas 14 (NOAA 2018) For the Near West site.

Figure 3.1 Process Schematic

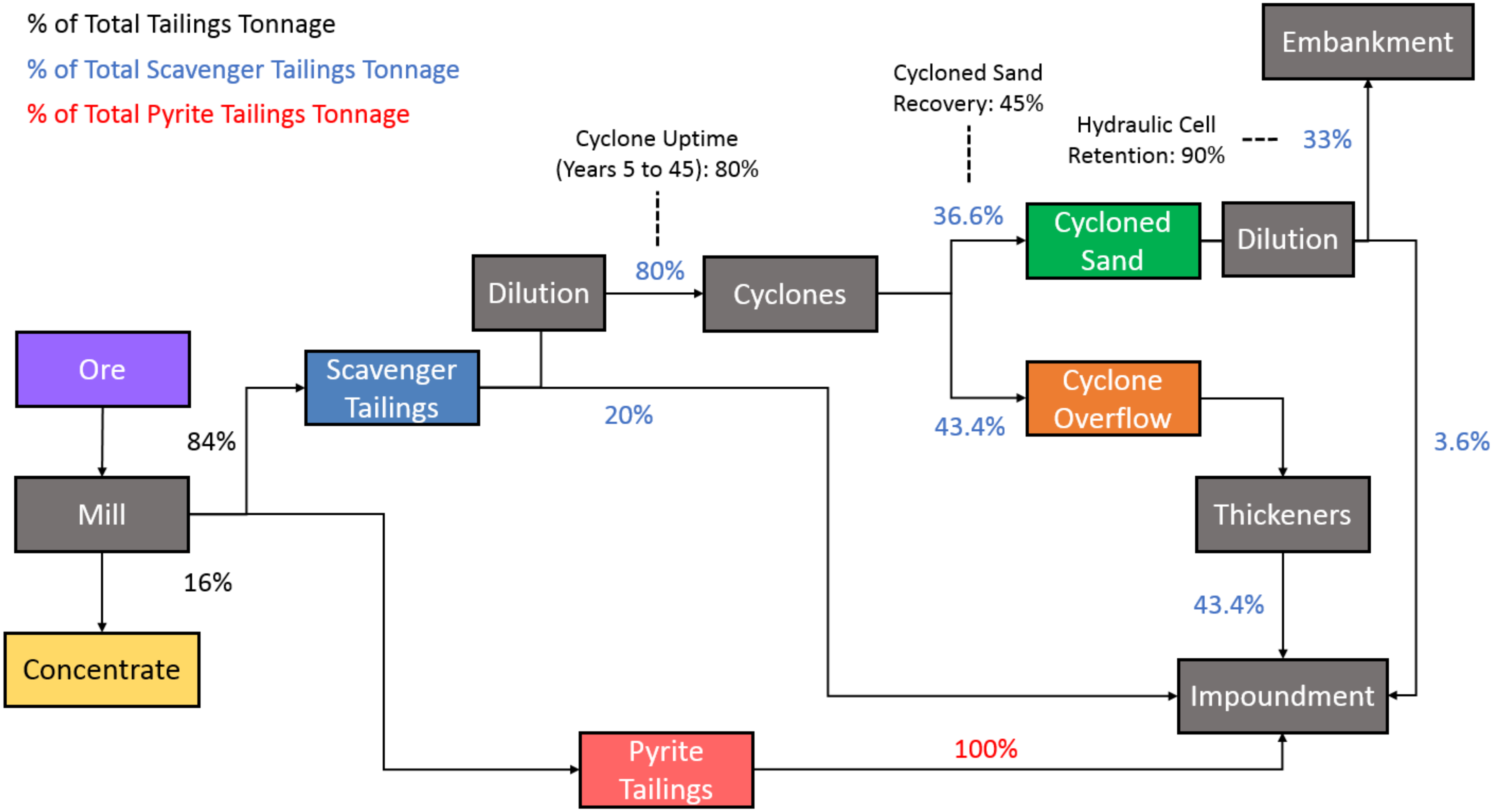


Figure 3.2 Modified Centerline Raise

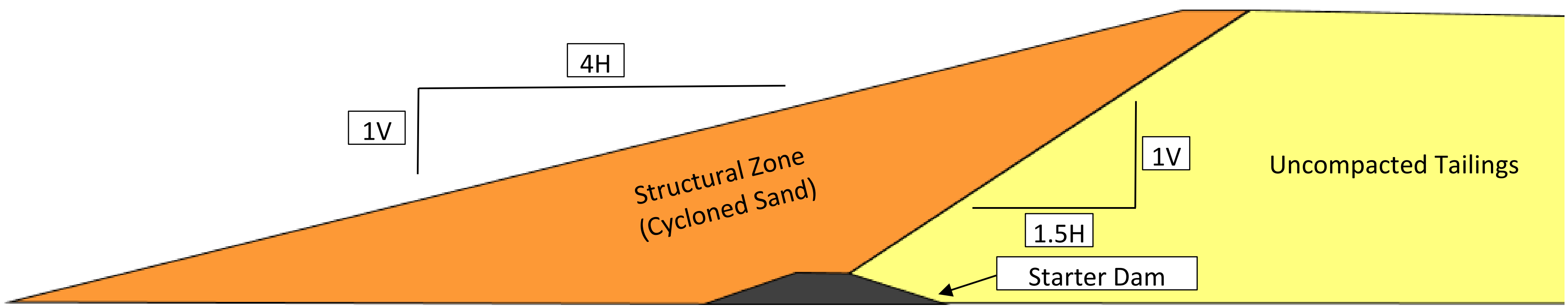
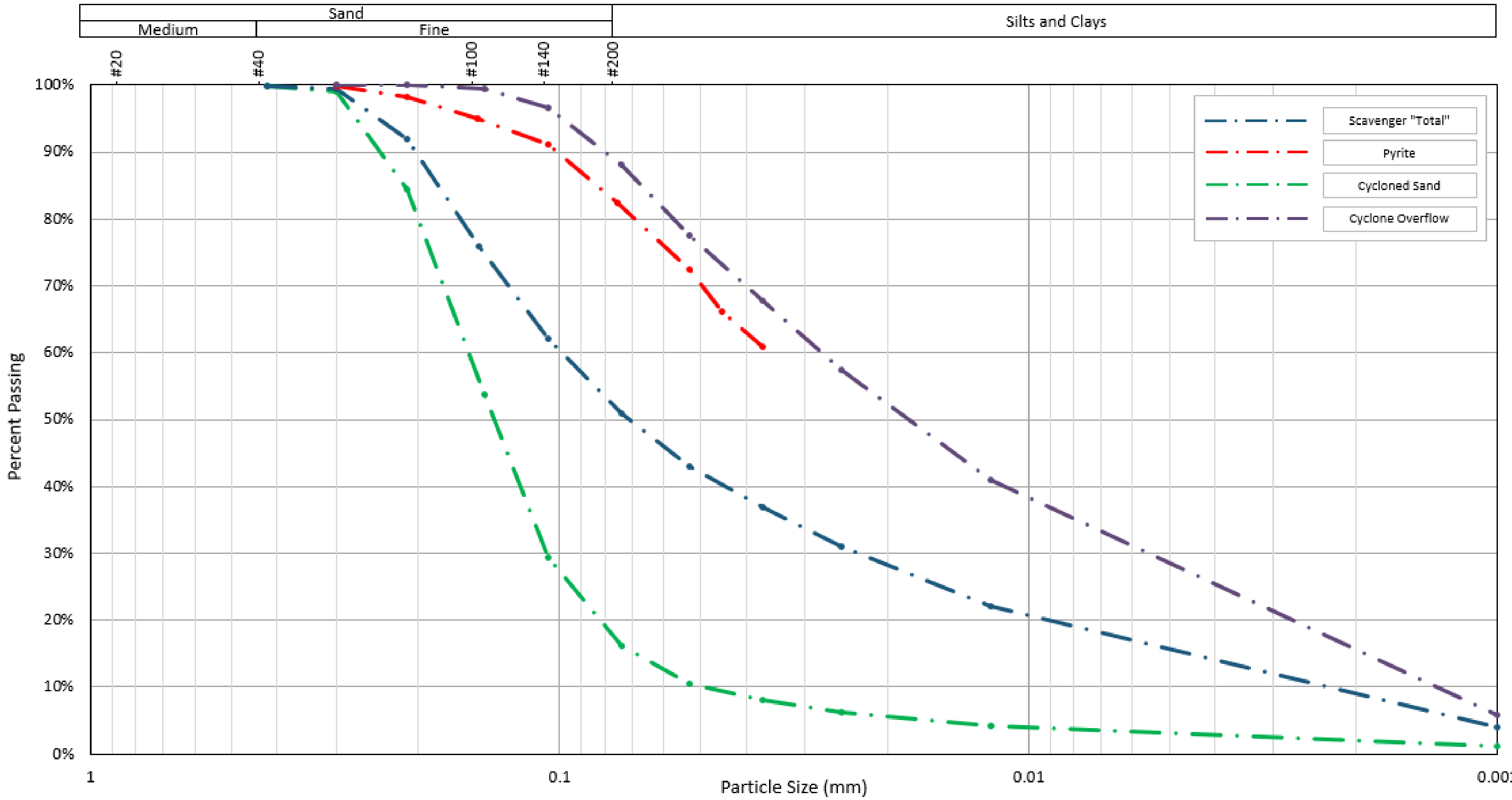


Figure 3.3 Target Tailings Gradations for Design



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DEIS Design for Alternative 3B – Near West Modified Proposed Action (High Density Thickened NPAG Scavenger and Segregated PAG Pyrite Cell), DBM

Resolution Copper Project

DEIS Design for Alternative 3B – Near West Modified Proposed Action (High Density Thickened NPAG Scavenger and Segregated PAG Pyrite Cell)

Technical Memorandum

Appendix I – Design Basis Memorandum

DISCLAIMER

1 INTRODUCTION

1.1 General

This is the design basis memorandum (DBM) for the design of Alternative 3B – Near West Modified Proposed Action (High-density thickened NPAG Scavenger and Segregated PAG Pyrite Cell) which is one of the tailings storage facility (TSF) design alternatives that Resolution Copper Mining LLC (RC) intends to include in the draft environmental impact statement (DEIS) for the proposed Resolution Copper Project. This TSF is located at the Near West location in Pinal County, Arizona. The DBM outlines the design objective as well as the design criteria and assumptions. This DBM is considered a "live" document that will be reviewed and updated throughout the design process.

1.2 Design Objective

The objective of the TSF is to store the tailings produced by the proposed Resolution Copper Project. The design incorporates findings from alternatives studies and site-specific data collected from site investigations, where applicable.

The design regulations and guidelines are outlined in Section 1.3, and the design criteria and assumptions are tabulated in Section 2.

The scope of the DEIS design is to provide a basis for comparing impacts from TSF alternatives.

1.3 Design Regulations and Guidelines

The TSF design is governed and guided by the regulations and guidelines listed below. The general approach adopted in this design is to set the design criteria based on the governing regulations, and then to supplement these regulations with guidelines from international practice where the governing regulations are not specific. Where international guidelines are more stringent than the governing regulations, consideration is also given to the additional measures needed to meet the more stringent guidelines.

Governing

Tailings Storage Facility and Seepage Collection Dams

- Arizona State Legislature. 2016. Arizona Administrative Code (A.A.C.).
  - Title 18. Environmental Quality. Chapter 9: Department of Environmental Quality – Water Pollution Control. Chapter 11: Department of Environmental Quality, Article 1: Water Quality Standards.
  - Arizona State Legislature. 2016. Arizona Revised Statutes (A.R.S.).
    - Title 49 – The Environment.
- Regulatory agency: Arizona Department of Environmental Quality (ADEQ).
- Environmental Protection Agency (EPA). Clean Water Act (CWA) - 33 U.S.C. §1251 et seq. (1972).
- Rio Tinto. 2017. D5 – Management of Tailings and Water Storage Facilities.

Seepage Collection Dams (only)

In addition to the above governing regulations, the seepage collection dams are regulated by the Arizona Department of Water Resources (ADWR). The additional application Arizona Administrative Code (A.A.C.) is Title 12. Natural Resources. Chapter 15. Department of Water Resources (A.A.C. R12-15).

Guidance

- Arizona Department of Environmental Quality (ADEQ). 2005. Arizona Mining Guidance Manual BADCT (Best Available Demonstrated Control Technology).
- British Columbia Ministry of Energy and Mines (MEM). 2016. *Health, Safety and Reclamation Code for Mines in British Columbia*.
- Canadian Dam Association (CDA). 2007a. *Dam Safety Guidelines (with 2013 revision).*
- Canadian Dam Association (CDA). 2007b. *Technical Bulletin: Hydrotechnical Considerations for Dam Safety*.
- Canadian Dam Association (CDA). 2014. *Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams*.
- Federal Emergency Management Agency (FEMA). 2005. *Federal Guidelines for Dam Safety – Earthquake Analyses and Design of Dams. FEMA-65.*
- Federal Emergency Management Agency (FEMA). 2013. *Selecting and Accommodating Inflow Design Floods for Dams. FEMA-P-94.*
- United States Army Corps of Engineers (USACE). 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).
- United States Army Corp of Engineers (USACE). 2004. *General Design and Construction Considerations for Earth and Rock-Fill Dams. EM 1110-2-2300.*
- United States Army Corp of Engineers (USACE). 2003. *Slope Stability. EM 1110-2-1902.*

1.4 BADCT Approach

The TSF will apply for an Aquifer Protection Permit (APP) with an “individual” Best Available Demonstrated Control Technology (BADCT) approach, which is performance based, and allows the applicant to select from all available Demonstrated Control Technologies (DCTs) that constitute BADCT. This process considers site specific characteristics, operational controls, and other DCTs.

Under the individual BADCT approach, the TSF is considered a “tailings impoundment” and will be designed in accordance with Section 3.5 of the BADCT manual (ADEQ 2005). The seepage dams are considered to be “surface ponds” and will be designed in accordance with Section 3.6 of the BADCT manual (ADEQ 2005) and the regulations pertaining to water dams (A.A.C. R12-15).

2 DESIGN CRITERIA

Table 2.1 Design Criteria

	Item	Design Criteria	Reference
1.0	**Tailings Storage Facility (TSF) Embankment Design**		
1.01a	CDA Consequence Classification	To be confirmed following inundation study	▪ CDA (2007a)
1.01b	Rio Tinto Risk Category	Class IV (considered Class IV until all necessary mitigations have been included in design)	▪ D5 Standard (Rio Tinto 2017)
1.02	Storage capacity	Capacity to store all NPAG scavenger (scavenger) and PAG pyrite (pyrite) tailings production	▪ RC requirement
1.03	Downstream slope	▪ No steeper than 2H:1V	▪ MEM (2016)
1.04	Minimum Factor of Safety	▪ Static (upstream or downstream) – 1.5 (during operation and long term) ▪ Liquefied/post-cyclic – 1.2 ▪ Rapid drawdown – N/A	▪ BADCT (ADEQ 2005) supplemented with MEM (2016) ▪ D5 Rio Tinto (2017) ▪ CDA (2007a) ▪ N/A
1.05	Deformations (seismic or static, e.g. settlement)	▪ For cases with no liquefiable materials, horizontal seismic coefficient for pseudo-static analysis = 0.6 x Peak ground acceleration (PGA). This seismic coefficient is selected to maintain consistency with the requirements of the seepage collection dams, as per A.A.C R12-15-1216. ▪ For elements of the TSF sensitive to deformation, a simplified deformation analysis is required. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not reduce freeboard sufficiently to lead to an uncontrolled release of fluid tailings, does not impact the functionality of the drains, etc.).	▪ BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
1.06	Seismicity	▪ Maximum Credible Earthquake (MCE). Earthquake design ground motions will be selected in future design stages for appropriate return period events.	BADCT (ADEQ 2005) supplemented with MEM (2016), CDA (2014), D5 Rio Tinto (2017) and industry practice
1.07	Pond Storage Capacity (within the Pyrite Cell)	See Figure 2.1 Storage capacity = minimum operating volume + maximum average seasonal volume + volume required for operational upset + volume for critical duration storm event including sediment (Environmental Design Flood and Inflow Design Flood) + volume required for “dry” freeboard (Table 2.1, Item 1.11)	BADCT (ADEQ 2005)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.08	Storage Volume for Operational Upset Conditions	RC to confirm after RC internal risk audit and to be updated in next stage of design.	
1.09	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. Design will assume 200-year 24 hr; EDF will be confirmed through water balance and water quality modeling.	BADCT (ADEQ 2005)
1.10	Inflow Design Flood (IDF) For Dam Safety	Return Period: Probable Maximum Flood (PMF) Duration: For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to contain the design flood volume. Therefore, the duration will be confirmed during the flood routing and water balance calculations: ▪ with a spillway: spillway sized for the critical duration of 6 hr to 72 hr; and ▪ without a spillway: minimum of 72 hr (to be confirmed based inflows and discharge rates).	BADCT (ADEQ 2005) FEMA (2013) MEM (2016) D5 Rio Tinto (2017)
1.11	"Dry" Freeboard for Perimeter Embankment	▪ Wind and wave run-up + 2 ft ▪ Wind event annual exceedance probability = 2-year ▪ Wave height and run-up to be calculated using industry standard methods ▪ Earthquake-induced settlements of the embankment crest to be assessed and included in minimum freeboard determination	▪ BADCT (ADEQ 2005) ▪ CDA (2007b) ▪ USACE (2002)
1.12	Beach length	Will become part of the Quantitative Performance Objectives (QPO) ▪ Sufficient to achieve seepage and hydraulic gradient criteria during normal operations and periods of flood storage. ▪ Sufficient to provide a secondary defense against loss of fluid tailings in the event of downstream slope displacement.	
1.13	Seepage	Water quality requirements at the point of compliance are to be assessed.	BADCT (ADEQ 2005), Clean Water Act (EPA) and Arizona State Legislature (A.A.C. R18-11)
1.14	Drains	▪ Provide drains/filters satisfying USACE (2004) guidelines to mitigate potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	USACE (2004)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.15	Construction and Operations	▪ Quantifiable performance objectives to be defined prior to construction. ▪ All construction and borrow materials with contingency to be defined prior to construction.	MEM (2016)
1.16	Closure	Planned closure landscape is to be a physically stable landform without a permanent water pond that meets point of compliance criteria.	D5 Rio Tinto (2017)
1.17	Closure Surface Diversions	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment.	BADCT (ADEQ 2005) D5 Rio Tinto (2017)
1.18	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact to structural zones, containment, other structures or the environment. BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.	BADCT (ADEQ 2005)
2.0	**Seepage Collection Dams**		
2.01	Assumed downstream hazard classification	High (will be reviewed for each individual seepage dam in future design stages).	A.A.C R12-15-1216
2.02	Downstream slope	As per Table 2.1, item 1.03	
2.03	Stability Factor of Safety (FOS)	▪ End of construction – Static (upstream or downstream) – 1.3 (≤ 50 ft high), 1.4 (> 50 ft high) ▪ Steady state seepage – Static – 1.5 ▪ Rapid drawdown – 1.2	A.A.C R12-15-1216 D5 Rio Tinto (2017)
2.04	Deformations (seismic or static, e.g. settlement)	▪ Pseudo-static – FOS = 1.0 with horizontal seismic coefficient = 0.6 x Peak ground acceleration (PGA). ▪ As per Table 2.1, item 1.05, where elements are sensitive to deformations, a simplified deformation analysis will be conducted to identify the potential displacements for comparison with allowable deformations for that element. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not impact the integrity of the dam core or the spillway, etc.)	A.A.C R12-15-1216 and BADCT (ADEQ 2005) D5 Rio Tinto (2017)
2.05	Seismicity	▪ MCE, assumed to be mean 1:10,000 year return period: ♦ Sensitivity to 95th percentile to be considered	A.A.C R12-15-1216 supplemented with MEM (2016) and CDA (2007a)
2.06	Pond Storage Capacity	See Table 2.1, item 1.07	
2.07	Storage Volume for Operational Upset Conditions	One week of average seepage and precipitation to account for a period of pump shut-down	

