REPORT

DEPARTMENT OF MINES INDUSTRY REGULATIONS AND SAFETY

Bulong Tailings Storage Facility

Likelihood of Failure Assessment & Dam Break Study

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TAILINGS.WATER.WASTE.

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EXECUTIVE SUMMARY

Introduction

The Department of Mines, Industry Regulation and Safety (DMIRS) Abandoned Mines Program (AMP) has engaged ATC Williams (ATCW) to undertake a likelihood of failure assessment and dam break study for the Bulong Tailings Storage Facility (TSF).

The Bulong TSF is located in Western Australia, approximately 40 km east of Kalgoorlie and adjacent to Lake Yindarlgooda. ATCW understand that the mine site has been abandoned since 2005 and the TSF has remained inactive since this time.

Likelihood of Failure Assessment

A Likelihood of Failure Assessment has been undertaken and documented in accordance with the following procedure:

1. The overarching failure mode categories for an embankment dam have been listed and detailed (Geotechnical Piping Failure, Overtopping Failure, Instability Failure)
2. A list of potential failure mechanisms was developed
3. The potential failure mechanisms were qualitatively screened to determine 'credible failure mechanisms
4. A Semi-Qualitative Risk Assessment (SQRA) was then undertaken for the identified credible failure mechanisms. The SQRA process involves using a fault tree-style analysis to assign a probability of failure to each credible failure mode.

The calculated individual annual probabilities for the credible failure mechanisms are presented in **Table 1**. All calculated probabilities are significantly below the adopted ANCOLD **[1]** Limit of Tolerability for Potential Loss of Life (PLL) of 1 in 1,000.

TABLE 1 : RESULTS FROM FAULT TREE ANALYSES

Top Faults (occurring as Failure-to-Contain Scenarios)	Annual Probability of Occurrence
Failure due to Overtopping of the Embankment Crest	1 in 8,106,795
Static Stability Failure	1 in 1,095,900
Seismic Stability Failure	1 in 25,000
Piping through the Embankment	1 in 14,501,021

Dam Break Study

ATCW have performed a dam break study for the Bulong TSF in order to estimate the inundation extents for a failure scenario, as well as the potential impacts. ATCW understand that there are no permanent population or infrastructure along the expected flow path, hence no Population-at-Risk (PAR) assessment was performed as part of the study.

The Bulong TSF has been inactive since 2005, and as such, has had significant time for the tailings to consolidate. A recent investigation **[12]** of the tailings strength has indicated that the tailings do not have the potential for significant mobilisation during a dam break event. Hence, it is assumed in this dam break study that the embankment breach is only triggered by a storm storage within the TSF, as essentially a water release with limited tailings washout. As such, the dam break model has only considered the effects of the retained storm storage being released.

The results of the dam break modelling are presented in **Appendix B**. From the inundation maps, it can be identified that the maximum inundation depths and velocities generally occur near the initial breach and directly downstream of the Bulong TSF. As the dam break flood wave travels downstream towards the Evaporation Pond perimeter wall to the south, the depth and velocity generally dissipate.

The breach flood will generate some level of impact on the Evaporation Pond perimeter wall and may cause some level of erosion. However, it is not expected that this would induce a failure of the structure.

As the Bulong site has been abandoned since 2005 and no permanent population or infrastructure is present within the modelled inundation area, there is not expected to be any Population at Risk associated with a breach of the Bulong TSF.

Conclusions

Based on the Likelihood of Failure Assessment, the most likely failure scenario is through seismic instability, with an estimated annual probability of occurrence of 1 in 25,000. An extreme seismic event may cause major deformation of the embankment, potentially leading to localised slumping of the tailings and an increased likelihood of overtopping from storm events.

All calculated failure scenario probabilities are significantly below the calculated ANCOLD **[1]** limit of tolerability of 1 in 1,000.

The consequences resulting from a failure of the Bulong TSF embankment are expected to be low for the following reasons:

- No Population at Risk is expected to be present within the inundation area of the TSF.
- The environmental impacts associated with a release of stored flood water are expected to be low – stored water will have negligibly low contamination from contact with the tailings.
- The tailings are expected to have limited mobilisation potential if the embankment was to fail. Some localised slumping of tailings may occur.

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1 INTRODUCTION

1.1 Overview

The Department of Mines, Industry Regulation and Safety (DMIRS) Abandoned Mines Program (AMP) has engaged ATC Williams (ATCW) to undertake a likelihood of failure assessment and dam break study for the Bulong Tailings Storage Facility (TSF).

The Bulong TSF is located in Western Australia, approximately 40 km east of Kalgoorlie and adjacent to Lake Yindarlgooda. ATCW understand that the mine site has been abandoned since 2005 and the TSF has remained inactive since this time.

This Report documents the outcomes of the failure modes assessment and dam break study.

1.2 TSF Details

An aerial image of the Bulong TSF is presented in **Diagram 1**. As shown, to the south of the TSF there are two inactive Evaporation Pond Facilities (EPF1 & EPF2). Lake Yindarlgooda is located to the south-east of the TSF.

The Bulong TSF starter embankment was constructed in 1998 to a crest height of RL 329 m. The embankment was subsequently centreline raised in 2001 to a crest height of RL 331 m. A third raise was designed to raise the embankment to RL 333 m, however this was never constructed. Throughout the operational life of the facility, tailings were discharged from the perimeter embankment to a central causeway decant structure.

The Bulong TSF embankment is comprised of three zones:

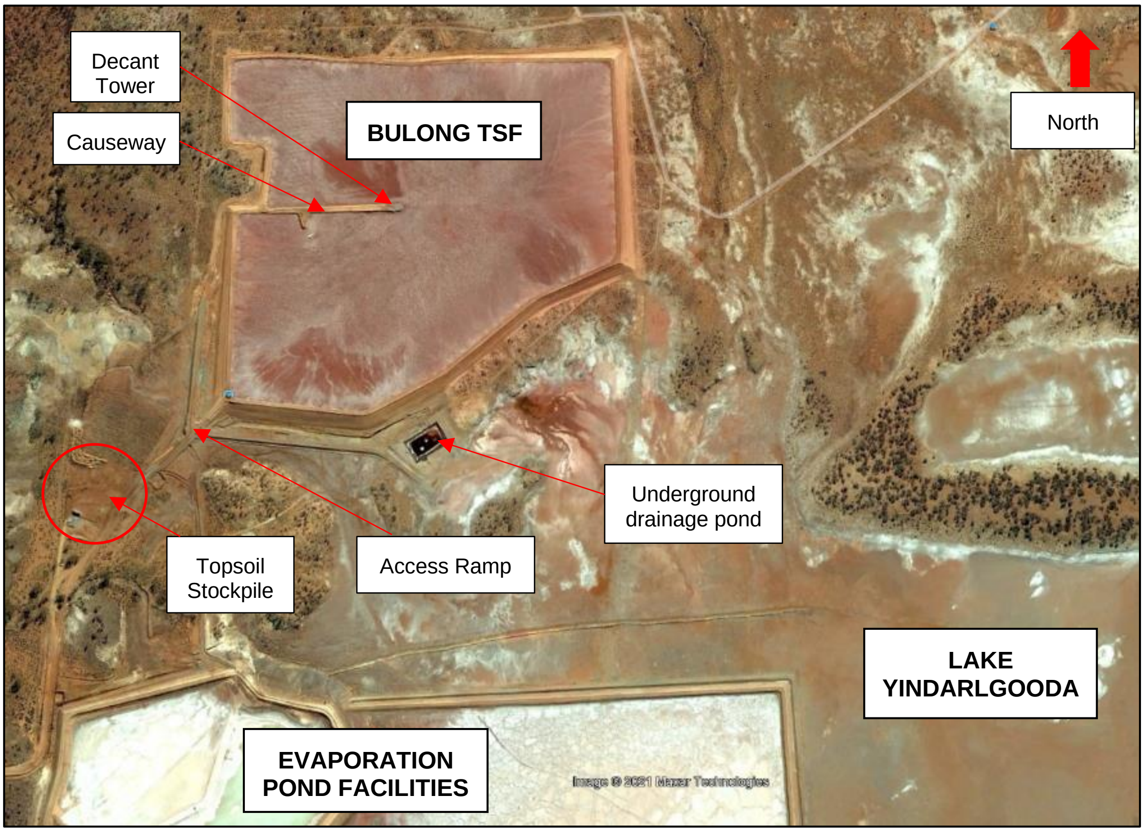
5. Zone A low permeability facing -
   Consisting of compacted clays and silts.
6. Zone B downstream structural zone -
   Consisting of compacted mine waste rock.
7. Zone E toe drain -
   Consisting of sand and gravel material, cut into the foundations at the base of the Stage 2 raise.

A summary of the design geometry for the Stage 2 raise of the Bulong TSF (existing condition) is presented in **Table 2**. It is noted that no as-constructed documentation is available, and as such, the data provided in the design reports has been relied upon.

TABLE 2 : BULONG TSF DESIGN GEOMETRY (STAGE 2 RAISE)

Criteria	Units	Value
Crest Length	m	2,800
Crest Width	m	8
Crest Elevation	m RL	331.0
Upstream Slope	H:V	2:1
Downstream Slope	H:V	2.75:1
TSF Stored Volume	m^3	2.3×10^6

DIAGRAM 1 : BULONG TSF ANNOTATED AERIAL IMAGE



2 LIKELIHOOD OF FAILURE ASSESSMENT

2.1 Overview

A Likelihood of Failure Assessment has been undertaken and documented in accordance with the following procedure:

8. The overarching failure mode categories for an embankment dam have been listed and detailed – refer **Section 2.2**.
9. A list of potential failure mechanisms was developed based on risk assessments that ATCW have performed for similar types of TSFs, as well as databases of historical tailings failure case histories – refer **Section 2.3**.
10. The potential failure mechanisms were qualitatively screened to determine 'credible failure mechanisms' based on engineering judgement by ATCW and involvement with similar structures – refer **Section 2.3**.
11. A Semi-Qualitative Risk Assessment (SQRA) was then undertaken for the identified credible failure mechanisms. The SQRA process involves using a fault tree-style analysis to assign a probability of failure to each credible failure mode. Refer **Section 2.4, 2.5, 2.7 & 2.8**.

The SQRA approach was adopted and deemed appropriate for the Bulong TSF Likelihood of Failure Assessment for the following reasons:

- A number of data gaps exist within the available documentation, making a fully quantitative assessment unachievable. The data gaps include a lack of construction documentation, seismicity studies and detailed information on the foundations and embankment materials.

- The level of detail of the SQRA approach is considered suitable based on the estimated risk level of the facility, i.e. no population at risk has been identified.

2.2 Failure Mode Categories

2.2.1 Overview

Failure of an earthen structure can be broadly grouped into the following categories:

- Geotechnical Piping Failure
- Overtopping Failure
- Instability Failure

Details of the mechanisms and contributing factors of each failure mode are discussed in the following sections.

2.2.2 Geotechnical Piping Failure

Geotechnical piping failures are caused by the internal erosion of embankment or foundation materials. Fell et al. **[4]** describe the geotechnical piping process in four phases:

- Initiation – The water level within the dam rises to meet an existing flaw. This may be a continuous crack, a high permeability or poorly compacted zone in which a concentrated leak may form. From this, the erosion process begins.
- Continuation – The continuation of the erosion process, relating to whether the filters or transition zones within an embankment will arrest the erosion process.
- Progression – The progression of the erosion across the entire width of the structure. Progression is related to the following factors –
  - whether the soil within which the pipe is forming, or overlying a concentrated leak or contact erosion, will support the roof of the pipe;
  - whether the upstream zones may limit flows to reach an equilibrium condition (the piping process progresses no further); or
  - whether soil from the upstream zone washes into the eroding soil and stops the process.
- Breach – Potential breach mechanisms are:
  - Gross enlargement of the pipe,
  - Unravelling of the downstream toe,
  - Crest settlement, or sinkhole development on the crest leading to overtopping, or
  - Instability of the downstream slope.

The piping process is sequential in nature, requiring all steps of the process to occur before a failure occurs. In probabilistic terms, this represents the intersection of all contributing faults.

2.2.3 Overtopping Failure

Overtopping failure relates to the loss of containment of surface water over the embankment crests, caused by either:

- Inundation of storm water from extreme storm events that consume all available freeboard and overtop the embankment crest, or
- Significant settlement of the embankment crest greater than the operational freeboard available.

Breach of the facility may be caused by cascading water over the downstream batter, eroding the downstream shoulder material, leading to embankment instability and eventual embankment failure.

2.2.4 Instability Failure

Instability failure of an embankment occurs when the available shearing resistance along a potential surface of sliding is greater than the available shear stress. Instability failure can occur within the embankment itself or through the foundation.

Contributing factors to instability failure include:

- Non-conservative design parameters analysed, such as -
  - Significantly weaker construction materials;
  - An elevated phreatic surface within the dam; or
  - Previously unknown unfavourable foundation conditions.
- Weak foundation layers / defects.
- Liquefaction of foundations (loose cohesionless materials).
- Application of seismic loading beyond what the structure has been designed for.

2.3 Potential Failure Mechanisms & Qualitative Screening

A list of potential failure mechanisms for the Bulong TSF was identified based on risk assessments that ATCW have performed for similar types of TSFs, as well as databases of historical tailings failure case histories.

The potential failure modes have then been screened to exclude failure modes for which the likelihood is considered to be negligibly low or inconceivable (not credible).

Table 3 presents a list of the conceivable failure modes for the Bulong TSF. Commentary and justifications have been provided in regard to the inclusion or exclusion of each failure mode.

TABLE 3 : INITIAL QUALITATIVE SCREENING OF POTENTIAL FAILURE MECHANISMS

Case No.	Failure Mechanism	Credibility	Justification
Piping / Internal Erosion			
P1	Piping through the foundation.	Not Credible	• This would require re-saturation of the tailings to occur. • Due to the low permeability of the tailings, saturation to a significant degree will not occur under flood loading conditions.
P2	Piping through the embankment.	Credible	• Credible under flood conditions.
P3	Piping through the embankment into the foundations.	Not Credible	• Only initiator for piping is a flood event ponding water against the embankment. Therefore, only piping through the upper embankment is conceivable (above the tailings). • Foundation preparation consisted of stripping of loose and / or granular materials, followed by compaction. Unlikely for a pathway to exist within the foundations.
Overtopping			
O1	Overtopping due to exceedance of storage capacity (extreme storm event)	Credible	
O2	Overtopping due to embankment settlement	Credible	
O3	Overtopping due to seismic induced deformation	Credible	
Instability Failure			
S1	Static Slope Failure	Credible	
S2	Seismic Stability Failure	Credible	
S3	Slope Failure due to Liquefaction of Embankment Materials	Not Credible	• Embankment not in a sufficiently loose state (required for liquefaction) due to compaction of materials during construction, and the loading/consolidation following construction. • Embankment not in a saturated or partially saturated state (required for liquefaction).
S4	Slope Failure due to Liquefaction of Foundation Materials	Not Credible	• No liquefiable materials believed to be present within foundation. Foundation preparation consisted of stripping of loose and / or granular materials, followed by compaction. • Foundation not in a sufficiently loose state.