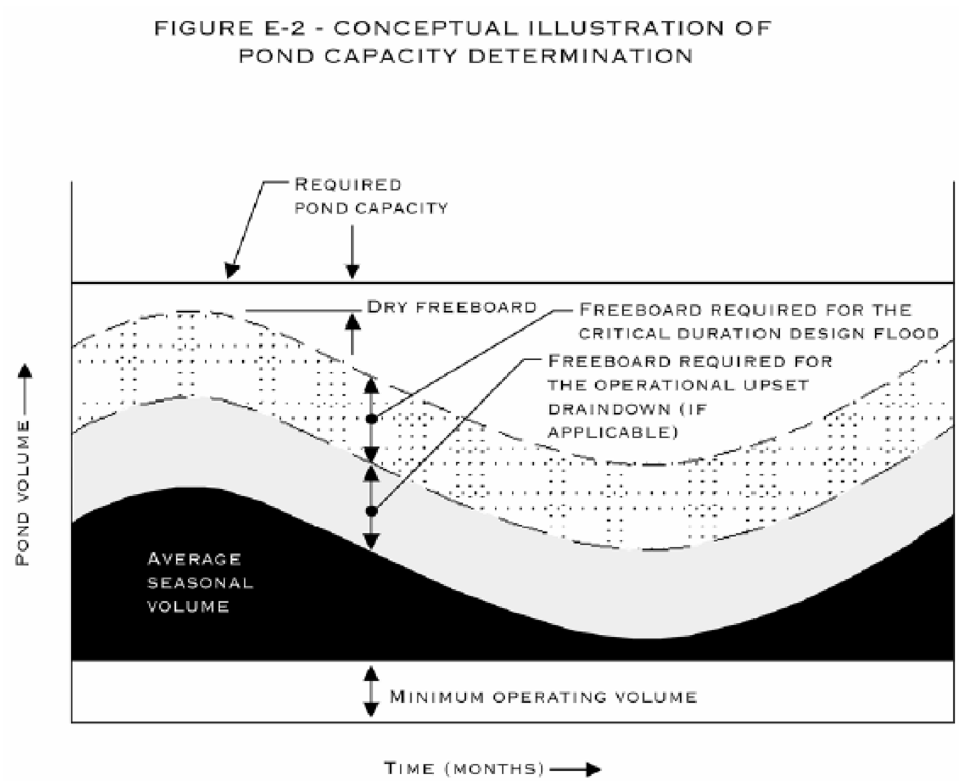
Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.08	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. TSF design will assume 200-year 24 hr; EDF will be confirmed through water balance and water quality modeling.	BADCT (ADEQ 2005)
2.09	Inflow Design Flood (IDF) For Dam Safety	Storm to be routed through spillway - Probable Maximum Flood (PMF) BADCT: Return Period: if failure of dam would pose an imminent risk to human life and/or high downstream incremental consequences the PMF should be used. Duration: For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to route the design flood volume. The range of storm duration to be considered are 6 hr to 72 hr. A.A.C R12-15-1216: For a high hazard potential dam, the applicant shall design the dam to withstand an inflow design flood that varies from .5 PMF to the full PMF, with size increasing based on persons at risk and potential for downstream damage. The applicant shall consider foreseeable future conditions. FEMA (2013): PMF for a dam classified as high hazard.	BADCT (ADEQ 2005) A.A.C R12-15-1216 D5 Rio Tinto (2017) FEMA (2013)
2.10	Freeboard	Largest of: ▪ IDF + wave run up with a critical wind annual exceedance probability of the 1 in 2 year event ▪ IDF + 3 ft ▪ 5 ft	A.A.C R12-15-1216 with consideration from CDA (2007b)
2.11	Low level outlet (or discharge - pump)	Can discharge 90% of storage volume within 30 days (minimum capacity).	A.A.C R12-15-1216
2.12	Seepage	See Table 2.1, item 1.13	
2.13	Drains	▪ Provide core and drains/filters satisfying USACE (2004) guidelines to limit potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	BADCT (ADEQ 2005), USACE (2004) and A.A.C R12-15-1216
2.14	Crest width	Minimum of dam height (centerline) divided by 5, plus 5 ft. Minimum crest width = 12 ft, maximum crest width = 25 ft.	A.A.C R12-15-1216

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.15	Erosion protection	Well graded, durable riprap, sized to withstand wave action, placed on a well graded pervious sand and gravel bedding or geotextile with filtering capacity suitable for the site.	A.A.C R12-15-1216
2.16	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment. (BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.)	BADCT (ADEQ 2005)

Figure 2.1 Pond Capacity Determination (ADEQ 2005)



3 DESIGN BASIS

Table 3.1 Design Assumptions, Constraints & Data Sources

	Item	Design Basis	Comments
1.0	**General Design Basis**		
1.01	TSF location	▪ Near West site, Pinal County, Arizona (USFS land) ▪ Coordinates (Arizona State Plane Central NAD83): 920,000' E, 880,000' N	
1.02	Mine Flow Sheet	Selective	
1.03	Mine life	41 years	Received from RC
1.04	TSF operating life	41 years	Received from RC
1.05	Tailings types	Two types of tailings are produced: ▪ scavenger tailings (84% of total weight); and ▪ pyrite tailings (16% of total weight).	Received from RC
1.06	Tailings technology	High-density thickened slurry (scavenger tailings); thickened slurry pyrite tailings).	
1.07	Tailings delivery	See process schematic (Figure 3.1). Scavenger "total" tailings and cyclone overflow discharged into the impoundment using a "thin lift" deposition method to maximize drying.	
1.08	Total tailings production	1.37 billion short tons	Received from RC
1.09	Ore and tailings production schedule	Table 3.2	
1.10	Units	U.S. Customary	
1.11	Embankment raise methodology	Hydraulically placed cycloned sand modified centerline (see Figure 3.2)	KCB (2017a)
1.12	Cycloned sand availability	Cycloned Sand Recovery: 45% Cyclone uptime: 50% (Year 1-2); 70% (Year 3-5); 80% (Year 6-41) Cycloned sand retention in hydraulic cells: 90%	Lower bound recovery from Krebs simulations (KCB 2018). To account for reduced efficiency at the start of operations; communicated by RC.
2.0	**Topography**		
2.01	Projection	Arizona State Plane Central	
2.02	Datum	NAD83	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

<table>
<tr><th></th><th>Item</th><th>Design Basis</th><th>Comments</th></tr>
<tr><td>2.03</td><td>Unit of measurement</td><td>U.S. Customary</td><td></td></tr>
<tr><td>2.04</td><td>Survey</td><td>2013 LiDAR survey received from RC on June 5/6, 2013.</td><td></td></tr>
<tr><td>3.0</td><td colspan="2">Seismicity</td><td></td></tr>
<tr><td>3.01</td><td>Ground Motions</td><td>Not analyzed at this stage of design (refer to Table 3.1, Item 8.02).</td><td></td></tr>
<tr><td>3.0</td><td colspan="2">Climate and Hydrology</td><td></td></tr>
<tr><td>4.01</td><td>Average precipitation (in inches)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>Total</th></tr><tr><td>2.0</td><td>2.0</td><td>2.0</td><td>0.8</td><td>0.3</td><td>0.3</td><td>1.9</td><td>2.8</td><td>1.5</td><td>1.2</td><td>1.4</td><td>2.1</td><td>18.2</td></tr></table></td><td>Data collected at the Superior climate station (ID: 028348) with gaps filled using data from the regional climate stations.</td></tr>
<tr><td>4.02</td><td>Wet and dry year precipitations</td><td>Consideration to wet and dry years for the water balance will not be made at this stage of design.</td><td></td></tr>
<tr><td>4.03</td><td>Average annual pan evaporation</td><td>96.5 in</td><td>Pan evaporation data collected at the Roosevelt 1 WNW climate station (ID: 027281).
Free water surface evaporation determined using the Evaporation Atlas for the Contiguous 48 United States (NOAA 1982).</td></tr>
<tr><td>4.04</td><td>Evapotranspiration for reference surface/crop (in inches)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>Total</th></tr><tr><td>2.9</td><td>3.4</td><td>5.0</td><td>6.6</td><td>8.5</td><td>9.2</td><td>9.0</td><td>8.0</td><td>7.0</td><td>5.8</td><td>3.8</td><td>3.1</td><td>72.3</td></tr></table></td><td>Calculated using the Penman-Monteith combined equation in Hydrus1D based on the generated Superior climate data set and reference vegetation parameters.</td></tr>
<tr><td>4.05</td><td>Natural catchment runoff coefficient</td><td>0.15</td><td>Calculated by dividing the average annual runoff from the nearby USGS hydromet station by the average annual precipitation at site (KCB 2014).</td></tr>
<tr><td>4.06</td><td>Probable Maximum Precipitation (PMP)</td><td><table><tr><th rowspan="2">Storm Type</th><th colspan="3">PMP Depth (inches)</th></tr><tr><th>6 hour Duration</th><th>24 hour Duration</th><th>72 hour Duration</th></tr><tr><td>General Winter</td><td>4.9</td><td>9.0</td><td>13.3</td></tr><tr><td>Tropical</td><td>12.4</td><td>16.3</td><td>20.4</td></tr><tr><td>Local</td><td>12.1</td><td>-</td><td>-</td></tr></table></td><td>Applied Weather Associates PMP Evaluation Tool. Determined as the critical storm for design. For the Near West site catchment.</td></tr>
<tr><td>4.07</td><td>Runoff coefficient during storm events</td><td>1.0</td><td>To account for high antecedent moisture conditions and the predominantly exposed rock in the catchment</td></tr>
<tr><td>4.08</td><td>Extreme point precipitation depths</td><td>See Table 3.3</td><td>From NOAA Atlas 14 (NOAA 2018).</td></tr>
</table>

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.0	**Tailings Characteristics and Deposition**			
		Scavenger Tailings	**Pyrite Tailings**	
5.01	Target gradation produced at mill	*"Total" Tailings:* Target P80 = 160 microns 50% fines (<74 microns) <10% clay (<2 microns)	Target P80 = 75 to 80 microns 80% fines (<74 microns) <20% clay (<2 microns)	Scavenger "Total" Tailings: Provided by RC. Pyrite Tailings: Provided by RC. Clay content assumed from previous test work on cleaner tailings. See Figure 3.3
5.02	Target gradation produced by cyclones	*Cycloned Sand (Underflow)*: Target P80 = 200 microns <20 % fines (<74 microns) 0% clay (<2 microns) *Cyclone Overflow:* Target P80 = 60 microns 90% fines (<74 microns) 15% clay (<2 microns)	N/A	Provided by RC. See Figure 3.3. Target fines content for cycloned sand to be less than 20%, based on seepage performance and constructability from other cycloned sand embankment case histories.
5.03	Specific gravity	2.78	3.87	Average values from KCB laboratory testing programs on scavenger "total" tailings and cleaner tailings.
5.04	Solids content pumped from the mill	65%	50%	Provided by RC
5.05	Cyclone solids content	*Cyclone Feed:* 35% *Cyclone Overflow:* 25% *Cycloned Sand:* 70%	N/A	From most recent Krebs simulations (KCB 2018).
5.06	Solids content discharged into TSF	*"Total" Tailings:* 70% *Cyclone Overflow:* 62% *Cycloned Sand:* 60%	50%	"Total" scavenger tailings and cyclone overflow solids content preliminarily estimated to minimize slurry bleed water, while still allowing for the use of a high-rate thickener type and allowing the tailings to be transported and deposited as a slurry. Cycloned sand solids content based on case history data and construction performance at other large cycloned sand embankments that use hydraulic cell construction. To be confirmed from ongoing rheology testing and future design and constructability trade-offs.
5.07	Liquefaction assumption	All potentially liquefiable tailings will liquefy at the TSF, regardless of triggering mechanism.		

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.08	Pyrite tailings management	N/A	Subaqueous deposition	
5.09	Tailings beach slopes (above water)	1% within 1,500 ft of discharge point, 0.5% thereafter	N/A	Scavenger Tailings - Based on topography and bathymetry surveys from two large, cycloned sand impoundment beaches and slopes below water. These facilities have long exposed beaches, up to five miles. High-density thickened tailings may have steeper slopes than unthickened slurry tailings for the first few hundred feet along the beach, however, the preliminary beach slopes were kept consistent with Alternative 3A at this conceptual stage.
5.10	Tailings beach slopes (below water)	N/A	10% within 100 ft of discharge point; 0.5% thereafter	Pyrite Tailings - Based on topography and bathymetry surveys of subaqueous disposal of high-pyrite tailings from floating barges.
5.11	Dry beach runoff coefficient	0.15	N/A	Estimate based on Hydrus1D infiltration modeling.
5.12	Dry density for annual staging assessments	*Interlayered "Total" Tailings and Cyclone Overflow (Composite Beach):* 75 pcf (first 5 years of operations); 81 pcf (remaining years of operations) *Cycloned Sand (compacted):* 113 pcf	106 pcf	KCB (2018)
6.0	**Cyclone Plant Design**			
6.01	No. of Clusters	2		
6.02	Feed Tonnage	5,040 dry stph		
6.03	Feed Flow	45,267 USGPM		
6.04	Solids Content of Feed, Overflow, Underflow	see Table 3.1, Item 5.05		
6.05	Pressure Drop	15 psi		
6.06	Target No. of Spare Cyclones per Cluster	2		

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
6.07	Target No. of Spare Ports per Cluster	1	
6.08	Selected Cyclone Model	gMAX15U	
6.09	Selected Cyclone Vortex	6.75 inches	
6.10	Selected Cyclone Apex	3 inches	
6.11	Selected Cyclone Diameter	15 inches	
6.12	Selected Operating Cyclones per Cluster	24	
6.13	Selected No. of Spare Cyclones per Cluster	2	
6.14	Selected No. of Cyclones Installed per Cluster	26	
6.15	Selected No. of Spare Ports per Cluster	2	
7.0	**Thickener Design**		
7.01	Thickener Type	High-Density	
7.02	No. of Thickeners	2	
7.03	Design Tonnage	144,000 tpd ore	
7.04	Diluted Feed %solids	20%	
7.05	Underflow %solids (Cyclone Overflow Feed)	62%	
7.06	Underflow %solids (Scavenger Total Tailings Feed)	70%	
7.07	Unit Settling Rate	0.98 ft^2/tpd	
7.08	Sizing Design Allowance	15%	
7.09	Thickener Diameter	250 ft	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
8.0	**Tailings Storage Facility (TSF) Impoundment Design**		
8.01	Design criteria	As per Table 2.1.	
8.02	Stability and Deformations	Embankment section (Figure 3.2) assumed to meet design stability and deformation criteria for DEIS	Based on preliminary stability analyses reported in KCB (2017a) and assumed typical foundation conditions at the Near West site (KCB 2017b)
8.03	Perimeter Embankment Crest width	100 ft	Sufficient to accommodate 2-way vehicle traffic, pipelines and any other equipment required to be on the crest (e.g. cyclones).
8.04	Perimeter Embankment Downstream Slope	3H:1V (see Figure 3.2)	Assumed based on preliminary stability analysis reported in KCB (2017a)
8.05	Perimeter Embankment Upstream Slope	1H:1V (see Figure 3.2)	Assumed based on preliminary stability analysis reported in KCB (2017a)
8.06	Pyrite Cell Splitter Berm Crest Width	100 ft	Sufficient to accommodate hydraulic cell construction
8.07	Pyrite Cell Splitter Berm Downstream Slope	Vertical	Assumed based on support provided on both sides of the berm by tailings. To be analyzed in future design stages.
8.08	Pyrite Cell Splitter Berm Upstream Slope	Vertical	
8.09	Liner	Pyrite cell: Engineered low-permeability liner[2] beneath the cell, and extended vertically to separate from scavenger tailings Scavenger area: selective engineered low-permeability liner[2] placement over the foundation	
8.10	Drainage	Sand and gravel drainage blanket in the embankment footprint; gravel/rockfill finger drains in existing drainage channels in the embankment footprint	
8.11	Closure	TSF Surfaces: slope, cover and revegetate to shed water, limit infiltration, limit erosion and return the landscape to a similar condition prior to mining. Pyrite management: limit oxygen ingress through subaqueous deposition, cover and encourage saturation of the pyrite tailings in the long term (i.e. after removal of the pond).	Approach agreed by RC