S5	Upstream Slope Failure due to Liquefaction of Tailings	Not Credible	• Tailings judged to be non-liquefiable, based on:
			  ○ High plasticity of tailings (Plasticity Index of 35, Liquid Limit of 88), based on research by Seed et al. (2003) **[6]**
			  ○ No saturation of tailings observed during recent site visit (up to 4 m depth)

2.4 SQRA: Approach Outline

The Semi-Qualitative Risk Assessment (SQRA) has adopted the technique of Fault Tree analysis. This approach systematically reconciles the potential failure mechanisms that could affect the operating performance of the system against the potential consequences of such failures. It is emphasised from the outset that the scope of the risk assessment is limited to failure-to-contain scenarios, initiated by a physical failure of one or a series of elements within the containment, resulting in a release of tailings or water into the receiving environment.

The technique to identify critical conditions draws upon a “fault tree” to represent the potential combination of faults that can initiate the failure scenario (also referred to as the “Top Fault”). Probability analyses can then be undertaken to assess the most critical combination of faults.

The Fault Tree analysis follows the approach outlined in the ANCOLD Guidelines on Risk Assessment **[1]** and the Australian Standard for Risk Management **[2]**. Differentiation is made between a quantitative and semi-quantitative risk assessment, to the extent that the SQRA provides an intermediary level analysis, between a textual evaluation of qualitative risk and numerical evaluation of quantitative risk.

The approach recognises that there are in some cases no certain means to quantify probability.

The sequence of steps applied in the SQRA are listed below:

- Potential hazards that could initiate mechanisms potentially resulting in failure are identified. Such hazards include foundation conditions, rainfall, seismic events etc.
- The failure scenario or “Top Fault”, resulting from any combination of potential hazards are identified.
- Combinations of contributory faults to each Top Fault are logically combined through a series of ‘AND’ and ‘OR’ gates, depending on whether the faults are dependent or independent of each other, progressively “drilling down” to a basic causal level at which probabilities can be assigned with a reasonable level of confidence. This process yields the fault tree.
- First-order probabilities for causal level faults are analysed using appropriate techniques.
- The probability of the “Top Fault” is calculated via contributory faults identified within the fault tree according to the following formulae:
  - AND gates, where all the contributory faults are required to happen concurrently to produce the failure event. This is represented as the intersection of all contributory faults, which is calculated as follows:

    $$Pr_T = Pr_1 \cap Pr_2 \ldots \cap Pr_N = Pr_1 * Pr_2 * \ldots * Pr_N$$

    Where Pr_1, Pr_2 . are contributory components to P_T.

  - OR gates, where at least one or more of the contributory faults are required to occur to produce the failure event. In traditional probabilistic terms, this is represented as the union of all contributory faults. However, there is no practical method of computing the overall probability of multiple faults. ANCOLD **[1]** recommends adopting the upper bound of these faults, which is estimated as follows:

    $$Pr_T = Pr_1 \cup Pr_2 \ldots \cup Pr_N \approx 1 - ((1 - Pr_1) * (1 - Pr_2) * \ldots * (1 - Pr_N))$$

    Where Pr_1, Pr_2 . are contributory components to P_T.

  It should be noted that as the individual conditional probabilities decrease (or become less likely), the equation above converges on the sum of the individual probabilities. However, for good measure, the above equation has been used in all “OR” gate calculations.

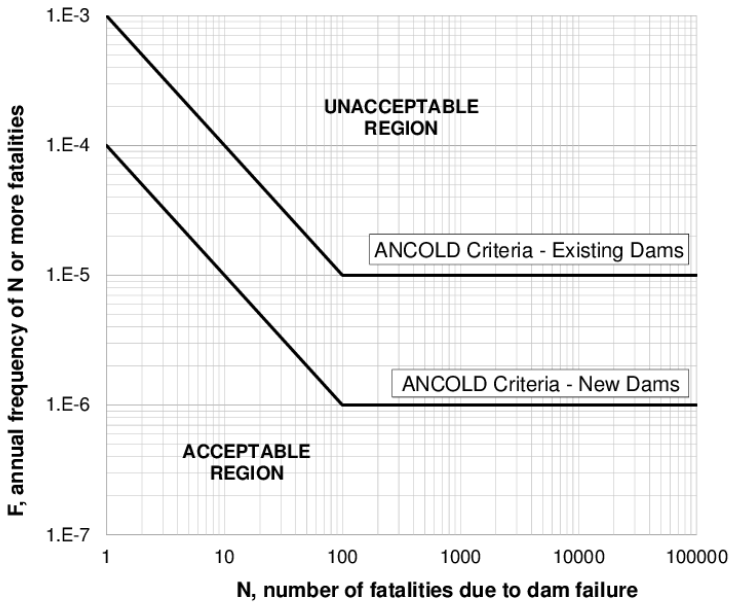
Typically, system faults forming the fault tree analysis are identified from experience, and an understanding of the mechanisms and triggers that contribute to each “Top Fault”.

2.5 SQRA: Tolerability Levels

The Tolerability Level for Potential Loss of Life (PLL) derived from ANCOLD **[1]** is reproduced in **Chart** 1. This plot characterises the acceptable region for probability of loss of life resulting from a failure-to-contain event.

As previously discussed, no population at risk has been identified for the Bulong TSF site. However, by conservatively adopting a PLL of at least one under any failure mode, a a worst-case frequency from **Chart 1** for an existing dam structure of **1 x 10^{-3} (1 in 1,000)** is identified. This has been adopted as a basis for assessing the tolerability of the assessed failure mode probabilities.

CHART 1 : TOLERABILITY LEVEL OF POTENTIAL LOSS OF LIFE (ANCOLD 2003)



2.6 SQRA: Credible Failure Scenarios

Following the initial qualitative failure modes screening process detailed in **Section 2.3**, a list of credible failure scenarios was formulated and is presented in **Table 4**. The probability of occurrence for the credible failure scenarios was evaluated using the SQRA process, as detailed in the proceeding sections.

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TABLE 4 : CREDIBLE FAILURE SCENARIOS

Failure Mode	Failure-to-Contain Scenario
Overtopping of the Embankment Crest	• Overtopping due to an extreme storm event A significant storm event occurs, causing a rainfall event that is capable of exceeding the capacity of the TSF and overtops embankment. • Overtopping due to embankment settlement and an extreme storm event The embankment crest experiences settlement over time, reducing freeboard. An extreme storm event then occurs, causing overtopping of the embankment. • Overtopping due to seismic deformation A significant seismic event occurs, and whilst no slope stability failure occurs, there is a significant amount of embankment crest settlement and deformation, reducing freeboard. This loss of freeboard is in conjunction with a storm event that will cause an overtopping of the embankment. Any of these overtopping events then cause significant and ongoing erosion of the embankment that cannot be rectified. This erosion results in a failure of the TSF.
Embankment Instability	• Static stability failure Poor embankment construction quality or incorrect material characterisation leads to a global slope failure of the embankment, allowing uncontrolled release of water during nominal storm events. • Seismic stability A significant seismic event occurs, causing a slope stability failure of the embankment, allowing uncontrolled release of water during nominal storm events.
Internal Erosion / Piping	• Piping through embankment during a storm event A storm event causes ponding of water against the embankment, which is then able to permeate into the embankment. The mobilisation of water begins to erode the embankment materials and create a flowing geotechnical pipe that continually erodes the embankment from the inside. This continual erosion increases and eventually blows out at the downstream face of the embankment, resulting in an uncontrolled release of the stormwater.

2.7 SQRA: Calculation of Probabilities

2.7.1 Basis for Assessment

Quantitative assessments were performed to estimate the storm event probabilities and seismic event probabilities, using engineering judgement (refer **Section 2.7.2** and **2.7.3**). Other contributory faults within the fault trees have been assigned through judgement, experience and published literature.

For events that could not be modelled or accurately quantified, and where judgement was required to assign probability, the mapping scheme developed by Barneich et al **[3]**, and shown in Table 8.1 of ANCOLD **[1]**, reproduced below in **Table 5**, was used.

TABLE 5 : MAPPING SCHEME (REPRODUCED FROM ANCOLD, REF. 1)

Description of Condition or Event	Order of Magnitude of Probability
Occurrence is virtually certain.	1
Occurrence of the condition or event are observed in the database.	10^{-1}
The occurrence of the condition or event is not observed, or is observed in one isolated instance, in the available database; several potential failure scenarios can be identified.	10^{-2}
The occurrence of the condition or event is not observed in the available database. It is difficult to think about any plausible failure scenario; however, a single scenario could be identified after considerable effort.	10^{-3}
The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.	10^{-4}

It is noted that “Database” does not refer to the knowledge held by any particular analyst; rather it represents the knowledge of all reasonably accessible information across a wide variety of sources.

2.7.2 Storm Event Probabilities

To estimate the probability of overtopping scenarios, the storm storage capacity of the TSF was assessed and equated to an AEP storm event. This process entailed:

1. **Assessment of the storm storage capacity**
   (above the tailings beach up to the embankment crest)

   To generate the storm storage curve, aerial 10 m grid survey provided by Landgate in July 2021 was relied upon. Due to the coarse nature of the survey, 3d modelling of the embankment was undertaken to replicate the existing geometry more accurately.

   The estimated storm storage capacity for Bulong TSF is presented in **Graph 1**. Assuming a flat embankment crest at RL 331 m, the storm storage capacity is 593,500 m^3.

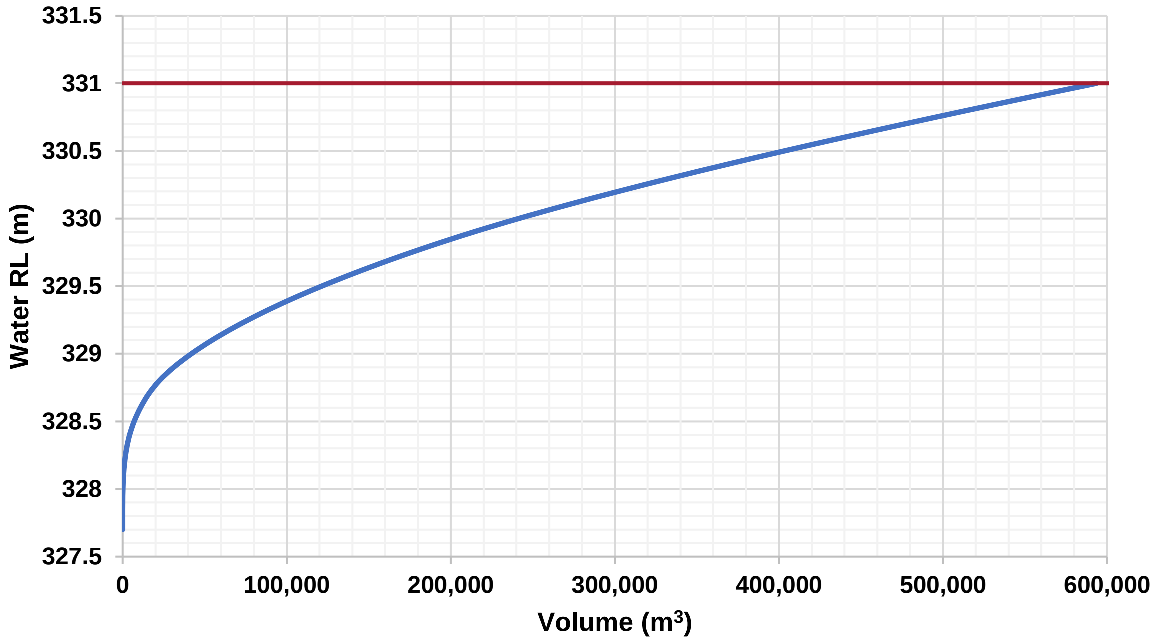
2. **Estimation of Design Rainfall**
   Design rainfall depths up to a 1 in 2,000 AEP event were obtained from the Bureau of Meteorology (BoM).

   Estimation of the Probable Maximum Precipitation (PMP) was performed using the ‘GSAM-GTSMR WA Transition’ zone method applicable to Bulong TSF, described in Australian Rainfall and Runoff (ARR) **[9]**.

   Estimation of extreme rainfall events between the 1 in 2,000 AEP event and the PMP was performed using the interpolation method outlined in ARR.

A chart of the design rainfall depths is presented in **Figure B3 & B4** of **Appendix B**.

GRAPH 1 : BULONG TSF STORM STORAGE CAPACITY



3. **Overtopping Storm Event**
   Based on the Bulong TSF catchment area of approx. 445,200 m^2 and the estimated storm storage capacity of 593,500 m^3 (**Graph 1**), the design rainfall depth required to overtop the embankment is approximately 1,330 mm.

   This is approximately equivalent to the 1 in 1,000,000 yr (PMP), 72-hr duration event, estimated at 1,340 mm (refer **Figure B4** of **Appendix B**).

   The above overtopping rainfall depth calculation is based on the design embankment crest level of RL 331 m. Other overtopping probabilities have been determined from the storage curve for the SQRA for differing embankment crest levels (i.e. due to settlement).

2.7.3 Seismic Event Probabilities

No Seismic Hazard Assessment (SHA) is available for the Bulong TSF site. As such, it is not possible to determine accurate probabilities for seismic events at the site. In lieu of this data, the Geosciences Australia 'Earthquakes@GA' tool was utilised, which includes the 2018 National Seismic Hazard map.

Based on the National Seismic Hazard map shown in **Diagram 2**, the Bulong TSF site is estimated to have a Peak Ground Acceleration (PGA) in the range of 0.12 to 0.16 g for a 2% chance of exceedance in 50 years event. This is equivalent to a return period of 2,500 years. ATCW has performed SHA's for various mine site within WA. Design earthquakes of the same return period for these sites have typical mean magnitudes of roughly 5.5 to 6.0.

The Pells and Fell method **[5]** was utilised to assess the likely damage class and resultant deformation from various seismic events. A chart to establish the 'damage class' to the embankment is presented in **Diagram 3**.

For a 1 in 2,500 yr seismic event at the Bulong TSF site, assuming a PGA of 0.16 g and a magnitude of 6.0, the Damage Class Number is estimated to be '0'. An interpretation of the damage classification system is presented in **Table 6**, in addition to estimated settlement values for Bulong TSF for the various damage classes (based on the maximum 9 m height of the embankment). The Bulong TSF is expected to experience negligible damage and crest settlement under a 1 in 2,500 yr seismic event.

It has also been considered if a larger, less frequent event could potentially cause significant deformation of the embankment (and a loss of freeboard). A maximum credible magnitude of 7.5 has commonly been used within Australia (an area no major active faults). For a seismic event of this magnitude, the Damage Class Number could potentially increase to ‘3’, which is estimated to induce crest settlement up to 135 mm.