[2] The engineered low-permeability liner could be comprised of one or more of the following: compacted fine tailings, geomembrane liner, asphalt, slurry bentonite, and/or cemented paste tailings

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
9.0	**Pond Management**		
9.01	Pond management	▪ No permanent water pond in the scavenger tailings area; permanent pond maintained in the pyrite cell. Ponded water on the scavenger tailings surfaces will be collected and transferred to the pyrite cell.	D5 Rio Tinto (2017)
9.02	Minimum operating pond volume	▪ Minimum amount to keep pyrite tailings saturated and provide operating pond depth.	
9.03	Minimum operating pond depth	▪ Seepage Collection Dams: 10 ft for reclaim pump (could be accounted for by a sump). ▪ Minimum Water Cover above Maximum Tailings El. in pyrite cell: 10 ft	

Table 3.2 Mine and Tailings Production Schedule

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Care and Maintenance	2017	-	1	-	-	-
Care and Maintenance	2018	-	2	-	-	-
Care and Maintenance	2019	-	3	-	-	-
Care and Maintenance	2020	-	4	-	-	-
Construction	2021	-	5	-	-	-
Construction	2022	-	6	-	-	-
Construction	2023	-	7	-	-	-
Construction	2024	-	8	-	-	-
Construction	2025	-	9	-	-	-
Construction	2026	-	10	-	-	-
Construction	2027	-	11	-	-	-
First Ore	2028	1	12	5,346,486	766,631	6,113,118
Ramp up	2029	2	13	7,187,504	991,640	8,179,144
Ramp up	2030	3	14	7,897,945	1,014,556	8,912,501
Ramp up	2031	4	15	15,085,826	2,110,526	17,196,352
Ramp up	2032	5	16	21,902,288	3,328,288	25,230,577
Ramp up	2033	6	17	28,780,765	4,569,518	33,350,283
Ramp up	2034	7	18	34,178,734	5,793,075	39,971,810
Full Production	2035	8	19	37,849,588	7,340,459	45,190,047
Full Production	2036	9	20	37,128,274	8,184,034	45,312,308
Full Production	2037	10	21	36,749,978	8,772,867	45,522,845
Full Production	2038	11	22	37,121,210	8,792,910	45,914,120
Full Production	2039	12	23	38,040,923	8,019,027	46,059,950
Full Production	2040	13	24	37,486,298	6,800,935	44,287,232
Full Production	2041	14	25	39,582,789	6,518,836	46,101,626
Full Production	2042	15	26	39,666,729	6,589,905	46,256,634
Full Production	2043	16	27	39,211,923	6,919,174	46,131,097
Full Production	2044	17	28	38,679,739	7,360,739	46,040,478
Full Production	2045	18	29	38,273,841	7,838,027	46,111,868

Table 3.2 Mine and Tailings Production Schedule (cont'd)

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Full Production	2046	19	30	38,130,733	8,150,877	46,281,610
Full Production	2047	20	31	38,448,597	7,968,471	46,417,068
Full Production	2048	21	32	38,926,908	7,537,946	46,464,854
Full Production	2049	22	33	39,028,952	7,382,565	46,411,517
Full Production	2050	23	34	39,006,219	7,367,901	46,374,120
Full Production	2051	24	35	38,564,309	7,824,341	46,388,650
Full Production	2052	25	36	38,008,651	8,406,901	46,415,552
Full Production	2053	26	37	37,822,090	8,629,862	46,451,952
Full Production	2054	27	38	38,599,981	7,902,469	46,502,450
Full Production	2055	28	39	39,472,443	6,988,070	46,460,513
Full Production	2056	29	40	39,579,974	6,796,869	46,376,843
Full Production	2057	30	41	39,595,841	6,786,681	46,382,522
Full Production	2058	31	42	39,503,382	6,740,343	46,243,725
Ramp Down	2059	32	43	31,481,866	5,391,484	36,873,350
Ramp Down	2060	33	44	24,576,943	4,320,111	28,897,054
Ramp Down	2061	34	45	18,707,166	3,478,519	22,185,685
Ramp Down	2062	35	46	13,146,108	2,643,079	15,789,186
Ramp Down	2063	36	47	9,566,562	1,952,428	11,518,989
Ramp Down	2064	37	48	4,993,554	1,079,281	6,072,835
Ramp Down	2065	38	49	2,121,484	545,241	2,666,725
Ramp Down	2066	39	50	928,110	274,819	1,202,929
Ramp Down	2067	40	51	326,877	99,724	426,602
Ramp Down	2068	41	52	19,505	4,936	24,440
Closure	2069	-	53	-	-	-
			TOTAL TAILINGS	**1,150,727,095**	**219,984,066**	**1,370,711,161**

Notes: Tailings production schedule supplied by Resolution Copper.
Mine plan descriptions, mine years and modeling years supplied by Resolution Copper.

Table 3.3 Precipitation Depth-Duration-Frequency Estimates for the TSF

Average Recurrence Interval (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr	2 day	3 day	4 day	7 day	10 day	20 day	30 day	45 day	60 day
Precipitation in inches																			
1	0.2	0.4	0.4	0.6	0.7	0.9	0.9	1.1	1.3	1.6	1.8	2.0	2.1	2.4	2.7	3.3	4.0	4.7	5.5
2	0.3	0.5	0.6	0.8	1.0	1.1	1.2	1.4	1.7	2.0	2.3	2.5	2.7	3.0	3.4	4.2	5.1	6.0	6.9
5	0.4	0.6	0.8	1.1	1.3	1.5	1.5	1.8	2.1	2.6	2.9	3.2	3.5	3.9	4.3	5.4	6.5	7.7	8.7
10	0.5	0.8	0.9	1.3	1.6	1.7	1.8	2.1	2.4	3.0	3.5	3.8	4.1	4.7	5.1	6.4	7.6	8.9	10.1
25	0.6	0.9	1.1	1.5	1.9	2.1	2.2	2.5	2.8	3.6	4.2	4.6	5.0	5.8	6.2	7.7	9.1	10.6	11.9
50	0.7	1.0	1.3	1.7	2.2	2.4	2.5	2.8	3.2	4.1	4.7	5.2	5.7	6.7	7.2	8.7	10.3	12.0	13.3
100	0.8	1.2	1.5	2.0	2.4	2.7	2.8	3.1	3.5	4.6	5.3	5.9	6.5	7.6	8.2	9.8	11.6	13.3	14.7
200	0.9	1.3	1.6	2.2	2.7	3.0	3.1	3.4	3.9	5.1	5.9	6.6	7.4	8.7	9.2	10.9	12.9	14.6	16.1
500	1.0	1.5	1.8	2.4	3.0	3.4	3.6	3.9	4.4	5.8	6.8	7.7	8.5	10.2	10.7	12.4	14.7	16.5	17.9
1000	1.1	1.6	2.0	2.7	3.3	3.7	3.9	4.2	4.7	6.4	7.4	8.5	9.5	11.4	12.0	13.6	16.1	17.9	19.3

Note: From NOAA Atlas 14 (NOAA 2018) for the Near West site.

Figure 3.1 Process Schematic

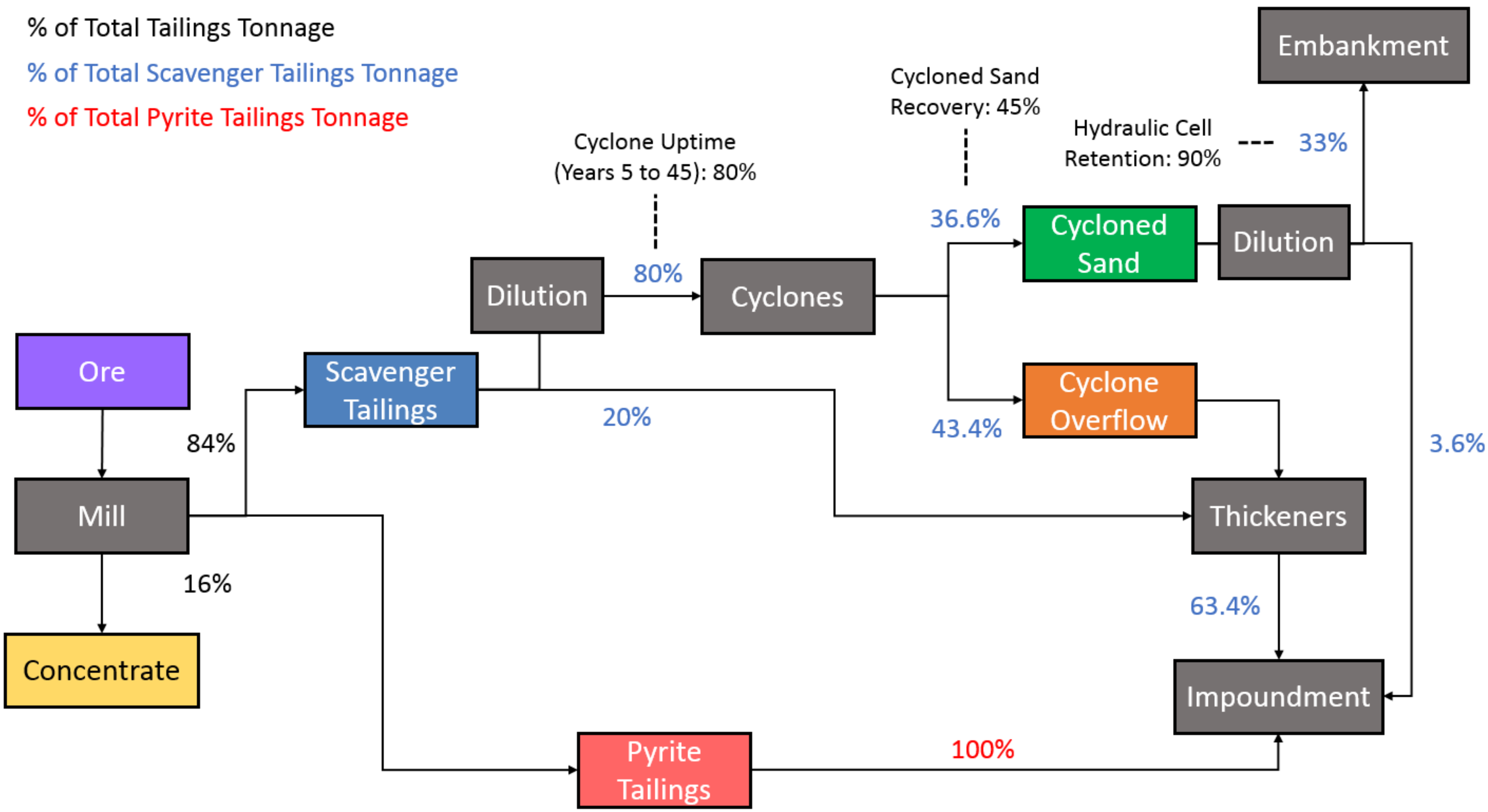


Figure 3.2 Modified Centerline Raise

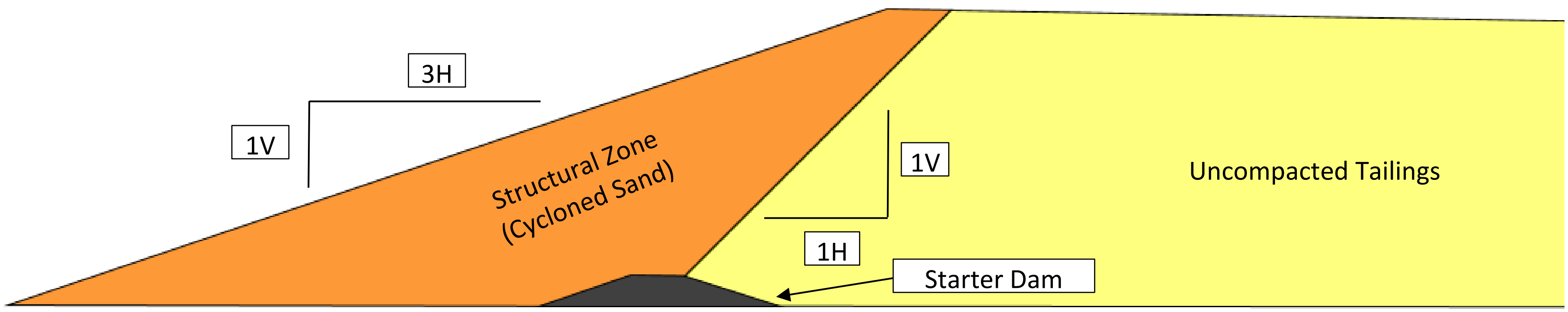
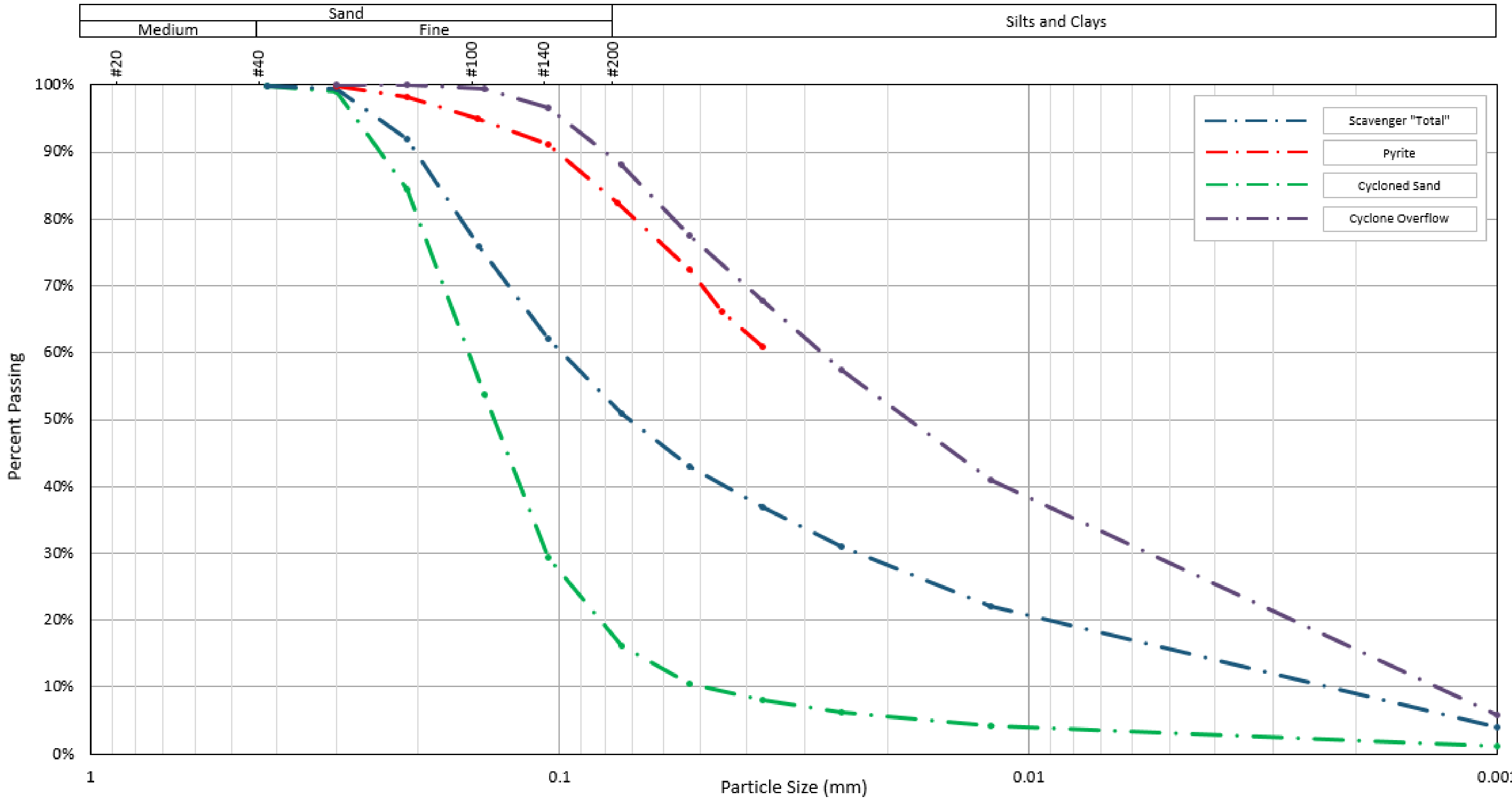


Figure 3.3 Target Tailings Gradations for Design



4 ADDITIONAL REFERENCES

Klohn Crippen Berger Ltd. (KCB). 2014. *Near West Tailings Management Mine Plan of Operations Study.* September 5.

Klohn Crippen Berger Ltd. (KCB). 2017a. *Near West Tailings Storage Facility Embankment Design Alternatives Analysis.* March 2.

Klohn Crippen Berger Ltd. (KCB). 2017b. *Near West Tailings Storage Facility Geotechnical Site Characterization Report.* October 2017.