Based on a similar seismicity setting within Western Australia (for which a seismic hazard assessment has been performed), it is estimated that a 1 in 10,000 yr seismic event may result in a ‘Major’ damage classification (150 mm max settlement). Extrapolating this data, it is estimated that a 1 in 25,000 yr seismic event may result in a ‘Severe’ damage classification, capable of reducing the embankment freeboard to zero and allowing the release of stored water under frequent storm events, as well as inducing localised slumping of tailings.

It is noted that the probabilities stated in the above commentary are based on high-level approximations only, and have been performed for the purpose of obtaining a sense of the likelihood of seismic induced failures. A detailed seismic hazard assessment would need to be performed to obtain more accurate probabilities.

DIAGRAM 2 : NATIONAL SEISMIC HAZARD MAP
PGA WITH 2% CHANCE OF EXCEEDANCE IN 50 YEARS

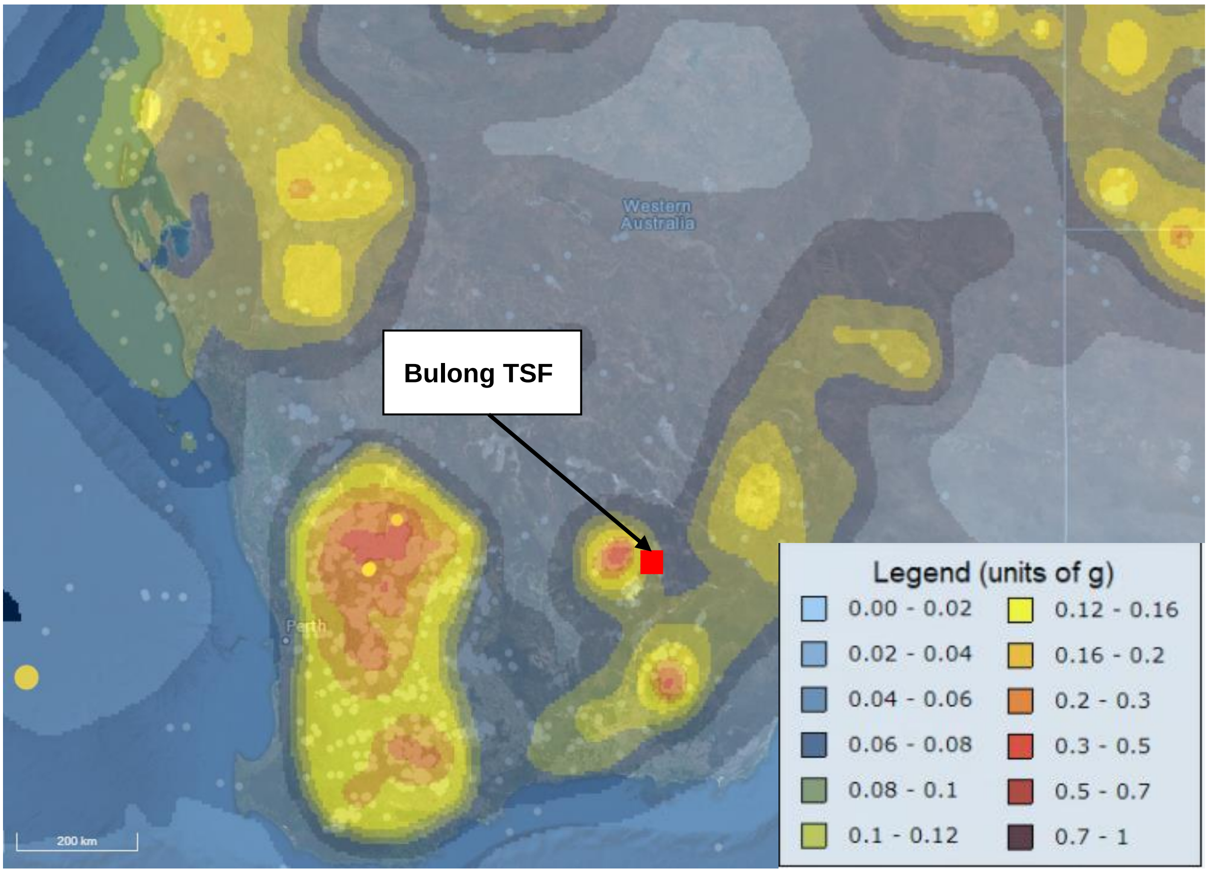


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DIAGRAM 3 : CONTOURS OF DAMAGE CLASS (PELLS AND FELL 2003)

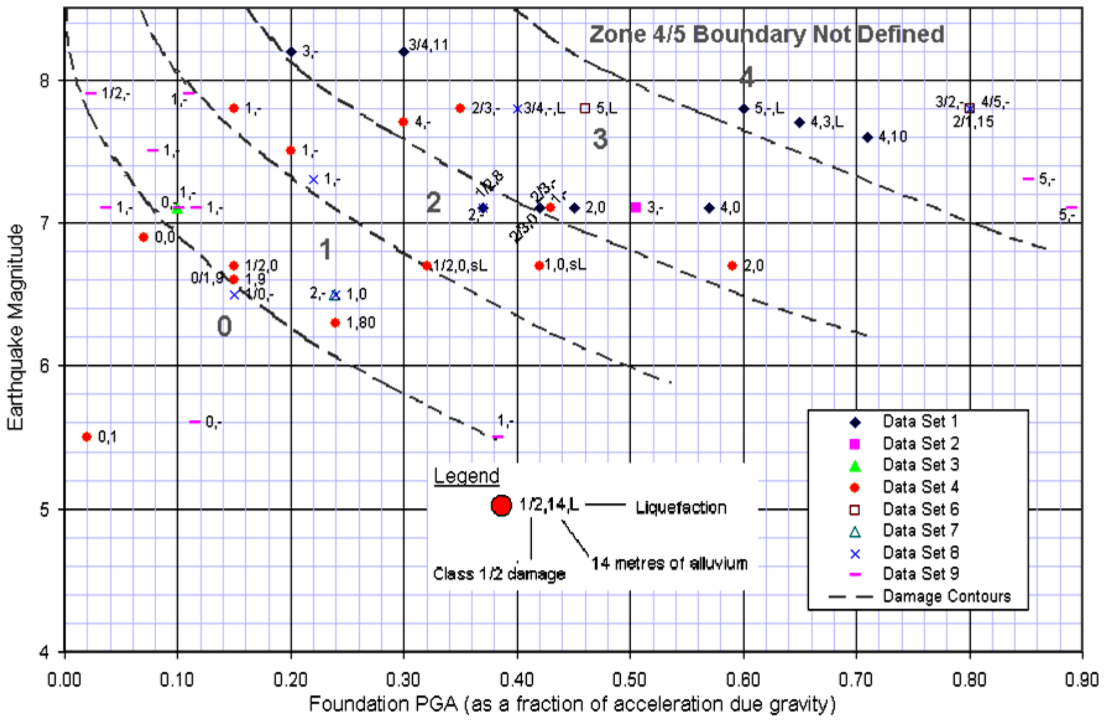


TABLE 6 : DAMAGE CLASSIFICATION SYSTEM (PELLS AND FELL 2003)

Damage Class Number	Description	Max. Longitudinal Crack Width (mm)	Max. Relative Crest Settlement (%)	Estimated Crest Settlement for Bulong TSF (mm)
0	No or Slight	< 10	< 0.03	0 to 3
1	Minor	10 to 30	0.03 to 0.2	3 to 18
2	Moderate	30 to 80	0.2 to 0.5	18 to 45
3	Major	80 to 150	0.5 to 1.5	45 to 135
4	Severe	150 to 500	1.5 to 5	135 to 450
5	Collapse	> 500	> 5	> 450

2.8 SQRA: Results

2.8.1 Fault Tree Analyses

Fault trees for each failure scenario (refer **Table 4**) are presented in **Appendix A**. Each of the fault trees model the pathway to a failure-to-contain scenario, developed using the approach as outlined in **Section 2.4**.

2.8.2 Results from Fault Tree Analyses

The results of the fault tree analyses as produced in **Appendix A**, with calculated probabilities estimated for each individual scenario, are summarised in **Table 7** below.

The Assigned Probabilities for individual events, together with appropriate justifications, are also presented in **Appendix A**. These values include calculated probability of an event (as described in **Section 2.7**) where the calculation of probability was possible through technical analyses, and estimations of the Order of Magnitude of Probability of an event (as outlined in **Table 5** in **Section 2.7.1**) where there is no practical way of calculating the estimated probability.

The justification for the estimated events has been based on the knowledge and experience of ATCW, and how likely an event is to occur given the assumed correct implementation of adequate control measures and mitigatory design features included as part of the overall design.

All calculated probabilities are significantly below the limit of tolerability of 1 x 10^{-3} (1 in 1,000), as discussed in **Section 2.5**.

TABLE 7 : RESULTS FROM FAULT TREE ANALYSES

Top Faults (occurring as Failure-to-Contain Scenarios)	Fault Tree Figure	Annual Probability of Occurrence	Annual Probability of Occurrence
Failure due to Overtopping of the Embankment Crest	A1	1.23 x 10^{-7}	1 in 8,106,795
Static Stability Failure	A2	9.10 x 10^{-7}	1 in 1,095,900
Seismic Stability Failure	N/A - Refer commentary in **Section 2.7.3**	4.0 x 10^{-5}	1 in 25,000
Piping through the Embankment	A3	6.9 x 10^{-8}	1 in 14,501,021

3 DAM BREAK STUDY

3.1 Introduction

ATCW have performed a dam break study for the Bulong TSF in order to estimate the inundation extents for a failure scenario, as well as the potential impacts. The proceeding sections detail the methodology adopted for the modelling process, as well as a discussion on the key results.

ATCW understand that there are no permanent population or infrastructure along the expected flow path, hence no Population-at-Risk (PAR) assessment has been performed as part of the study.

Associated dam break figures are presented in **Appendix B**. An overall layout of the Bulong TSF is presented in **Figure B1**.

3.2 Modelling Methodology

3.2.1 Overview

The Bulong TSF has been inactive since 2005, and as such, has had significant time for the tailings to consolidate. A recent investigation of the tailings strength has indicated that the tailings do not have the potential for significant mobilisation during a dam break event (refer **Section 3.2.2**).

Hence, it is assumed in this dam break study that the embankment breach is only triggered by a storm storage within the TSF, as essentially a water release with limited tailings washout. As a result, a post-flood Sunny Day Failure (SDF) has been assumed to be the critical scenario for potential impact to the downstream area.

The breach location has been conservatively assumed to be at the southern embankment of the Bulong TSF, based on the high point of the embankment and the preferred breach flow path is towards the south-east.

3.2.2 Adopted Modelling Techniques & Tailings Mobilisation Potential

Under the design dam break scenario, limited tailings are assumed to be mobilised or discharged. This assumption has been made on the following basis:

- No tailings deposition has occurred in the facility since the mine was abandoned in 2005. After this time, the tailings have been allowed to dry and consolidate without extended periods of ponded water. The tailings are therefore assumed to have very limited flow potential.
- A stored flood within the Bulong TSF (i.e., storm storage to the dam crest level prior to failure) will not have sufficient time to saturate the tailings to a depth which would allow mobilisation of the tailings in a failure scenario.
- A tailings investigation **[12]** was performed by ATCW in July 2021 using a PANDA Dynamic Cone Penetrometer. The tailings were classified as having a 'Stiff' to 'Very Stiff' consistency up to the investigated depth of 4.2 m.
- Tailings are assessed to be non-liquefiable, based on:
  - High plasticity of tailings (Plasticity Index of 35, Liquid Limit of 88), based on research by Seed et al. (2003) **[6]**
  - No saturation of tailings observed during recent site visit (up to 4 m depth)

As such, the dam break model has only considered the effects of the retained storm storage being released. The flood wave has therefore been modelled as water, a Newtonian fluid. **Section 3.5.2** details the assumptions made for the dam breach propagation.

The breach formation at the embankment is estimated using Froehlich's empirical equations **[7]** where the stored flood water within the Bulong TSF forms the flood wave that drains into the downstream receiving environment.

3.2.3 Modelling Process

The following process was undertaken to complete the Bulong TSF dam break analysis:

1. Assemble a 3-dimensional topographic model of the Bulong TSF site together with the downstream receiving environment, extending past the Evaporation Pond;
2. Estimate Bulong TSF embankment breach parameters and set up an initial condition for the critical case and the storm storage, which is taken to be a dam crest flood (i.e., up to the embankment crest at RL 331 m);
3. Based on the topographic model, create a 2-dimensional unsteady flow hydraulic model to simulate the dam break scenario;
4. Run the hydraulic dam break model for the simulated breach of the embankment, incorporating a total stored water release of 594,000 m^3 (refer to **Section 3.5.2**);
5. Create flood inundation maps and estimate maximum flood depths, velocities, arrival time and flood impact within the downstream receiving area;
6. Provide assessments and discussions regarding the dam break outcomes.

3.2.4 Failure Scenario

A Sunny Day Failure (SDF) generally represents a sudden dam failure that may be caused by overtopping, piping, or earthquake. This failure condition generally involves little to no existing flooding of the downstream receiving environment.

Considering the prolonged inactive and dry condition of the Bulong TSF, it is envisaged that the failure of the TSF embankment would only occur after an extreme storm event. The failure scenario has considered the TSF to be full up to the embankment crest in order to assess the most critical downstream impact.

By comparison, an Incremental Flood Failure (IFF) considers a TSF breach occurring coincident with an existing downstream flooding condition. This scenario has not been analysed in this study as the catchment of the Bulong TSF (i.e., the impoundment area) is significantly smaller comparing to the contributing natural catchment of the downstream flow path. Therefore, it is estimated that the release of a storm storage from the TSF would generate negligible incremental impact relative to the natural downstream flood conditions during such an extreme storm event.

The following assumptions have been adopted for the Sunny Day Failure scenario of the Bulong TSF:

1. An extreme storm event has occurred and has filled the Bulong TSF up to the embankment crest;
2. The downstream flooding due to the storm subsides but the stored stormwater within the Bulong TSF is retained;
3. The Bulong TSF embankment consequently fails due to overtopping or piping failure, initiating a breach that releases almost all of the storm storage.

3.3 Rainfall Analysis

Rainfall data for the Bulong TSF has been obtained from the Bureau of Meteorology (BoM) **[8]**. Estimations of the rainfall intensities for the ARI (Average Recurrence Interval) of 1 year to 100 years for event durations of up to 72 hours have been determined from the BoM Design Rainfall Database**[8]**, and are presented in **Figure B3** of **Appendix B**.

The extreme rainfall depths for short durations (up to 3 hrs) and long durations (up to 72 hrs) have been estimated in accordance with the Australian Rainfall and Runoff (AR&R) Guidelines **[9]** and the BoM estimation methods **[10]** & **[11]**. These methods estimate the extreme rainfall depths at the Bulong TSF up to an ARI of 1,000,000 (i.e., Probable Maximum Precipitation, PMP). The extreme rainfall depths for various durations of storms are presented in **Figure B4**.