Klohn Crippen Berger Ltd. (KCB). 2018. *Resolution Tailings Geotechnical Characterization – Rev. 1.* April 24.

Lettis Consultants International Inc. (LCI). 2017. *Updated Site-Specific Seismic Hazard and Development of Time Histories for Resolution Copper's Near West Site, Southern Arizona.* November 27.

National Oceanic and Atmospheric Administration (NOAA). 2018. "NOAA Atlas 14 Point Precipitation Frequency Estimates: AZ." Accessed January 15, 2018. https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

DEIS Design for Alternative 4 – Silver King Filtered, DBM

Resolution Copper Project

DEIS Design for Alternative 4 – Silver King Filtered

Technical Memorandum

Appendix I – Design Basis Memorandum

DISCLAIMER

1 INTRODUCTION

1.1 General

This is the design basis memorandum (DBM) for the design of Alternative 4 – Silver King Filtered which is one of the tailings storage facility (TSF) design alternatives that Resolution Copper Mining LLC (RC) intends to include in the draft environmental impact statement (DEIS) for the proposed Resolution Copper Project. This TSF is located at the Silver King Canyon location in Pinal County, Arizona. The DBM outlines the design objective as well as the design criteria and assumptions. This DBM is considered a “live” document that will be reviewed and updated throughout the design process.

1.2 Design Objective

The objective of the TSF is to store the tailings produced by the proposed Resolution Copper Project. The design incorporates findings from alternatives studies and site-specific data collected from site investigations, where applicable.

The design regulations and guidelines are outlined in Section 1.3, and the design criteria and assumptions are tabulated in Section 2.

The scope of the DEIS design is to provide a basis for comparing impacts from TSF alternatives. The design is tailored to meet United States Forest Service (USFS) requirements for the EIS.

1.3 Design Regulations and Guidelines

The TSF design is governed and guided by the regulations and guidelines listed below. The general approach adopted in this design is to set the design criteria based on the governing regulations, and then to supplement these regulations with guidelines from international practice where the governing regulations are not specific. Where international guidelines are more stringent than the governing regulations, consideration is also given to the additional measures needed to meet the more stringent guidelines.

Governing

Tailings Storage Facility and External Water Collection Dams

- Arizona State Legislature. 2016. Arizona Administrative Code (A.A.C.).
    - Title 18. Environmental Quality. Chapter 9: Department of Environmental Quality – Water Pollution Control. Chapter 11: Department of Environmental Quality, Article 1: Water Quality Standards.
    - Arizona State Legislature. 2016. Arizona Revised Statutes (A.R.S.).
        - Title 49 – The Environment.
- Regulatory agency: Arizona Department of Environmental Quality (ADEQ).

- Environmental Protection Agency (EPA). Clean Water Act (CWA) - 33 U.S.C. §1251 et seq. (1972).
- Rio Tinto. 2017. D5 – Management of Tailings and Water Storage Facilities.

<u>External Water Collection Dams (only)</u>

In addition to the above governing regulations, the seepage collection dams are regulated by the Arizona Department of Water Resources (ADWR). The additional application Arizona Administrative Code (A.A.C.) is Title 12. Natural Resources. Chapter 15. Department of Water Resources (A.A.C. R12-15).

Guidance

- Arizona Department of Environmental Quality (ADEQ). 2005. Arizona Mining Guidance Manual BADCT (Best Available Demonstrated Control Technology).
- British Columbia Ministry of Energy and Mines (MEM). 2016. *Health, Safety and Reclamation Code for Mines in British Columbia*.
- Canadian Dam Association (CDA). 2007a. *Dam Safety Guidelines (with 2013 revision).*
- Canadian Dam Association (CDA). 2007b. *Technical Bulletin: Hydrotechnical Considerations for Dam Safety*.
- Canadian Dam Association (CDA). 2014. *Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams*.
- Federal Emergency Management Agency (FEMA). 2005. *Federal Guidelines for Dam Safety – Earthquake Analyses and Design of Dams. FEMA-65.*
- Federal Emergency Management Agency (FEMA). 2013. *Selecting and Accommodating Inflow Design Floods for Dams. FEMA-P-94.*
- United States Army Corps of Engineers (USACE). 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).
- United States Army Corp of Engineers (USACE). 2004. *General Design and Construction Considerations for Earth and Rock-Fill Dams. EM 1110-2-2300.*
- United States Army Corp of Engineers (USACE). 2003. *Slope Stability. EM 1110-2-1902.*

<u>Upstream Diversion Dams (only)</u>

The upstream diversion dams are regulated in the same way as the external water collection dams with the exception of ADEQ, as they are not considered part of the TSF.

1.4 BADCT Approach

The TSF will apply for an Aquifer Protection Permit (APP) with an "individual" Best Available Demonstrated Control Technology (BADCT) approach, which is performance based, and allows the applicant to select from all available Demonstrated Control Technologies (DCTs) that constitute BADCT. This process considers site specific characteristics, operational controls, and other DCTs.

Under the individual BADCT approach, the TSF is considered a “tailings impoundment[1]” and will be designed in accordance with Section 3.5 of the BADCT manual (ADEQ 2005). The external water collection dams are considered to be “surface ponds” and will be designed in accordance with Section 3.6 of the BADCT manual (ADEQ 2005) and the regulations pertaining to water dams (A.A.C. R12-15).

[1] BADCT (ADEQ 2005) defines a tailings impoundment as one storing thickened tailings slurry and does not provide separate guidance provided for filtered tailings piles. For this DBM, design criteria for tailings impoundments are applied for filtered tailings piles.

2 DESIGN CRITERIA

Table 2.1 Design Criteria

	Item	Design Criteria	Reference
1.0	**Tailings Storage Facility (TSF) Scavenger and Pyrite Tailings Pile Design**		
1.01a	CDA Consequence Classification	Runout analysis required to confirm.	▪ CDA (2007a)
1.01b	Rio Tinto Risk Category	Assumed Class IV.	▪ D5 Standard (Rio Tinto 2017)
1.02	Storage capacity	Capacity to store all NPAG scavenger (scavenger) and PAG pyrite (pyrite) tailings production.	▪ RC requirement
1.03	Downstream slope	▪ No steeper than 2H:1V	▪ MEM (2016)
1.04	Minimum Factor of Safety	▪ Static (upstream or downstream) – 1.5 (during operation and long term) ▪ Liquefied/post-cyclic – 1.2 ▪ Rapid drawdown – N/A	▪ BADCT (ADEQ 2005) supplemented with MEM (2016) ▪ D5 Rio Tinto (2017) ▪ CDA (2007a) ▪ N/A
1.05	Deformations (seismic or static, e.g. settlement)	▪ For cases with no liquefiable materials, horizontal seismic coefficient for pseudo-static analysis = 0.6 x Peak ground acceleration (PGA). This seismic coefficient is selected to maintain consistency with the requirements of the seepage collection dams, as per A.A.C R12-15-1216. ▪ For elements of the TSF sensitive to deformation, a simplified deformation analysis is required. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not impact the functionality of the drains, engineered low permeability liners, etc.).	BADCT (ADEQ 2005) D5 Rio Tinto (2017)
1.06	Seismicity	▪ Maximum Credible Earthquake (MCE). Earthquake design ground motions would be selected for appropriate return period events.	BADCT (ADEQ 2005) supplemented with MEM (2016), CDA (2014), D5 Rio Tinto (2017) and industry practice
1.07	Tailings Surface Water Management	The tailings pile and collection ditches will be designed to safely pass the Probable Maximum Flood from the tailings surface (e.g. sloped and with sufficient freeboard so that flooded water will not overtop and erode the structural zones).	BADCT (ADEQ 2005)
1.08	Seepage	Water quality requirements at the point of compliance are to be assessed.	BADCT (ADEQ 2005), Clean Water Act (EPA) and Arizona State Legislature (A.A.C. R18-11)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.09	Drains	▪ Provide drains/filters satisfying USACE (2004) guidelines. ▪ Drains designed to maintain phreatic surface to acceptable levels within the structural zones with adequate safety factor to account from clogging and uncertainty.	USACE (2004)
1.10	Construction and Operations	▪ Quantifiable performance objectives to be defined prior to construction. ▪ All construction and borrow materials with contingency to be defined prior to construction.	MEM (2016)
1.11	Closure	Planned closure landscape is to be a physically stable landform without a permanent water pond that meets point of compliance criteria.	D5 Rio Tinto (2017)
1.12	Closure Surface Diversions	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment.	BADCT (ADEQ 2005) D5 Rio Tinto (2017)
1.13	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact to structural zones, containment, other structures or the environment. BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.	BADCT (ADEQ 2005)
2.0	**External Water Collection Dams**		
2.01	Assumed downstream hazard classification	High (would need to be assessed for each individual seepage dam).	A.A.C R12-15-1216
2.02	Crest width	Minimum of dam height (centerline) divided by 5, plus 5 ft. Minimum crest width = 12 ft, maximum crest width = 25 ft.	A.A.C R12-15-1216
2.03	Downstream slope	As per Table 2.1, item 1.03.	
2.04	Stability Factor of Safety (FOS)	▪ End of construction – Static (upstream or downstream) – 1.3 (≤ 50 ft high), 1.4 (> 50 ft high) ▪ Steady state seepage – Static – 1.5 ▪ Rapid drawdown – 1.2	A.A.C R12-15-1216 D5 Rio Tinto (2017)
2.05	Deformations (seismic or static, e.g. settlement)	▪ Pseudo-static – FOS = 1.0 with horizontal seismic coefficient = 0.6 x Peak ground acceleration (PGA). ▪ As per Table 2.1, item 1.05, where elements are sensitive to deformations, a simplified deformation analysis will be conducted to identify the potential displacements for comparison with allowable deformations for that element. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not impact the integrity of the dam core or the spillway, etc.).	A.A.C R12-15-1216 and BADCT (ADEQ 2005) D5 Rio Tinto (2017)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.06	Seismicity	▪ MCE, assumed to be mean 1:10,000 year return period: ♦ Sensitivity to 95th percentile to be considered	A.A.C R12-15-1216 supplemented with MEM (2016) and CDA (2007a)
2.07	Pond Storage Capacity	Storage capacity = sediment storage + minimum operating volume + maximum average seasonal volume + volume required for operational upset + volume for critical duration storm event including sediment (Environmental Design Flood and Inflow Design Flood) + volume required for freeboard (see Table 2.1, item 2.11)	BADCT (ADEQ 2005)
2.08	Storage Volume for Operational Upset Conditions	One week of average seepage and precipitation to account for a period of pump shut-down	
2.09	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. Scavenger tailings water collection dam sized for the 200-year 24 hr. Pyrite tailings water collection dam sized more stringently for the 200-year 7-day event (due to concerns with poor water quality). EDF would be confirmed through water balance and water quality modeling.	BADCT (ADEQ 2005)
2.10	Inflow Design Flood (IDF) For Dam Safety	Storm to be routed through spillway - Probable Maximum Flood (PMF) <u>BADCT:</u> <u>Return Period:</u> if failure of dam would pose an imminent risk to human life and/or high downstream incremental consequences the PMF should be used. <u>Duration:</u> For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to route the design flood volume. The range of storm duration to be considered are 6 hr to 72 hr. <u>A.A.C R12-15-1216:</u> For a high hazard potential dam, the applicant shall design the dam to withstand an inflow design flood that varies from .5 PMF to the full PMF, with size increasing based on persons at risk and potential for downstream damage. The applicant shall consider foreseeable future conditions. <u>FEMA (2013):</u> PMF for a dam classified as high hazard.	BADCT (ADEQ 2005) A.A.C R12-15-1216 D5 Rio Tinto (2017) FEMA (2013)

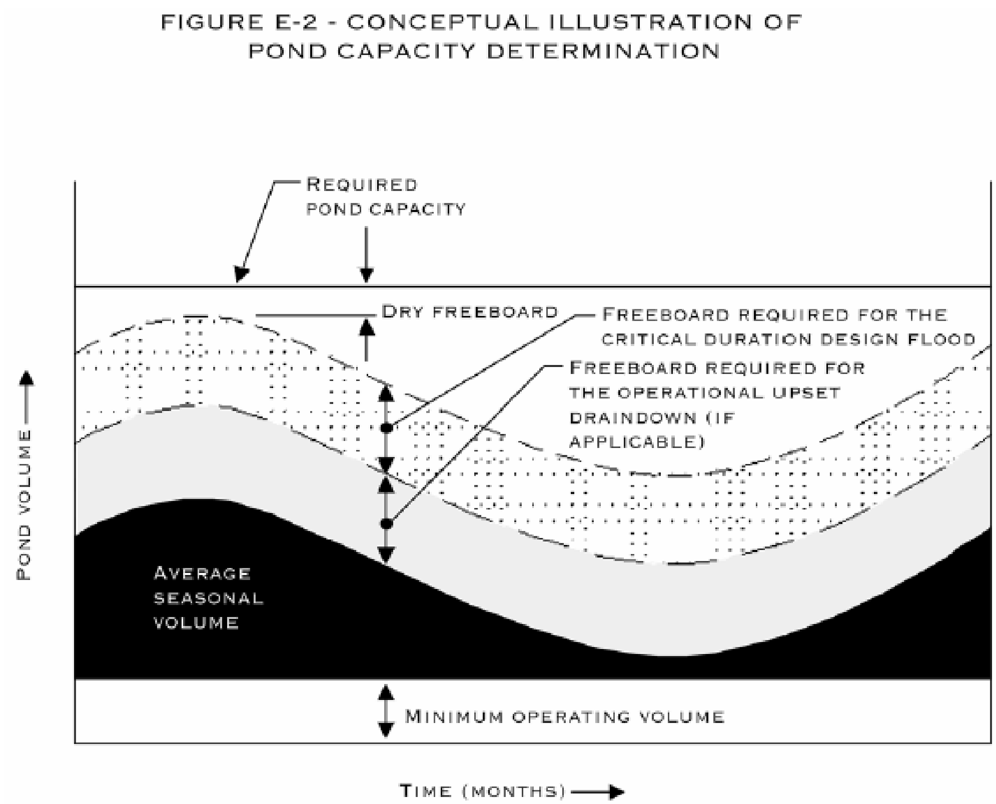
Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.11	Freeboard	Largest of: ▪ IDF + wave run up with a critical wind annual exceedance probability of the 1 in 2 year event ▪ IDF + 3 ft ▪ 5 ft	A.A.C R12-15-1216 with consideration from CDA (2007b)
2.12	Low level outlet (or discharge - pump)	Can discharge 90% of storage volume within 30 days (minimum capacity).	A.A.C R12-15-1216
2.13	Seepage	See Table 2.1, item 1.08.	
2.14	Drains	▪ Provide core and drains/filters satisfying USACE (2004) guidelines to limit potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	BADCT (ADEQ 2005), USACE (2004) and A.A.C R12-15-1216
2.15	Erosion protection	Well graded, durable riprap, sized to withstand wave action, placed on a well graded pervious sand and gravel bedding or geotextile with filtering capacity suitable for the site.	A.A.C R12-15-1216
2.16	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment. (BADCT requires, at a minimum, that if the structure is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows)	BADCT (ADEQ 2005)
3.0	**Upstream Diversion Dams**		
3.01	Assumed downstream hazard classification	High (would need to be assessed for each individual dam)	A.A.C R12-15-1216
3.02	Crest width	Minimum of dam height (centerline) divided by 5, plus 5 ft. Minimum crest width = 12 ft, maximum crest width = 25 ft.	A.A.C R12-15-1216
3.03	Downstream slope	As per Table 2.1, item 1.03.	
3.04	Stability Factor of Safety (FOS)	▪ End of construction – Static (upstream or downstream) – 1.3 (≤ 50 ft high), 1.4 (> 50 ft high) ▪ Steady state seepage – Static – 1.5 ▪ Rapid drawdown – 1.2	A.A.C R12-15-1216 Rio Tinto (2017)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
3.05	Deformations (seismic or static, e.g. settlement)	▪ Pseudo-static – FOS = 1.0 with horizontal seismic coefficient = 0.6 x Peak ground acceleration (PGA). ▪ As per Table 2.1, item 1.05, where elements are sensitive to deformations, a simplified deformation analysis will be conducted to identify the potential displacements for comparison with allowable deformations for that element. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not impact the integrity of the dam core or the spillway, etc.)	A.A.C R12-15-1216 and BADCT (ADEQ 2005)
3.06	Seismicity	▪ MCE, assumed to be mean 1:10,000 year return period: ♦ Sensitivity to 95th percentile to be considered	A.A.C R12-15-1216 supplemented with MEM (2016) and CDA (2007a)
3.07	Inflow Design Flood (IDF) For Dam Safety	A.A.C R12-15-1216: For a high hazard potential dam, the applicant shall design the dam to withstand an inflow design flood that varies from .5 PMF to the full PMF, with size increasing based on persons at risk and potential for downstream damage. The applicant shall consider foreseeable future conditions. FEMA (2013): PMF for a dam classified as high hazard.	A.A.C R12-15-1216 D5 Rio Tinto (2017) FEMA (2013)
3.08	Freeboard	Largest of: ▪ IDF + wave run up with a critical wind annual exceedance probability of the 1 in 2 year event ▪ IDF + 3 ft ▪ 5 ft	A.A.C R12-15-1216 with consideration from CDA (2007b)
3.09	Low level outlet (or discharge - pump)	Can discharge 90% of storage volume within 30 days (minimum capacity).	A.A.C R12-15-1216

Figure 2.1 Pond Capacity Determination (ADEQ 2005)



3 DESIGN BASIS

Table 3.1 Design Assumptions, Constraints & Data Sources

	Item	Design Basis	Comments
1.0	**General Design Basis**		
1.01	TSF location	▪ Silver King Canyon site, Pinal County, Arizona (USFS land) ▪ Coordinates (Arizona State Plane Central NAD83): 945,000' E, 850,000' N	
1.02	Mine Flow Sheet	Selective	
1.03	Mine life	41 years	Received from RC; email dated December 12, 2018
1.04	TSF operating life	41 years	Received from RC; email dated December 12, 2018
1.05	Tailings types	Two types of tailings are produced: ▪ scavenger tailings (84% of total weight); and ▪ pyrite tailings (16% of total weight).	Received from RC; email dated December 12, 2018
1.06	Tailings technology	Filtered (scavenger and pyrite tailings)	
1.07	Tailings delivery	See process schematic (Figure 3.1).	
1.08	Total tailings production	1.37 billion short tons	Received from RC; email dated December 12, 2018
1.09	Ore and tailings production schedule	Table 3.2.	
1.10	Units	U.S. Customary	
2.0	**Topography**		
2.01	Projection	Arizona State Plane Central	
2.02	Datum	NAD83	
2.03	Unit of measurement	U.S. Customary	
2.04	Survey	2013 LiDAR survey received from RC on June 5/6, 2013.	
3.0	**Seismicity**		
3.01	Ground Motions	Not analyzed for this design (refer to Table 3.1, Item 7.02).	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

<table>
<tr><th></th><th>Item</th><th>Design Basis</th><th>Comments</th></tr>
<tr><td>4.0</td><td>Climate and Hydrology</td><td></td><td></td></tr>
<tr><td>4.01</td><td>Average precipitation (in inches)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>Total</th></tr><tr><td>2.0</td><td>2.0</td><td>2.0</td><td>0.8</td><td>0.3</td><td>0.3</td><td>1.9</td><td>2.8</td><td>1.5</td><td>1.2</td><td>1.4</td><td>2.1</td><td>18.2</td></tr></table></td><td>Data collected at the Superior climate station (ID: 028348) with gaps filled using data from the regional climate stations.</td></tr>
<tr><td>4.02</td><td>Wet and dry year precipitations</td><td>Consideration to wet and dry years for the water balance will not be made for this design.</td><td></td></tr>
<tr><td>4.03</td><td>Average annual pan evaporation</td><td>96.5 in</td><td>Pan evaporation data collected at the Roosevelt 1 WNW climate station (ID: 027281).
Free water surface evaporation determined using the Evaporation Atlas for the Contiguous 48 United States (NOAA 1982).</td></tr>
<tr><td>4.04</td><td>Evapotranspiration for reference surface/crop (in inches)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>Total</th></tr><tr><td>2.9</td><td>3.4</td><td>5.0</td><td>6.6</td><td>8.5</td><td>9.2</td><td>9.0</td><td>8.0</td><td>7.0</td><td>5.8</td><td>3.8</td><td>3.1</td><td>72.3</td></tr></table></td><td>Calculated using the Penman-Monteith combined equation in Hydrus1D based on the generated Superior climate data set and reference vegetation parameters.</td></tr>
<tr><td>4.05</td><td>Natural catchment runoff coefficient</td><td>0.15</td><td>Calculated by dividing the average annual runoff from the nearby USGS hydromet station by the average annual precipitation at site (KCB 2014).</td></tr>
<tr><td>4.06</td><td>Probable Maximum Precipitation (PMP)</td><td><table><tr><th rowspan="2">Storm Type</th><th colspan="3">PMP Depth (inches)</th></tr><tr><th>6 hour Duration</th><th>24 hour Duration</th><th>72 hour Duration</th></tr><tr><td>General Winter</td><td>6</td><td>11</td><td>16</td></tr><tr><td>Tropical</td><td>15.5</td><td>20.3</td><td>24</td></tr><tr><td>Local</td><td>13.7</td><td>-</td><td>-</td></tr></table></td><td>Applied Weather Associates PMP Evaluation Tool.
Determined as the critical storm for design.
For Whitford Canyon</td></tr>
<tr><td>4.07</td><td>Runoff coefficient during storm events</td><td>1.0</td><td>To account for high antecedent moisture conditions and the predominantly exposed rock in the catchment</td></tr>
<tr><td>4.08</td><td>Extreme point precipitation depths</td><td>See Table 3.3</td><td>From NOAA Atlas 14 (NOAA 2018).</td></tr>
</table>

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.0	**Tailings Characteristics and Deposition**			
		Scavenger Tailings	**Pyrite Tailings[2]**	
5.01	Target gradation produced at mill	*"Total" Tailings:* Target P80 = 160 microns 50% fines (<74 microns) <10% clay (<2 microns)	Target P80 = 75-80 microns 80% fines (<74 microns) <20% clay (<2 microns)	Scavenger "Total" Tailings: Provided by RC. Pyrite Tailings: Provided by RC. Clay content assumed from previous test work on cleaner tailings. See Figure 3.3
5.02	Specific gravity	2.78	3.87	Average values from KCB laboratory testing programs on scavenger "total" tailings and cleaner[1] tailings.
5.03	Solids content pumped from the mill	65%	50%	Provided by RC.
5.04	Liquefaction assumption	All potentially liquefiable tailings will liquefy at the TSF, regardless of triggering mechanism.		
5.05	Pyrite tailings management	N/A	Stored separately from scavenger tailings in a facility with an engineered low-permeability liner (see Table 3.1, item 6.08).	
5.06	Tailings pile surface slopes	Sloped away from structural zones to collection ditches	Sloped away from structural zones to collection ditches.	To limit ponding on tailings surfaces adjacent to the structural zones.

[2] Previous tailings characterization was based on the Bulk Flowsheet which produced cleaner tailings as an end-product. However, RC updated their preferred process flow sheet to the Selective Flowsheet in 2012, which produces "pyrite tailings" as the end-product instead of cleaner tailings. In the Selective Flowsheet, the scavenger tailings are further desulfurized. The cleaner tailings and the scavenger concentrate de-sulfurization by-product are combined to produce pyrite tailings. Further laboratory testing to characterize the scavenger and pyrite tailings from the Selective Flowsheet is currently ongoing. For the purposes of this study, it is assumed that the cleaner tailings and pyrite tailings are physically and geochemically similar.

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.07	Dry tailings pile surface runoff coefficient (top surfaces)	0.10	0.10	Estimated based on Hydrus1D infiltration modeling. Coefficient was reduced compared to the "wet" alternatives due to higher expected absorption potential of the filtered tailings surface.
5.08	Dry tailings pile surface runoff coefficient (external slopes)	0.15	0.15	Estimated based on Hydrus1D infiltration modeling.
5.09	Dry density for annual staging assessments	structural zone : 110 pcf non-structural zone : 103 pcf	structural zone : 137 pcf non-structural zone : 125 pcf	KCB (2018)
6.0	**Filter Plant Design**			
		Scavenger Tailings	**Pyrite Tailings**	
6.01	Target Filter Plant tailings solids content (for placement)	89%	86%	Based on compaction testing of filtered tailings with similar properties to the RC tailings. Solids content must be high enough (or, conversely, water content must be low enough) to allow for tailings transportation and adequate compaction.
6.02	Target Filter Plant tailings moisture content (weight of water / weight of solids) (for placement and compaction at optimum moisture content)	13.5%	17%	
6.03	Filter cycle time	17 min	11 min	Based on the results of pilot-scale pressure filtration testing performed on scavenger tailings and on copper concentrate (used as an analogue for pyrite tailings) (Pocock 2015). Air blow time was chosen to achieve the target water content (see Table 3.1, Item 6.02)
6.04	Filter availability	85%	85%	Preliminary design assumption
6.05	Filter unit contingency	15%	15%	Preliminary design assumption

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
7.0	**Tailings Storage Facility (TSF) Tailings Pile Design**		
7.01	Design criteria	As per Table 2.1.	
7.02	Stability and Deformations	Tailings piles (typical section, refer to Figure 3.2) assumed to meet design stability and deformation criteria for DEIS.	Based on preliminary stability analyses reported in KCB (2017a) and assumed typical foundation conditions at the Near West site, located approximately 5 miles to the southwest (KCB 2017b). The filter pile preliminarily assessed in KCB (2017a) was approximately 500 ft high, whereas the scavenger pile at Silver King is approximately 1,000 ft high (refer to Appendix II). Foundation conditions at Silver King would be investigated further.
7.03	Width of structural zone crest at full pile build-out	100 ft	Sufficient to accommodate 2-way vehicle traffic, pipelines and any other equipment required to be on the crest (e.g. conveyance infrastructure).
7.04	Downstream Slope	3H:1V (see Figure 3.2)	Assumed based on preliminary stability analysis reported in KCB (2017a).
7.05	Slope of Structural/Non-Structural Interface	1H:1V (see Figure 3.2)	Assumed based on preliminary stability analysis reported in KCB (2017a).
7.06	Pond Management	No permanent water ponds on the pile surfaces. Stormwater runoff will be collected and transferred to the external water collection ponds.	
7.07	Surface Erosion and Dust Control	Progressive reclamation of exterior slopes throughout operations; non-water based dust suppressants used on tailings surfaces.	
7.08	Liner	Engineered low-permeability liner[3] below the pyrite tailings pile; no engineered lining below the scavenger tailings pile.	
7.09	Drainage	Sand and gravel drainage blanket and/or finger drains in the structural zone footprint.	
7.10	Closure	TSF Surfaces: slope, cover and revegetate to shed water, limit infiltration, limit erosion and return the landscape to a similar condition prior to mining. Pyrite management: limit oxygen and water ingress by covering with scavenger tailings.	Approach agreed with RC.

[3] The engineered low-permeability liner could be comprised of one or more of the following: compacted fine tailings, geomembrane liner, asphalt, slurry bentonite, and/or cemented paste tailings

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
8.0	**External Water Collection Dams**		
8.01	Design Criteria	As per Table 2.1.	
8.02	Crest width	25 ft, as per Table 2.1., item 2.02.	Preliminary allowances.
8.03	Downstream and upstream slopes	2.5H:1V, as per Table 2.1., item 2.03.	Preliminary allowances.
8.04	Minimum operating water pond depth	10 ft depth for reclaim pump (could be accounted for by a sump)	Preliminary allowances.
8.05	Maximum average seasonal volume	10 ft depth	Preliminary allowances.
8.06	Volume required for operational upset	10 ft depth, as per Table 2.1., item 2.08	Preliminary allowances.
8.07	Environmental Design Flood	200-year 24-hour for scavenger tailings water collection dam and 200-year 7-day for pyrite tailings water collection dam, as per Table 2.1., item 2.09	Preliminary allowances.
8.08	Inflow Design Flood	10 ft depth allowance to route the Probable Maximum Flood (PMF), as per Table 2.1., item 2.10	Preliminary allowances.
8.09	Freeboard	5 ft depth to account for wind runup, wave setup and embankment crest settlement, as per Table 2.1., item 2.11	Preliminary allowances.
9.0	**Upstream Diversion Structures**		
9.01	Design Criteria	As per Table 2.1.	
9.02	Crest width	25 ft, as per Table 2.1., item 3.02.	Preliminary allowances
9.03	Downstream and upstream slopes	2.5H:1V, as per Table 2.1., item 3.03.	Preliminary allowances
9.04	Inflow Design Flood	PMF with a duration that is the critical duration of 6 hr to 72 hr, as per Table 2.1., item 3.07.	Preliminary allowances
9.05	"Dry" Freeboard	6 ft depth to account for wind runup, wave setup and embankment crest settlement, as per Table 2.1., item 3.08.	Preliminary allowances
9.06	Tunnel outlets	Sized to optimize dam height and tunnel dimension using a slope of 1% and a manning's n of 0.035 for rock cuts.	Preliminary allowances Manning's n reference (FHWA, 2005).
9.07	Pump and pipe discharge	Capacity to be determined as per Table 2.1., item 3.09.	

Table 3.2 Mine and Tailings Production Schedule

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Care and Maintenance	2017	-	1	-	-	-
Care and Maintenance	2018	-	2	-	-	-
Care and Maintenance	2019	-	3	-	-	-
Care and Maintenance	2020	-	4	-	-	-
Construction	2021	-	5	-	-	-
Construction	2022	-	6	-	-	-
Construction	2023	-	7	-	-	-
Construction	2024	-	8	-	-	-
Construction	2025	-	9	-	-	-
Construction	2026	-	10	-	-	-
Construction	2027	-	11	-	-	-
First Ore	2028	1	12	5,346,486	766,631	6,113,118
Ramp up	2029	2	13	7,187,504	991,640	8,179,144
Ramp up	2030	3	14	7,897,945	1,014,556	8,912,501
Ramp up	2031	4	15	15,085,826	2,110,526	17,196,352
Ramp up	2032	5	16	21,902,288	3,328,288	25,230,577
Ramp up	2033	6	17	28,780,765	4,569,518	33,350,283
Ramp up	2034	7	18	34,178,734	5,793,075	39,971,810
Full Production	2035	8	19	37,849,588	7,340,459	45,190,047
Full Production	2036	9	20	37,128,274	8,184,034	45,312,308
Full Production	2037	10	21	36,749,978	8,772,867	45,522,845
Full Production	2038	11	22	37,121,210	8,792,910	45,914,120
Full Production	2039	12	23	38,040,923	8,019,027	46,059,950
Full Production	2040	13	24	37,486,298	6,800,935	44,287,232
Full Production	2041	14	25	39,582,789	6,518,836	46,101,626
Full Production	2042	15	26	39,666,729	6,589,905	46,256,634
Full Production	2043	16	27	39,211,923	6,919,174	46,131,097
Full Production	2044	17	28	38,679,739	7,360,739	46,040,478
Full Production	2045	18	29	38,273,841	7,838,027	46,111,868

Table 3.2 Mine and Tailings Production Schedule (cont'd)

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Full Production	2046	19	30	38,130,733	8,150,877	46,281,610
Full Production	2047	20	31	38,448,597	7,968,471	46,417,068
Full Production	2048	21	32	38,926,908	7,537,946	46,464,854
Full Production	2049	22	33	39,028,952	7,382,565	46,411,517
Full Production	2050	23	34	39,006,219	7,367,901	46,374,120
Full Production	2051	24	35	38,564,309	7,824,341	46,388,650
Full Production	2052	25	36	38,008,651	8,406,901	46,415,552
Full Production	2053	26	37	37,822,090	8,629,862	46,451,952
Full Production	2054	27	38	38,599,981	7,902,469	46,502,450
Full Production	2055	28	39	39,472,443	6,988,070	46,460,513
Full Production	2056	29	40	39,579,974	6,796,869	46,376,843
Full Production	2057	30	41	39,595,841	6,786,681	46,382,522
Full Production	2058	31	42	39,503,382	6,740,343	46,243,725
Ramp Down	2059	32	43	31,481,866	5,391,484	36,873,350
Ramp Down	2060	33	44	24,576,943	4,320,111	28,897,054
Ramp Down	2061	34	45	18,707,166	3,478,519	22,185,685
Ramp Down	2062	35	46	13,146,108	2,643,079	15,789,186
Ramp Down	2063	36	47	9,566,562	1,952,428	11,518,989
Ramp Down	2064	37	48	4,993,554	1,079,281	6,072,835
Ramp Down	2065	38	49	2,121,484	545,241	2,666,725
Ramp Down	2066	39	50	928,110	274,819	1,202,929
Ramp Down	2067	40	51	326,877	99,724	426,602
Ramp Down	2068	41	52	19,505	4,936	24,440
Closure	2069	-	53	-	-	-
			TOTAL TAILINGS	**1,150,727,095**	**219,984,066**	**1,370,711,161**

Notes: Tailings production schedule supplied by Resolution Copper in an email dated December 12, 2017.
Mine plan descriptions, mine years and modeling years supplied by Resolution Copper in an email dated January 12, 2018.

Table 3.3 Precipitation Depth-Duration-Frequency Estimates for the TSF

Average Recurrence Interval (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr	2 day	3 day	4 day	7 day	10 day	20 day	30 day	45 day	60 day
Precipitation in inches																			
1	0.2	0.4	0.4	0.6	0.7	0.9	0.9	1.1	1.3	1.6	1.8	2.0	2.1	2.4	2.7	3.3	4.0	4.7	5.5
2	0.3	0.5	0.6	0.8	1.0	1.1	1.2	1.4	1.7	2.0	2.3	2.5	2.7	3.0	3.4	4.2	5.1	6.0	6.9
5	0.4	0.6	0.8	1.1	1.3	1.5	1.5	1.8	2.1	2.6	2.9	3.2	3.5	3.9	4.3	5.4	6.5	7.7	8.7
10	0.5	0.8	0.9	1.3	1.6	1.7	1.8	2.1	2.4	3.0	3.5	3.8	4.1	4.7	5.1	6.4	7.6	8.9	10.1
25	0.6	0.9	1.1	1.5	1.9	2.1	2.2	2.5	2.8	3.6	4.2	4.6	5.0	5.8	6.2	7.7	9.1	10.6	11.9
50	0.7	1.0	1.3	1.7	2.2	2.4	2.5	2.8	3.2	4.1	4.7	5.2	5.7	6.7	7.2	8.7	10.3	12.0	13.3
100	0.8	1.2	1.5	2.0	2.4	2.7	2.8	3.1	3.5	4.6	5.3	5.9	6.5	7.6	8.2	9.8	11.6	13.3	14.7
200	0.9	1.3	1.6	2.2	2.7	3.0	3.1	3.4	3.9	5.1	5.9	6.6	7.4	8.7	9.2	10.9	12.9	14.6	16.1
500	1.0	1.5	1.8	2.4	3.0	3.4	3.6	3.9	4.4	5.8	6.8	7.7	8.5	10.2	10.7	12.4	14.7	16.5	17.9
1000	1.1	1.6	2.0	2.7	3.3	3.7	3.9	4.2	4.7	6.4	7.4	8.5	9.5	11.4	12.0	13.6	16.1	17.9	19.3

Note: From NOAA Atlas 14 (NOAA 2018) for the Near West site.