It is estimated that a 72 hrs PMP event would have a rainfall depth of 1,340 mm, which corresponds to a total storm storage volume of approximately 596,000 m^3 within the impoundment area of the Bulong TSF. This is slightly greater than the estimated maximum storage capacity within the TSF up to the embankment crest level (as discussed in **Section 3.5.2**). Hence it is assumed in this study that in the worst-case scenario, the storm storage pond is at the embankment crest level of RL 331 m before triggering the embankment breach.

3.3.1 Adopted Initial Conditions

The adopted Bulong TSF and downstream receiving conditions upon initiation of the dam break are summarised as follows:

- Bulong TSF configuration:
  - Tailings were discharged from the embankment perimeter and the beach is sloping to the centre of TSF, with a central elevation of RL 327.7 m around the decant causeway;
  - Dam crest flood stored up to embankment crest RL 331 m.
- Downstream receiving area configuration:
  - No antecedent flows in existing watercourse;
  - Downstream soil is fully saturated following the flood event. No losses are assumed in the model.

3.4 Modelling Overview

3.4.1 Breach Parameter Estimation

The characteristics of the embankment breach have been determined using Froehlich's empirical equations **[7]**. Key inputs required for the Froehlich parameter estimation as follows:

- Volume of water lost through the breach (V_w); and
- Ultimate breach depth.

The adopted breach geometry is assumed to be trapezoidal-shaped, with key breach outcomes comprising:

- Ultimate breach width (B_w);
- Breach formation side slopes (for overtopping failure); and
- Breach development time (t_f).

3.4.2 Hydraulic (Flood) Model

2-Dimensional (2D) dam breach modelling was performed using the software package HEC-RAS 6.0.0 **[13]**. HEC-RAS was developed by the U.S. Army Corps of Engineers Hydraulic Engineering Centre originally as a 1D flow modelling tool, with the 2D modelling capacities developed and released in 2016.

For the Bulong TSF dam break analysis, both the TSF impoundment and the downstream receiving area were modelled as 2D flow grids.

HEC-RAS 2D hydraulic modelling does not require a pre-determined failure path, which helps to identify more realistic potential failure impact zones. The model estimates the flow paths, velocities and depths based on the hydraulic conditions and topography and allows assessment of inundation of critical infrastructure and locations caused from the flood flows.

3.5 Model Inputs

3.5.1 Digital Elevation Model (DEM)

The DEM used for the dam break model is a 10 m grid aerial survey received on the 29th of July 2021 from Landgate, which contains approx. 3,425,422 points and covers an area of 342.2 km^2.

3.5.2 Dam Breach Parameters

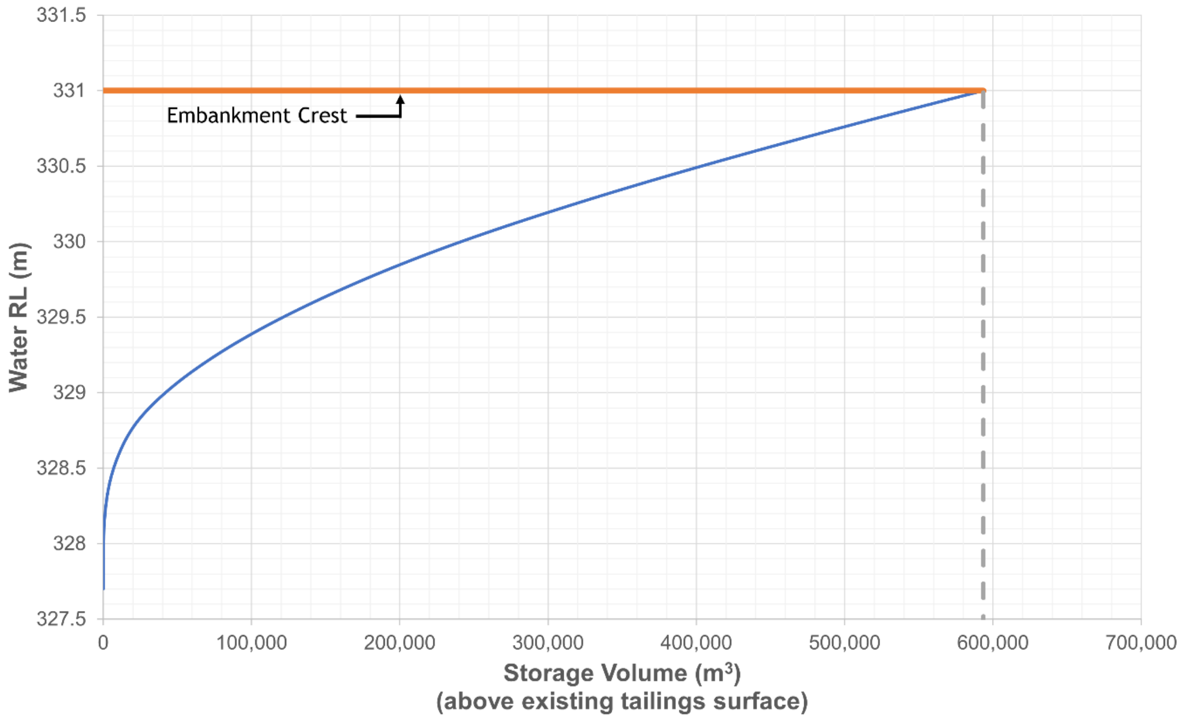
Flow into the system is generated by the breach of the Bulong TSF embankment. One of the key considerations in dam break modelling is the vertical extent of the breach propagation. Considering that the tailings beach is sloping towards the central decant, a failure of the perimeter embankment may not release all the stored water, especially near the TSF centre, due to the retained tailings preventing water release.

Nonetheless, it has conservatively been assumed in this study that after the breach initiates, the water release will gradually erode the embankment and the tailings surface forming a channel which would results in the release of the majority of the stored water. An eroded channel with a gradient of 0.5% has been assumed, resulting in an embankment breach bottom elevation of RL 326.5 m (i.e., 4.5 m below the embankment crest).

The TSF breach layout is presented in **Figure B2**.

Based on the pond storage curve presented in **Chart 2**, the total maximum storm storage within the TSF is approximately 594,000 m^3.

CHART 2 : BULONG TSF POND STORAGE CURVE



The characteristics of the embankment breach, through which release would occur, have been determined using Froehlich's empirical equations **[7]**.

Froehlich's empirical breach equations consist of estimator equations based on historical dam failure case studies. The equations determine breach width and breach development time and specify breach geometry side slopes based upon the failure mode (piping or overtopping). The equations are:

$$B_{AVE} = 0.27\, K_0 V_W^{0.32} h_b^{0.04}$$

$$t_f = 63.2 \sqrt{\frac{V_W}{g h_b^2}}$$

Where

B_{AVE}	*Average Breach Width, (B_{TOP} + B_{Bottom})/2*	*m*
K_0	*Failure Mode Coefficient* *(K_{Piping} = 1.0, $K_{Overtopping}$ = 1.3)*	-
V_W	*Volume Above Breach Level*	*m^3*
h_b	*Depth of Breach Measured from Embankment Crest Level*	*m*
t_f	*Breach Progression Time*	*second*

The Froehlich equations require the total depth and volume of the failure as an input. The adopted breach geometry is trapezoidal-shaped with a side slope of 1H:1V for the overtopping scenario.

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The calculated embankment breach parameters using Froehlich's empirical equations **[7]** are summarised in **Table 8**.