Figure 3.1 Process Schematic

% of Total Tailings Tonnage

% of Total Scavenger Tailings Tonnage

% of Total Pyrite Tailings Tonnage

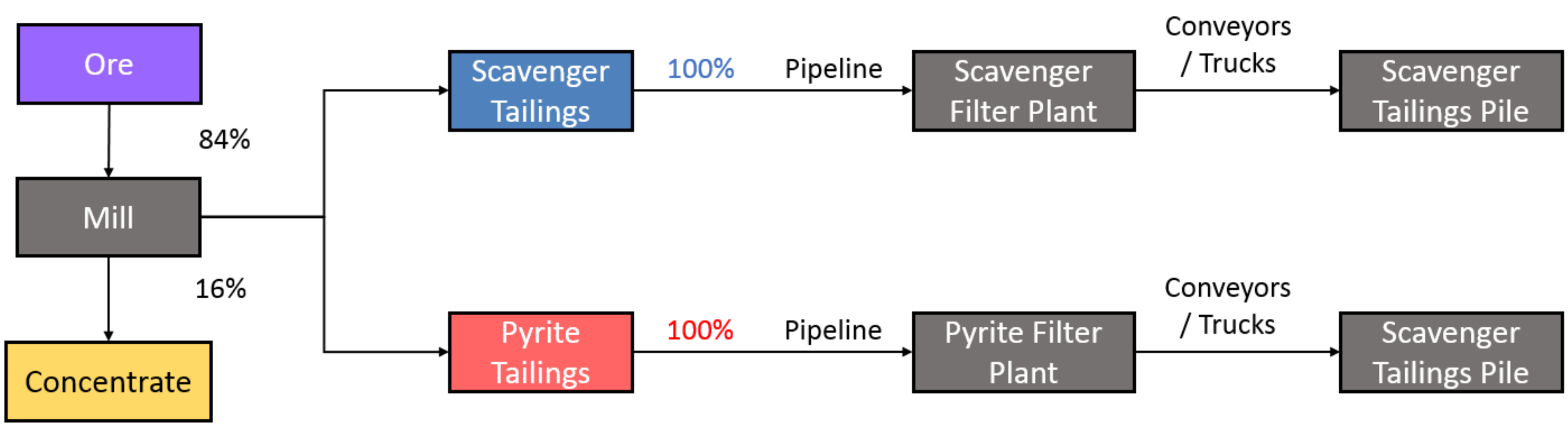


Figure 3.2 Tailings Pile Cross Section

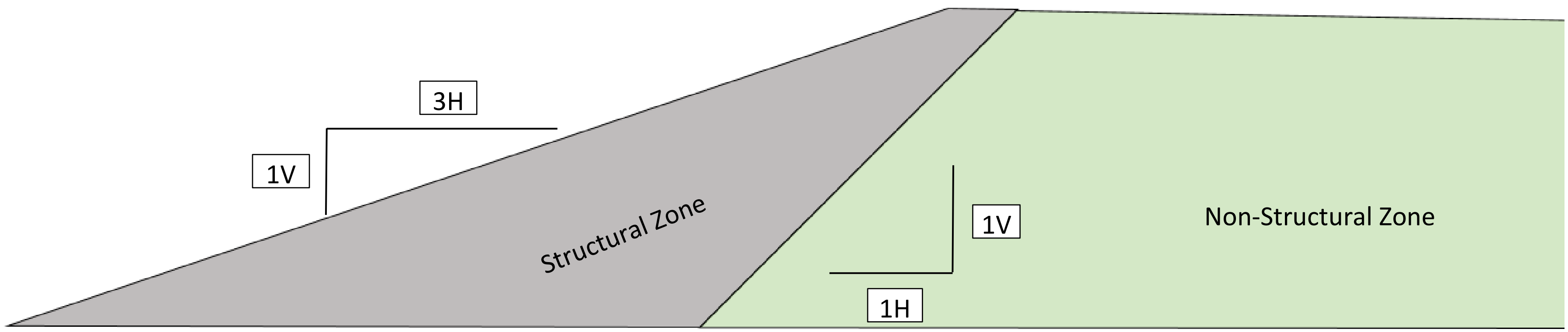
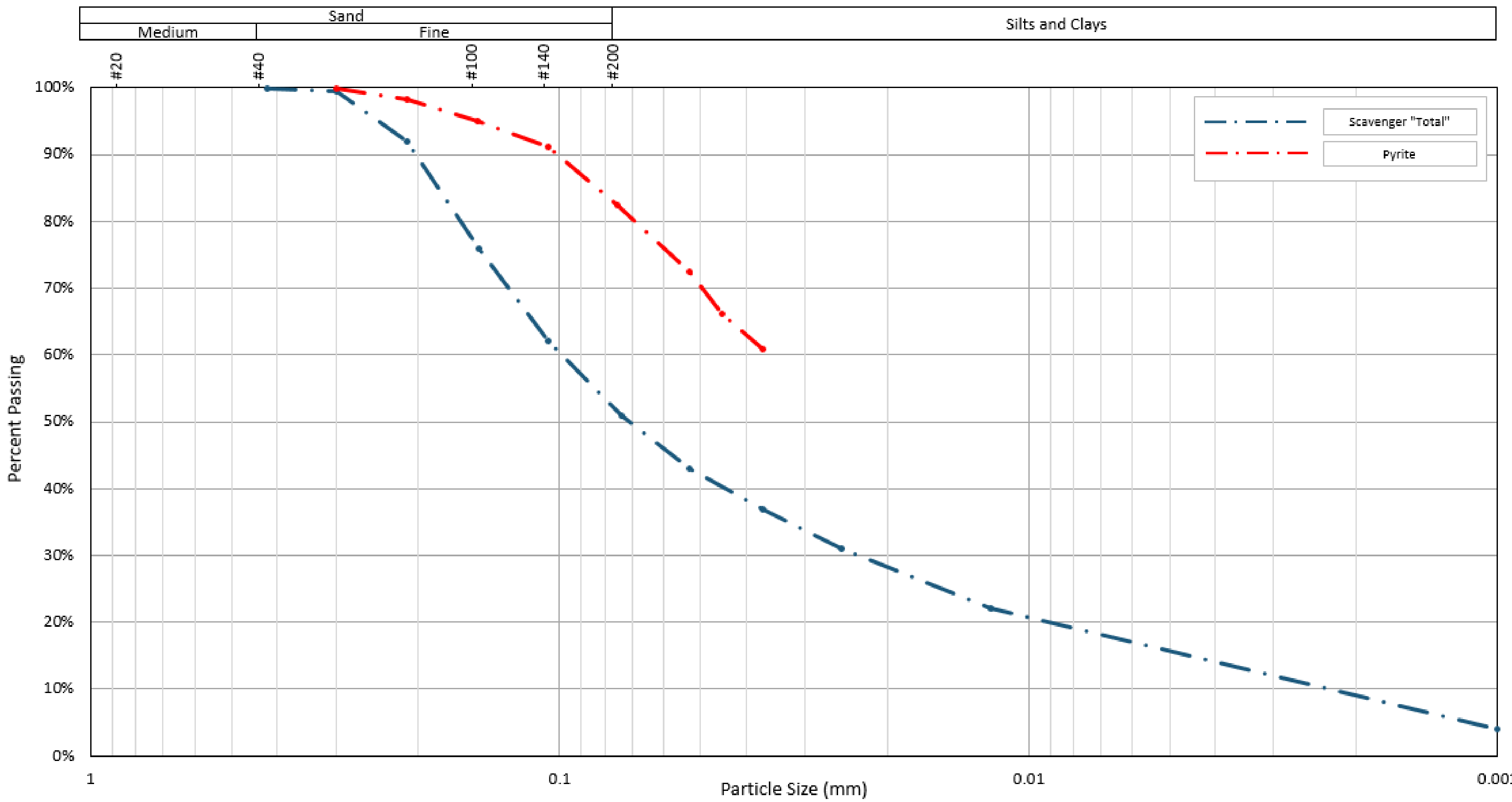


Figure 3.3 Target Tailings Gradations for Design



4 ADDITIONAL REFERENCES

Klohn Crippen Berger Ltd. (KCB). 2014. *Near West Tailings Management Mine Plan of Operations Study.* September 5.

Klohn Crippen Berger Ltd. (KCB). 2017a. *Near West Tailings Storage Facility Embankment Design Alternatives Analysis.* March 2.

Klohn Crippen Berger Ltd. (KCB). 2017b. *Near West Tailings Storage Facility Geotechnical Site Characterization Report.* October 2017.

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U.S. DoT Federal Highway Administration (FHWA). 2005. "Hydraulic Engineering Circular No. 15, Third Edition – Design of Roadside Channels with Flexible Linings." Accessed February 1, 2018. https://www.fhwa.dot.gov/engineering/hydraulics/pubs/05114/05114.pdf

DEIS Design for Alternative 6 – Skunk Camp, DBM

Resolution Copper Project

DEIS Design for Alternative 6 – Skunk Camp

Technical Memorandum

Appendix I – Design Basis Memorandum

DISCLAIMER

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1 INTRODUCTION

1.1 General

This is the design basis memorandum (DBM) for the design of Alternative 6 – Skunk Camp which is one of the tailings storage facility (TSF) design alternatives that Resolution Copper Mining LLC (RC) intends to include in the draft environmental impact statement (DEIS) for the proposed Resolution Copper Project. This TSF is located at the Skunk Camp location on the border of Pinal and Gila Counties, Arizona. The DBM outlines the design objective as well as the design criteria and assumptions. This DBM is considered a "live" document that will be reviewed and updated throughout the design process.

1.2 Design Objective

The objective of the TSF is to store the tailings produced by the proposed Resolution Copper Project. The design incorporates findings from the alternative studies. Limited site specific data has been collected at the site at the time of this study, primarily consisting of regional geological maps, well log information for a small number of wells, and preliminary site reconnaissance visits by RC and KCB staff. This conceptual level design is based on site condition assumptions from similar sites.

The design regulations and guidelines are outlined in Section 1.3, and the design criteria and assumptions are tabulated in Section 2.

The scope of the DEIS design is to provide a basis for comparing impacts from TSF alternatives. The design is tailored to meet United States Forest Service (USFS) requirements for the DEIS.

1.3 Design Regulations and Guidelines

The TSF design is governed and guided by the regulations and guidelines listed below. The general approach adopted in this design is to set the design criteria based on the governing regulations, and then to supplement these regulations with guidelines from international practice where the governing regulations are not specific. Where international guidelines are more stringent than the governing regulations, consideration is also given to the additional measures needed to meet the more stringent guidelines.

Governing

Tailings Storage Facility and Seepage Collection Dams

- Arizona State Legislature. 2016. Arizona Administrative Code (A.A.C.).
  - Title 18. Environmental Quality. Chapter 9: Department of Environmental Quality – Water Pollution Control. Chapter 11: Department of Environmental Quality, Article 1: Water Quality Standards.
  - Arizona State Legislature. 2016. Arizona Revised Statues (A.R.S.).
    - Title 49 – The Environment.

- Regulatory agency: Arizona Department of Environmental Quality (ADEQ).
- Environmental Protection Agency (EPA). Clean Water Act (CWA) - 33 U.S.C. §1251 et seq. (1972).
- Rio Tinto. 2017. D5 – Management of Tailings and Water Storage Facilities.

Seepage Collection Dams (only)

In addition to the above governing regulations, the seepage collection dams are regulated by the Arizona Department of Water Resources (ADWR). The additional application Arizona Administrative Code (A.A.C.) is Title 12. Natural Resources. Chapter 15. Department of Water Resources (A.A.C. R12-15).

Guidance

- Arizona Department of Environmental Quality (ADEQ). 2005. Arizona Mining Guidance Manual BADCT (Best Available Demonstrated Control Technology).
- British Columbia Ministry of Energy and Mines (MEM). 2016. *Health, Safety and Reclamation Code for Mines in British Columbia*.
- Canadian Dam Association (CDA). 2007a. *Dam Safety Guidelines (with 2013 revision).*
- Canadian Dam Association (CDA). 2007b. *Technical Bulletin: Hydrotechnical Considerations for Dam Safety*.
- Canadian Dam Association (CDA). 2014. *Technical Bulletin: Application of Dam Safety Guidelines to Mining Dams*.
- Federal Emergency Management Agency (FEMA). 2005. *Federal Guidelines for Dam Safety – Earthquake Analyses and Design of Dams. FEMA-65.*
- Federal Emergency Management Agency (FEMA). 2013. *Selecting and Accommodating Inflow Design Floods for Dams. FEMA-P-94.*
- United States Army Corps of Engineers (USACE). 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).
- United States Army Corp of Engineers (USACE). 2004. *General Design and Construction Considerations for Earth and Rock-Fill Dams. EM 1110-2-2300.*
- United States Army Corp of Engineers (USACE). 2003. *Slope Stability. EM 1110-2-1902.*

1.4 BADCT Approach

The TSF will apply for an Aquifer Protection Permit (APP) with an “individual” Best Available Demonstrated Control Technology (BADCT) approach, which is performance based, and allows the applicant to select from all available Demonstrated Control Technologies (DCTs) that constitute BADCT. This process considers site specific characteristics, operational controls, and other DCTs.

Under the individual BADCT approach, the TSF is considered a "tailings impoundment" and will be designed in accordance with Section 3.5 of the BADCT manual (ADEQ 2005). The seepage pond is considered to be a "surface pond" and will be designed in accordance with Section 3.6 of the BADCT manual (ADEQ 2005) and the regulations pertaining to water dams (A.A.C. R12-15).

2 DESIGN CRITERIA

Table 2.1 Design Criteria

	Item	Design Criteria	Reference
1.0	**Tailings Storage Facility (TSF) Embankment Design**		
1.01a	CDA Consequence Classification	To be confirmed following inundation study, which will be completed in a later design stage.	▪ CDA (2007a)
1.01b	Rio Tinto Risk Category	Class IV (considered Class IV until all necessary mitigations have been included in design)	▪ D5 Standard (Rio Tinto 2017)
1.02	Storage capacity	Capacity to store all NPAG scavenger (scavenger) and PAG pyrite (pyrite) tailings production	▪ RC requirement
1.03	Downstream slope	▪ No steeper than 2H:1V	▪ MEM (2016)
1.04	Minimum Factor of Safety	▪ Static (upstream or downstream) – 1.5 (during operation and long term) ▪ Liquefied/post-cyclic – 1.2 ▪ Rapid drawdown – N/A	▪ BADCT (ADEQ 2005) supplemented with MEM (2016) ▪ D5 Rio Tinto (2017) ▪ CDA (2007a) ▪ N/A
1.05	Deformations (seismic or static, e.g. settlement)	▪ For cases with no liquefiable materials, horizontal seismic coefficient for pseudo-static analysis = 0.6 x Peak ground acceleration (PGA). This seismic coefficient is selected to maintain consistency with the requirements of the seepage collection dams, as per A.A.C R12-15-1216. ▪ For elements of the TSF sensitive to deformation, a simplified deformation analysis is required. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not reduce freeboard sufficiently to lead to an uncontrolled release of fluid tailings, does not impact the functionality of the drains, etc.).	▪ BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
1.06	Seismicity	▪ Maximum Credible Earthquake (MCE). Earthquake design ground motions will be selected in future design stages for appropriate return period events.	▪ BADCT (ADEQ 2005) supplemented with MEM (2016), CDA (2014), D5 Rio Tinto (2017) and industry practice
1.07	Pond Storage Capacity	See Figure 2.1 Storage capacity = minimum operating volume + maximum average seasonal volume + volume required for operational upset + volume for critical duration storm event including sediment (Environmental Design Flood and Inflow Design Flood) + volume required for "dry" freeboard (Table 2.1, Item 1.11)	▪ BADCT (ADEQ 2005)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.08	Storage Volume for Operational Upset Conditions	RC to confirm after RC internal risk audit and to be updated in next stage of design.	
1.09	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. Design will assume 200-year 24 hr; EDF will be confirmed through water balance and water quality modeling.	▪ BADCT (ADEQ 2005)
1.10	Inflow Design Flood (IDF) For Dam Safety	<u>Return Period:</u> Probable Maximum Flood (PMF) <u>Duration:</u> For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to contain the design flood volume. Therefore, the duration will be confirmed during the flood routing and water balance calculations: ▪ with a spillway: spillway sized for the critical duration of 6 hr to 72 hr; and ▪ without a spillway: minimum of 72 hr (to be confirmed based inflows and discharge rates).	▪ BADCT (ADEQ 2005) ▪ FEMA (2013) ▪ MEM (2016) ▪ D5 Rio Tinto (2017)
1.11	"Dry" Freeboard	▪ Wind and wave run-up + 2 ft ▪ Wind event annual exceedance probability = 2-year ▪ Wave height and run-up to be calculated using industry standard methods ▪ Earthquake-induced settlements of the embankment crest to be assessed and included in minimum freeboard determination	▪ BADCT (ADEQ 2005) ▪ CDA (2007b) ▪ USACE (2002)
1.12	Beach length	Will become part of the Quantitative Performance Objectives (QPO) ▪ Sufficient to achieve seepage and hydraulic gradient criteria during normal operations and periods of flood storage. ▪ Sufficient to provide a secondary defense against loss of fluid tailings in the event of downstream slope displacement.	
1.13	Seepage	Water quality requirements at the point of compliance are to be assessed.	▪ BADCT (ADEQ 2005), Clean Water Act (EPA) and Arizona State Legislature (A.A.C. R18-11)
1.14	Drains	▪ Provide drains/filters satisfying USACE (2004) guidelines to mitigate potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	▪ USACE (2004)

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
1.15	Construction and Operations	▪ Quantifiable performance objectives to be defined prior to construction. ▪ All construction and borrow materials with contingency to be defined prior to construction.	▪ MEM (2016)
1.16	Closure	Planned closure landscape is to be a physically stable landform without a permanent water pond that meets point of compliance criteria.	▪ D5 Rio Tinto (2017)
1.17	Closure Surface Diversions	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment.	▪ BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
1.18	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact to structural zones, containment, other structures or the environment. BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.	▪ BADCT (ADEQ 2005)
2.0	**Seepage Collection Pond (and associated Dam(s))**		
2.01	Assumed downstream hazard classification for the dam	High (to be confirmed in future design stages)	▪ A.A.C R12-15-1216
2.02	Downstream slope	As per Table 2.1, item 1.03	
2.03	Stability Factor of Safety (FOS)	▪ End of construction – Static (upstream or downstream) – 1.3 (≤ 50 ft high), 1.4 (> 50 ft high) ▪ Steady state seepage – Static – 1.5 ▪ Rapid drawdown – 1.2	▪ A.A.C R12-15-1216 ▪ D5 Rio Tinto (2017)
2.04	Deformations (seismic or static, e.g. settlement)	▪ Pseudo-static – FOS = 1.0 with horizontal seismic coefficient = 0.6 x Peak ground acceleration. ▪ As per Table 2.1, item 1.05, where elements are sensitive to deformations, a simplified deformation analysis will be conducted to identify the potential displacements for comparison with allowable deformations for that element. ▪ Predicted deformations shall not jeopardize containment integrity (e.g. does not impact the integrity of the dam core or the spillway, etc.)	▪ A.A.C R12-15-1216 and BADCT (ADEQ 2005) ▪ D5 Rio Tinto (2017)
2.05	Seismicity	▪ MCE, assumed to be mean 1:10,000 year return period: ♦ Sensitivity to 95th percentile to be considered	▪ A.A.C R12-15-1216 supplemented with MEM (2016) and CDA (2007a) ▪ D5 Rio Tinto (2017)
2.06	Pond Storage Capacity	See Table 2.1, item 1.07	
2.07	Storage Volume for Operational Upset Conditions	One week of average seepage and precipitation to account for a period of pump shut-down	

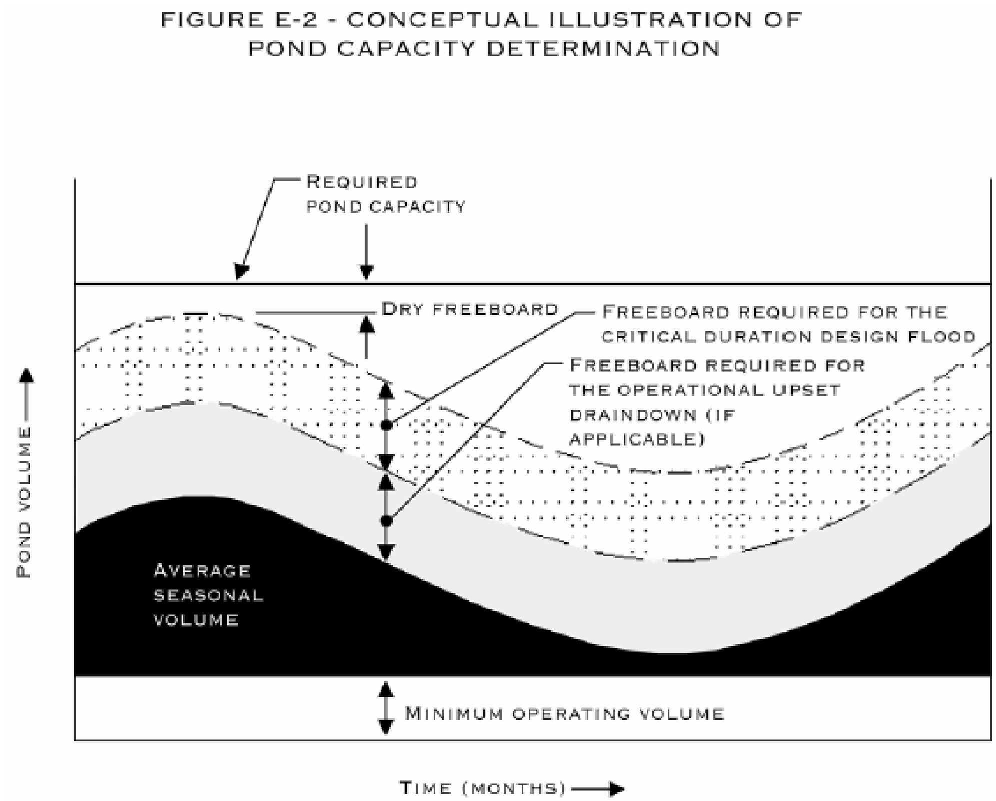
Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.08	Environmental Design Flood (EDF)	Minimum requirement for BADCT is 100-year 24 hr. TSF design will assume 200-year 24 hr; EDF will be confirmed through water balance and water quality modeling.	▪ BADCT (ADEQ 2005)
2.09	Inflow Design Flood (IDF) For Dam Safety	Storm to be routed through spillway - Probable Maximum Flood (PMF) BADCT: Return Period: if failure of dam would pose an imminent risk to human life and/or high downstream incremental consequences the PMF should be used. Duration: For individual BADCT, the facility-specific critical design storm duration is established by considering several durations and determining which results in the maximum required storage capacity to route the design flood volume. The range of storm duration to be considered are 6 hr to 72 hr. A.A.C R12-15-1216: For a high hazard potential dam, the applicant shall design the dam to withstand an inflow design flood that varies from .5 PMF to the full PMF, with size increasing based on persons at risk and potential for downstream damage. The applicant shall consider foreseeable future conditions. FEMA (2013): PMF for a dam classified as high hazard.	▪ BADCT (ADEQ 2005) ▪ A.A.C R12-15-1216 ▪ D5 Rio Tinto (2017) ▪ FEMA (2013)
2.10	Freeboard	Largest of: ▪ IDF + wave run up with a critical wind annual exceedance probability of the 1 in 2 year event ▪ IDF + 3 ft ▪ 5 ft	▪ A.A.C R12-15-1216 with consideration from CDA (2007b)
2.11	Low level outlet (or discharge - pump)	Can discharge 90% of storage volume within 30 days (minimum capacity).	▪ A.A.C R12-15-1216
2.12	Seepage	See Table 2.1, item 1.13	
2.13	Drains	▪ Provide core and drains/filters satisfying USACE (2004) guidelines to limit potential for internal erosion. ▪ Drains designed to maintain phreatic surface to acceptable levels within the embankment with adequate safety factor to account from clogging and uncertainty.	▪ BADCT (ADEQ 2005), USACE (2004) and A.A.C R12-15-1216
2.14	Crest width	Minimum of dam height (centerline) divided by 5, plus 5 ft. Minimum crest width = 12 ft, maximum crest width = 25 ft.	▪ A.A.C R12-15-1216

Table 2.1 Design Criteria (cont'd)

	Item	Design Criteria	Reference
2.15	Erosion protection	Well graded, durable riprap, sized to withstand wave action, placed on a well graded pervious sand and gravel bedding or geotextile with filtering capacity suitable for the site.	▪ A.A.C R12-15-1216
2.16	External Erosion Protection	The design criteria will be selected based on consequence of failure, e.g. impact on other structures or environment. (BADCT requires, at a minimum, that if the TSF is within the 100-year flood plain, drainage controls must be designed to protect the TSF from damage or flooding for 100-year peak streamflows.)	▪ BADCT (ADEQ 2005)

Figure 2.1 Pond Capacity Determination (ADEQ 2005)



3 DESIGN BASIS

Table 3.1 Design Assumptions, Constraints & Data Sources

	Item	Design Basis	Comments
1.0	**General Design Basis**		
1.01	TSF location	▪ Skunk Camp site, Pinal & Gila Counties, Arizona ▪ State land and private land ▪ Coordinates (Arizona State Plane Central NAD83): 920,000' E, 880,000' N	
1.02	Mine Flow Sheet	Selective	
1.03	Mine life	41 years	Received from RC; email dated December 12, 2018
1.04	TSF operating life	41 years	Received from RC; email dated December 12, 2018
1.05	Tailings types	Two types of tailings are produced: ▪ scavenger tailings (84% of total weight); and ▪ pyrite tailings (16% of total weight).	Received from RC; email dated December 12, 2018
1.06	Tailings technology	Thickened slurry (scavenger and pyrite tailings). Cycloning.	
1.07	Tailings delivery	See process schematic (Figure 3.1)	
1.08	Total tailings production	1.37 billion short tons	Received from RC; email dated December 12, 2018
1.09	Ore and tailings production schedule	Table 3.2	
1.10	Units	U.S. Customary	
1.11	Embankment raise methodology	Hydraulically placed cycloned sand using centerline raised methodology for the Main Embankment Hydraulically placed cycloned sand using downstream-raised methodology for the Pyrite Cell Embankments See Figure 3.2	
1.12	Cycloned sand availability	Cycloned Sand Recovery: 45% Cyclone uptime: 50% (Year 1-2); 70% (Year 3-5); 80% (Year 6-41) Cycloned sand retention in hydraulic cells: 90%	Lower bound recovery from Krebs simulations (dated January 10, 2018)
2.0	**Topography**		
2.01	Projection	Arizona State Plane Central	
2.02	Datum	NAD83	
2.03	Unit of measurement	U.S. Customary	

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

<table>
<tr><th></th><th>Item</th><th>Design Basis</th><th>Comments</th></tr>
<tr><td>3.0</td><td>Seismicity</td><td></td><td></td></tr>
<tr><td>3.01</td><td>Ground Motions</td><td>Not considered in analysis at this stage of design (refer to Table 3.1, Item 6.02).</td><td></td></tr>
<tr><td>4.0</td><td>Climate and Hydrology</td><td></td><td></td></tr>
<tr><td>4.01</td><td>Average precipitation (in inches)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>Total</th></tr><tr><td>1.5</td><td>2.0</td><td>2.0</td><td>0.7</td><td>0.3</td><td>0.4</td><td>3.1</td><td>2.5</td><td>1.4</td><td>1.6</td><td>2.2</td><td>1.4</td><td>19.0</td></tr></table></td><td>Based on elevation-precipitation correlation of regional climate stations; Superior (ID: 028348), Miami (ID: 025512), Kearny (ID: 024590), San Carlos Reservoir (ID: 027480), Roosevelt 1 WNW (ID: 027281) and Oracle 2 SE (ID: 026119).
Confirmed with regional estimate from Arizona Water Atlas.</td></tr>
<tr><td>4.02</td><td>Wet and dry year precipitations</td><td>Consideration to wet and dry years for the water balance will not be made at this stage of design.</td><td></td></tr>
<tr><td>4.03</td><td>Average annual pan evaporation</td><td>91.3 in</td><td>Pan evaporation data collected at the San Carlos Reservoir climate station (ID: 027480)</td></tr>
<tr><td>4.04</td><td>Evapotranspiration for reference surface/crop (in inches)</td><td><table><tr><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th><th>Total</th></tr><tr><td>2.9</td><td>3.4</td><td>5.0</td><td>6.6</td><td>8.5</td><td>9.2</td><td>9.0</td><td>8.0</td><td>7.0</td><td>5.8</td><td>3.8</td><td>3.1</td><td>72.3</td></tr></table></td><td>Calculated using the Penman-Monteith combined equation in Hydrus1D based on the generated Superior climate data set and reference vegetation parameters.</td></tr>
<tr><td>4.05</td><td>Natural catchment runoff coefficient</td><td>0.15</td><td>Calculated by dividing the average annual runoff from the nearby USGS hydromet station by the average annual precipitation at site (KCB 2014).</td></tr>
<tr><td>4.06</td><td>Probable Maximum Precipitation (PMP)</td><td><table><tr><th rowspan="2">Storm Type</th><th colspan="3">PMP Depth (inches)</th></tr><tr><th>6 hour Duration</th><th>24 hour Duration</th><th>72 hour Duration</th></tr><tr><td>General Winter</td><td>5.2</td><td>9.7</td><td>14.9</td></tr><tr><td>Tropical</td><td>11.8</td><td>16.6</td><td>22.1</td></tr><tr><td>Local</td><td>11.7</td><td>-</td><td>-</td></tr></table></td><td>Applied Weather Associates PMP Evaluation Tool.
Determined as the critical storm for design.
For the Skunk Camp site catchment.</td></tr>
<tr><td>4.07</td><td>Runoff coefficient during storm events</td><td>1.0</td><td>To account for high antecedent moisture conditions and the predominantly exposed rock in the catchment</td></tr>
<tr><td>4.08</td><td>Extreme point precipitation depths</td><td>See Table 3.3</td><td>From NOAA Atlas 14 (NOAA 2018).</td></tr>
</table>

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.0	**Tailings Characteristics and Deposition**			
		Scavenger Tailings	**Pyrite Tailings**[1]	
5.01	Target gradation produced at mill	*"Total" Tailings:* Target P80 = 160 microns 50% fines (<74 microns) <10% clay (<2 microns)	Target P80 = 75 to 80 microns 80% fines (<74 microns) <20% clay (<2 microns)	See Figure 3.3
5.02	Target gradation produced by cyclones	*Cycloned Sand (Underflow)*: Target P80 = 200 microns <20 % fines (<74 microns) 0% clay (<2 microns) *Cyclone Overflow:* Target P80 = 60 microns 90% fines (<74 microns) 15% clay (<2 microns)	N/A	See Figure 3.3. Target fines content for cycloned sand to be less than 20%, based on seepage performance and constructability from other cycloned sand embankment case histories.
5.03	Specific gravity	2.78	3.87	Average values from KCB laboratory testing programs on scavenger "total" tailings and cleaner tailings.
5.04	Solids content pumped from the mill	60%	50%	Provided by RC
5.05	Cyclone solids content	*Cyclone Feed:* 35% *Cyclone Overflow:* 25% *Cycloned Sand:* 70%	N/A	From most recent Krebs simulations (dated January 10, 2018) for "average" case. Cyclone overflow and cycloned sand solids content adjusted from the "average" simulation to account for the reduced cyclone recovery (see Table 3.1, Item 1.12).

[1] Previous tailings characterization was based on the Bulk Flowsheet which produced cleaner tailings as an end-product. However, RC updated their preferred process flow sheet to the Selective Flowsheet in 2012, which produces "pyrite tailings" as the end-product instead of "cleaner tailings". In the Selective Flowsheet, the scavenger tailings are further desulfurized. The cleaner tailings and the scavenger concentrate de-sulfurization by-product are combined to produce pyrite tailings. Further laboratory testing to characterize the scavenger and pyrite tailings from the Selective Flowsheet has been proposed and will be completed in future designs. For the purposes of this study, it is assumed that the cleaner tailings and pyrite tailings are physically and geochemically similar.

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis		Comments
5.06	Solids content discharged into TSF	*"Total" Tailings:* 60% *Cyclone Overflow:* 60% *Cycloned Sand:* 60%	50%	Cycloned sand solids content based on case history data and construction performance at other large cycloned sand embankments that use hydraulic cell construction. To be confirmed from ongoing rheology testing.
5.07	Liquefaction assumption	All potentially liquefiable tailings will liquefy at the TSF, regardless of triggering mechanism.		
5.08	Pyrite tailings management	N/A	Subaqueous deposition	
5.09	Tailings beach slopes (above water)	1% within 1,500 ft of discharge point, 0.5% thereafter	N/A	Scavenger Tailings - Based on topography and bathymetry surveys from two large, cycloned sand impoundment beaches and slopes below water. These facilities have long exposed beaches, up to five miles. Pyrite Tailings - Based on topography and bathymetry surveys of subaqueous disposal of high-pyrite tailings from floating barges. To be reviewed in future design stages.
5.10	Tailings beach slopes (below water)	2.5% within 1,000 ft of water's edge; 1.0% thereafter	10% within 100 ft of discharge point; 0.5% thereafter	
5.11	Dry beach runoff coefficient	0.15	N/A	Estimated based on Hydrus1D infiltration modeling
5.12	Dry density for staging assessment	*Interlayered "Total" Tailings and Cyclone Overflow (Composite Beach):* 75 pcf (first 5 years of operations); 81 pcf (remaining years of operations) *Cycloned Sand (compacted):* 113 pcf	106 pcf	KCB (2018)

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
6.0	**Tailings Storage Facility (TSF) Impoundment Design**		
6.01	Design criteria	As per Table 2.1.	
6.02	Stability	Embankment section (Figure 3.2) assumed to meet design stability criteria for DEIS	Based on preliminary stability analyses reported in KCB (2017a) and typical assumed foundation conditions for the Near West site (KCB 2017b)
6.03	Main Embankment Crest width	100 ft	Sufficient to accommodate 2-way vehicle traffic, pipelines and any other equipment required to be on the crest (e.g. cyclones).
6.04	Main Embankment Downstream Slope	3H:1V (see Figure 3.2)	
6.05	Main Embankment Upstream Slope	vertical slope (centerline raise; see Figure 3.2)	
6.06	Main Embankment Crest width	100 ft	
6.07	Pyrite Saddle Embankment Slopes	2.5H:1V	
6.08	Engineered Low-permeability Layer	Pyrite cell: Engineered low-permeability layer[2] beneath the cell, and extended on the upstream dam face to separate from scavenger tailings Scavenger area: foundation treatment to control seepage	Layout and design details to be confirmed in later design stages
6.09	Drainage	Sand and gravel drainage blanket in the embankment footprint; gravel/rockfill finger drains in existing drainage channels in the embankment footprint	Layout and design details to be confirmed in later design stages

[2] The engineered low-permeability layer could be comprised of one or more of the following: compacted fine tailings, geomembrane liner, asphalt, slurry bentonite, and/or cemented paste tailings

Table 3.1 Design Assumptions, Constraints & Data Sources (cont'd)

	Item	Design Basis	Comments
6.10	Closure	TSF Surfaces: slope, cover and revegetate to shed water, limit infiltration, limit erosion and return the landscape to a similar condition prior to mining. Pyrite management: limit oxygen ingress through subaqueous deposition, cover and encourage saturation of the pyrite tailings in the long term (i.e. after removal of the pond).	Approach agreed by RC
7.0		**Pond Management**	
7.01	Pond Management	▪ No permanent water pond in the scavenger tailings area; permanent pond maintained in the pyrite cell. Ponded water on the scavenger tailings surfaces will be collected and transferred to the pyrite cell.	
7.02	Minimum operating pond volume	▪ Minimum amount to keep pyrite tailings saturated and provide operating pond depth.	
7.03	Minimum operating pond depth	▪ Seepage Collection Dam: 0 ft (could be accounted for by a sump or other means). ▪ Minimum Water Cover above Maximum Tailings El. in pyrite cell: 10 ft	Preliminary allowances; to be confirmed in later design stages based on seepage collection pond and deposition barge design

Table 3.2 Mine and Tailings Production Schedule

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Care and Maintenance	2017	-	1	-	-	-
Care and Maintenance	2018	-	2	-	-	-
Care and Maintenance	2019	-	3	-	-	-
Care and Maintenance	2020	-	4	-	-	-
Construction	2021	-	5	-	-	-
Construction	2022	-	6	-	-	-
Construction	2023	-	7	-	-	-
Construction	2024	-	8	-	-	-
Construction	2025	-	9	-	-	-
Construction	2026	-	10	-	-	-
Construction	2027	-	11	-	-	-
First Ore	2028	1	12	5,346,486	766,631	6,113,118
Ramp up	2029	2	13	7,187,504	991,640	8,179,144
Ramp up	2030	3	14	7,897,945	1,014,556	8,912,501
Ramp up	2031	4	15	15,085,826	2,110,526	17,196,352
Ramp up	2032	5	16	21,902,288	3,328,288	25,230,577
Ramp up	2033	6	17	28,780,765	4,569,518	33,350,283
Ramp up	2034	7	18	34,178,734	5,793,075	39,971,810
Full Production	2035	8	19	37,849,588	7,340,459	45,190,047
Full Production	2036	9	20	37,128,274	8,184,034	45,312,308
Full Production	2037	10	21	36,749,978	8,772,867	45,522,845
Full Production	2038	11	22	37,121,210	8,792,910	45,914,120
Full Production	2039	12	23	38,040,923	8,019,027	46,059,950
Full Production	2040	13	24	37,486,298	6,800,935	44,287,232
Full Production	2041	14	25	39,582,789	6,518,836	46,101,626
Full Production	2042	15	26	39,666,729	6,589,905	46,256,634
Full Production	2043	16	27	39,211,923	6,919,174	46,131,097
Full Production	2044	17	28	38,679,739	7,360,739	46,040,478
Full Production	2045	18	29	38,273,841	7,838,027	46,111,868

Table 3.2 Mine and Tailings Production Schedule (cont'd)

Description	Year	Mine Year	Modeling Year	Tailings Tonnage (tons/year)		
				Scavenger	Pyrite	Total
Full Production	2046	19	30	38,130,733	8,150,877	46,281,610
Full Production	2047	20	31	38,448,597	7,968,471	46,417,068
Full Production	2048	21	32	38,926,908	7,537,946	46,464,854
Full Production	2049	22	33	39,028,952	7,382,565	46,411,517
Full Production	2050	23	34	39,006,219	7,367,901	46,374,120
Full Production	2051	24	35	38,564,309	7,824,341	46,388,650
Full Production	2052	25	36	38,008,651	8,406,901	46,415,552
Full Production	2053	26	37	37,822,090	8,629,862	46,451,952
Full Production	2054	27	38	38,599,981	7,902,469	46,502,450
Full Production	2055	28	39	39,472,443	6,988,070	46,460,513
Full Production	2056	29	40	39,579,974	6,796,869	46,376,843
Full Production	2057	30	41	39,595,841	6,786,681	46,382,522
Full Production	2058	31	42	39,503,382	6,740,343	46,243,725
Ramp Down	2059	32	43	31,481,866	5,391,484	36,873,350
Ramp Down	2060	33	44	24,576,943	4,320,111	28,897,054
Ramp Down	2061	34	45	18,707,166	3,478,519	22,185,685
Ramp Down	2062	35	46	13,146,108	2,643,079	15,789,186
Ramp Down	2063	36	47	9,566,562	1,952,428	11,518,989
Ramp Down	2064	37	48	4,993,554	1,079,281	6,072,835
Ramp Down	2065	38	49	2,121,484	545,241	2,666,725
Ramp Down	2066	39	50	928,110	274,819	1,202,929
Ramp Down	2067	40	51	326,877	99,724	426,602
Ramp Down	2068	41	52	19,505	4,936	24,440
Closure	2069	-	53	-	-	-
			TOTAL TAILINGS	**1,150,727,095**	**219,984,066**	**1,370,711,161**

Notes: Tailings production schedule supplied by Resolution Copper in an email dated December 12, 2017.
Mine plan descriptions, mine years and modeling years supplied by Resolution Copper in an email dated January 12, 2018.

Table 3.3 Precipitation Depth-Duration-Frequency Estimates for the TSF

Average Recurrence Interval (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr	2 day	3 day	4 day	7 day	10 day	20 day	30 day	45 day	60 day
Precipitation in inches																			
1	0.3	0.4	0.5	0.7	0.9	1.0	1.0	1.3	1.6	2.0	2.3	2.5	2.7	3.1	3.4	4.3	5.2	6.2	7.2
2	0.4	0.5	0.7	0.9	1.1	1.3	1.3	1.6	2.0	2.5	2.9	3.2	3.4	3.9	4.3	5.5	6.6	7.8	9.1
5	0.5	0.7	0.9	1.2	1.5	1.7	1.7	2.0	2.4	3.1	3.7	4.1	4.4	5.1	5.5	7.0	8.4	10.0	11.5
10	0.6	0.9	1.1	1.4	1.8	2.0	2.0	2.4	2.8	3.6	4.4	4.8	5.3	6.1	6.6	8.3	9.9	11.7	13.3
25	0.7	1.0	1.3	1.7	2.1	2.4	2.5	2.8	3.4	4.3	5.3	5.9	6.5	7.6	8.1	10.0	12.0	14.0	15.8
50	0.8	1.2	1.5	2.0	2.4	2.7	2.8	3.2	3.8	4.9	6.0	6.7	7.4	8.8	9.3	11.4	13.6	15.8	17.7
100	0.9	1.3	1.6	2.2	2.7	3.0	3.2	3.6	4.2	5.5	6.8	7.6	8.5	10.1	10.7	12.9	15.3	17.6	19.6
200	0.9	1.4	1.8	2.4	3.0	3.3	3.5	3.9	4.6	6.1	7.6	8.6	9.6	11.6	12.1	14.4	17.1	19.5	21.6
500	1.1	1.6	2.0	2.7	3.4	3.8	4.0	4.4	5.2	6.9	8.8	10.0	11.2	13.7	14.2	16.5	19.5	22.1	24.2
1000	1.2	1.8	2.2	3.0	3.7	4.1	4.4	4.8	5.6	7.6	9.7	11.1	12.5	15.5	16.0	18.2	21.5	24.2	26.2

Note: From NOAA Atlas 14 (NOAA 2018) for the Skunk Camp site.

Figure 3.1 Process Schematic

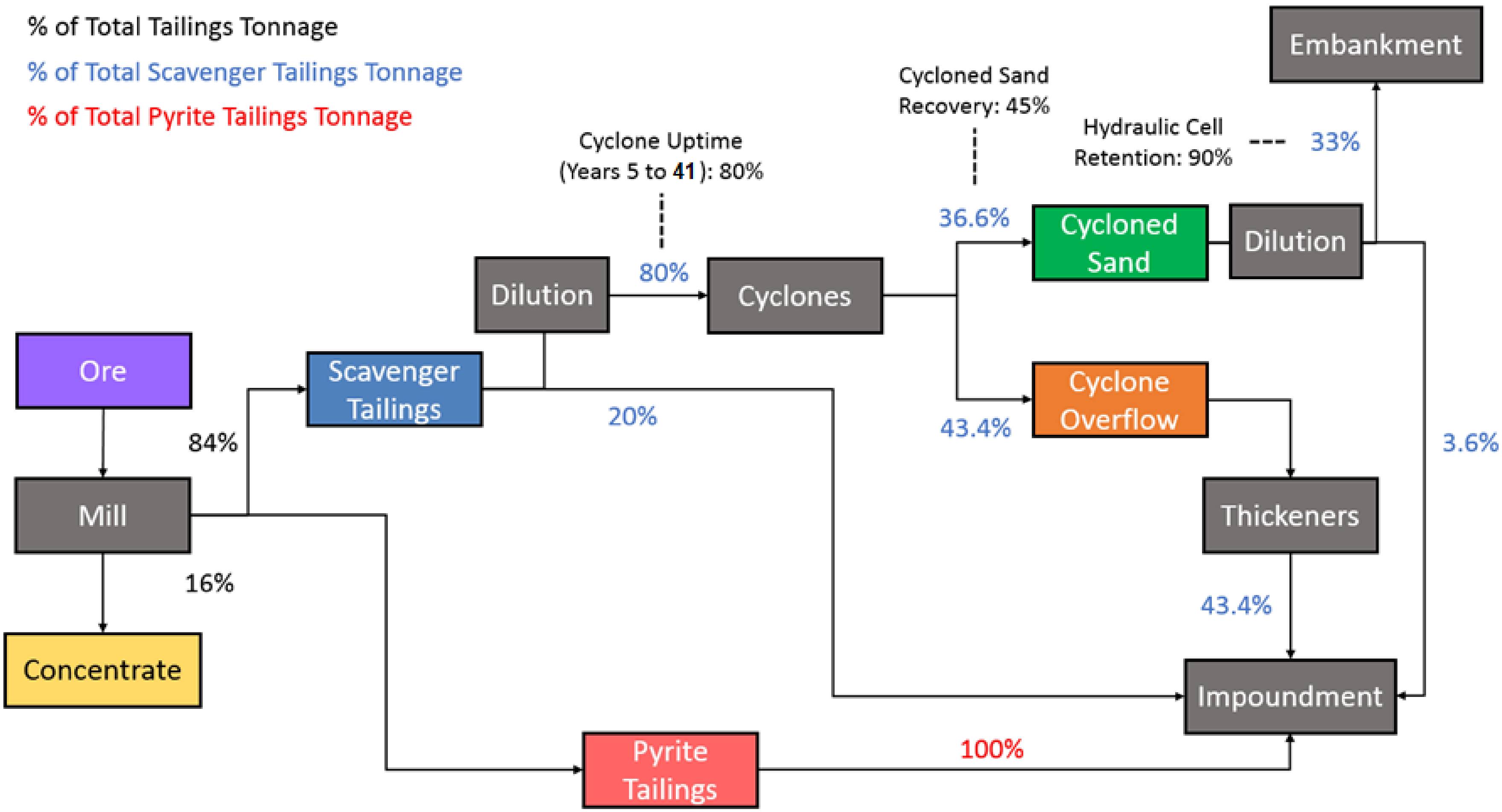
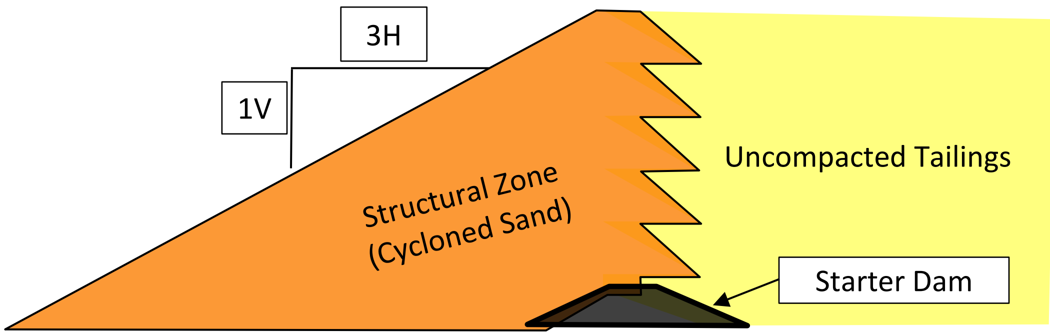


Figure 3.2 Embankment Centerline Raise and Embankment Design Schematic



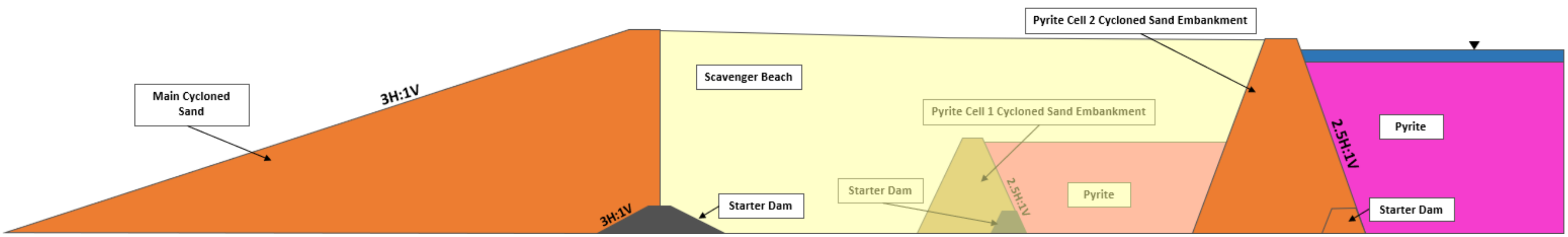
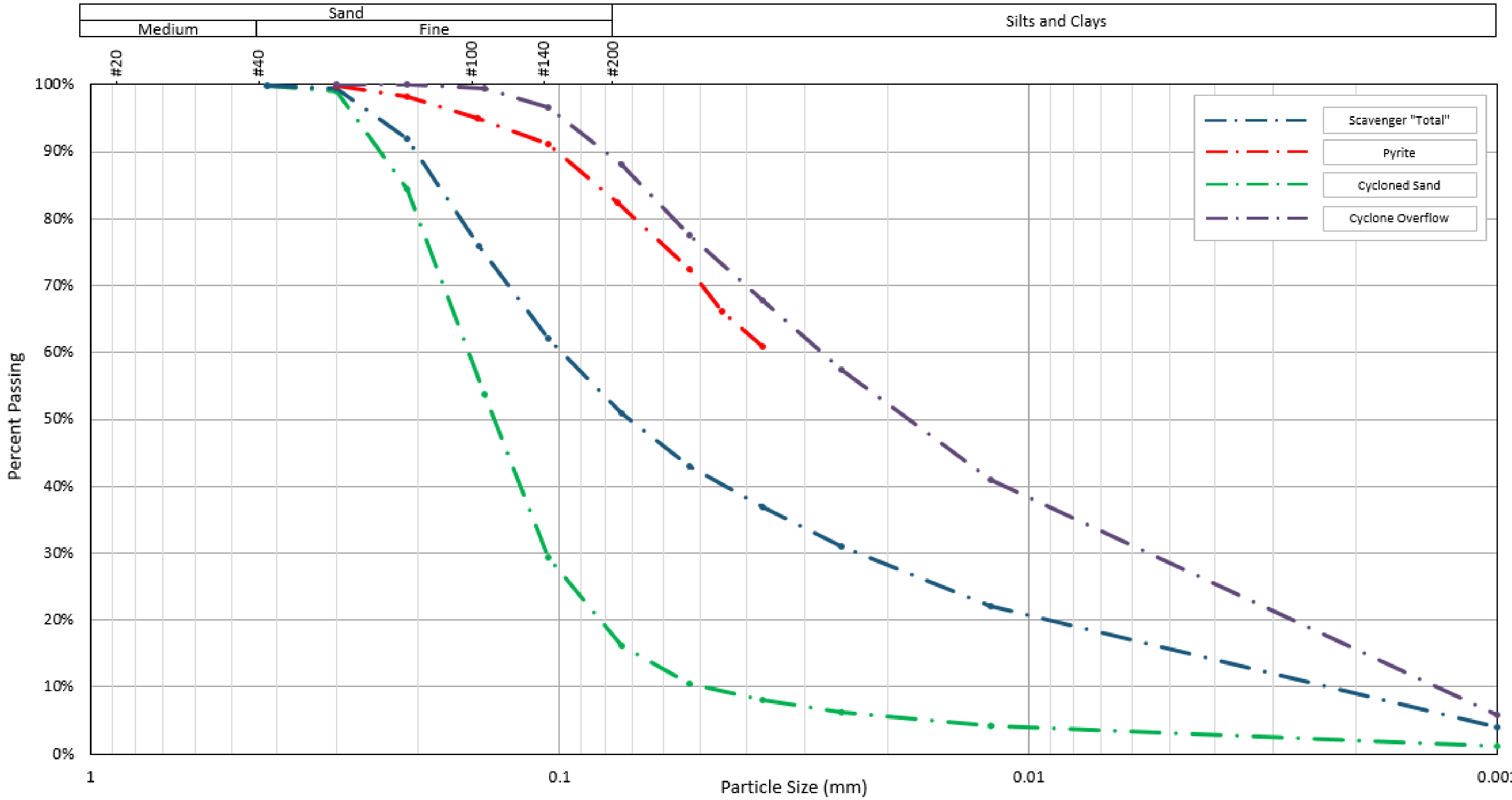


Figure 3.3 Target Tailings Gradations for Design



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