TABLE 8 : EMBANKMENT BREACH PARAMETERS

Parameter	Value
Embankment Breach Top RL	331 m
Embankment Breach Base RL	326.5 m
Total Breach Volume (V_w)	594,000 m^3
Breach Bottom Width (B_w)	22 m
Breach Side Slope	1 H : 1 V
Breach Development Time (t_f)	0.97 hrs

3.5.3 Computational Mesh

The computational mesh was defined to enable accurate calculations without sacrificing efficiency. An overall flow grid with 10 m spacing was adopted for the impoundment area of Bulong TSF, and a 2 m locally refined mesh spacing was used around the Bulong TSF embankment breach area.

3.5.4 Roughness Coefficients

A Manning's roughness coefficient (n) value was assigned to the downstream catchment. Roughness coefficients represent the resistance to flood flows in channels and floodplains.

Appropriate Manning's 'n' values were assigned as per Chow **[14]**.

The adopted Mannings 'n' value for modelling purpose was 0.03. This value was adopted based on the information on the aerial imagery showing the downstream receiving area with little to no pastures.

3.5.5 Boundary Conditions

The downstream model boundary is defined at the perimeter of the southern floodplain extent, to remove the excess water from the model domain, shown in **Figure B5**. It is also expected that the flow outside of the model domain will follow the natural drainage path.

3.6 Model Analysis

The HEC-RAS model was run for a total duration of 12 hours which allowed full flood wave propagation in the downstream receiving area.

The adopted time step is another critical aspect of the model computational setting. A fine time step setting is able to capture flow conditions during the rapid discharge period but will increase the computational time and reduce efficiency. HEC-RAS version 6.0.0 **[13]** supports the capability of using adaptive time steps to increase the computational efficiency and was implemented in this dam break study.

During the model analysis, HEC-RAS can maintain suitable modelling conditions by adapting the time steps under control by Courant conditions. A basic time step of 5 seconds was used for the simulation, and it was adaptively controlled between 0.16 seconds to 40 seconds. During the period around the peak breach flow, the time step was on average set at 0.31 seconds.

The following points are noted regarding the dam break model:

- Due to the resolution of the available TSF survey used in study, there may be ground surface features that cannot be captured in the terrain model, hence the actual breach flow patterns and behaviours from a potential dam break may vary from the presented model results.
- Breach flow beyond the defined model boundary is not modelled as it is considered to be contained within the natural drainage path and reaching limited incremental effect. Also, any surface channel erosion or sediment transportation associated with the breach flow in the natural systems is neglected and considered to be out of the scope of the current analysis.

3.7 Model Outcomes

3.7.1 Results Summary

The output from the hydraulic dam break modelling has been presented in the form of inundation maps, including maximum inundation depth, velocities, arrival time and impact (indicated by depth x velocity value). These inundation maps are shown in **Figure B5** to **Figure B8 of Appendix B**.

From the inundation maps, it can be identified that the maximum inundation depths and velocities generally occur near the initial breach and directly downstream of the Bulong TSF. As the dam break flood wave travels downstream towards the Evaporation Pond perimeter wall, the depth and velocity generally dissipate.

The flood wave is estimated to reach the Evaporation Pond perimeter wall in 30 – 45 mins following the initiation of the Bulong TSF embankment breach. The maximum inundation depth at the Evaporation Pond is 0.6 m, and the maximum flood velocity is 0.7 m/s. The maximum impact force represented by Depth × Velocity on the northern wall of the Evaporation Pond is generally less than 1 m^2/s.

It should be noted that whilst these inundation maps present the maximum inundation characteristics, the water surfaces as well as the values shown in the figures never actually occur simultaneously. These are rather representations of the maximum inundation area and the collections for the maximum values throughout the entire model duration.

3.7.2 Discussion

From the dam break modelling, it is identified that the breach flood will generate some level of impact on the Evaporation Pond perimeter wall and may cause some level of erosion. However, it is not expected that this would induce a failure of the structure.

As the Bulong site has been abandoned since 2005 and no permanent population or infrastructure is present within the modelled inundation area, there is not expected to be any Population at Risk associated with a breach of the Bulong TSF.

4 CONCLUSIONS

Based on the Likelihood of Failure Assessment (**Section 2**), the most likely failure scenario is through seismic instability, with an estimated annual probability of occurrence of 4.0 x 10^{-5} (1 in 25,000). An extreme seismic event may cause major deformation of the embankment, potentially leading to localised slumping of the tailings and an increased likelihood of overtopping from storm events.

All calculated failure scenario probabilities are significantly below the calculated ANCOLD **[1]** limit of tolerability of 1 x 10^{-3} (1 in 1,000).

The consequences resulting from a failure of the Bulong TSF embankment are expected to be low for the following reasons:

- No Population at Risk is expected to be present within the inundation area of the TSF.
- The environmental impacts associated with a release of stored flood water are expected to be low – stored water will have negligibly low contamination from contact with the tailings.

- The tailings are expected to have limited mobilisation potential if the embankment was to fail (refer **Section 3.2.2**). Some localised slumping of tailings may occur.

5 CLOSURE

Your attention is drawn to the "Conditions of Report" which appear after the References section of this Report.

REFERENCES

[1] ANCOLD (October 2003), "Guidelines on Risk Assessment", Australian National Committee on Large Dams.

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APPENDICES

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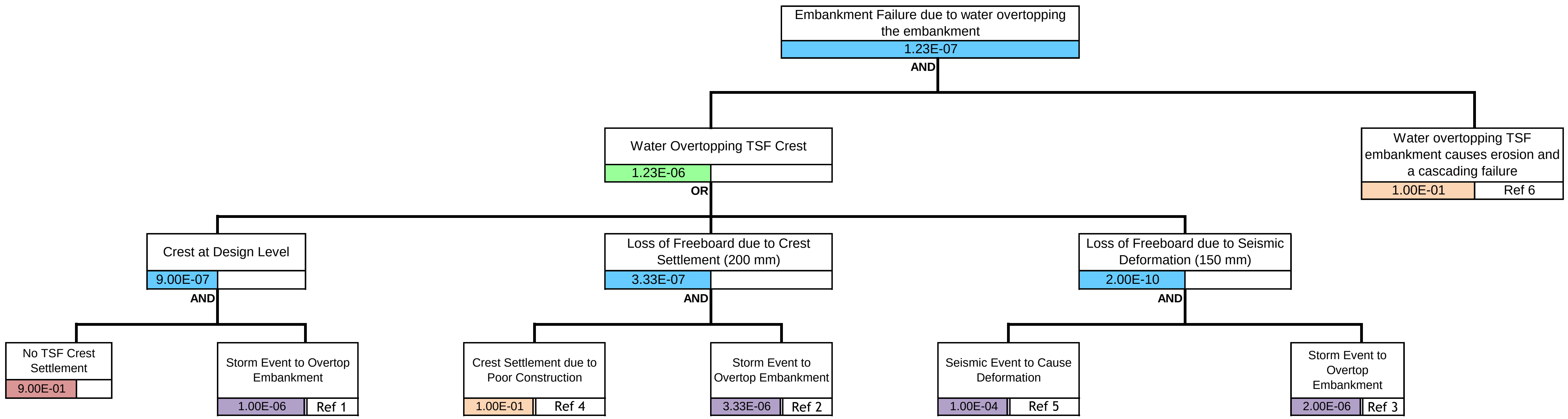
APPENDIX A – SEMI-QUANTITATIVE RISK ANALYSIS

'AND' Gate Calculation
'OR' Gate Calculation
Estimated Probability
Modelled Probability
Calculated Probability (from within Current Fault Tree)
Calculated Probability (from Independent Event Trees)
Reference Number



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DEPARTMENT OF MINES INDUSTRY REGULATION AND SAFETY

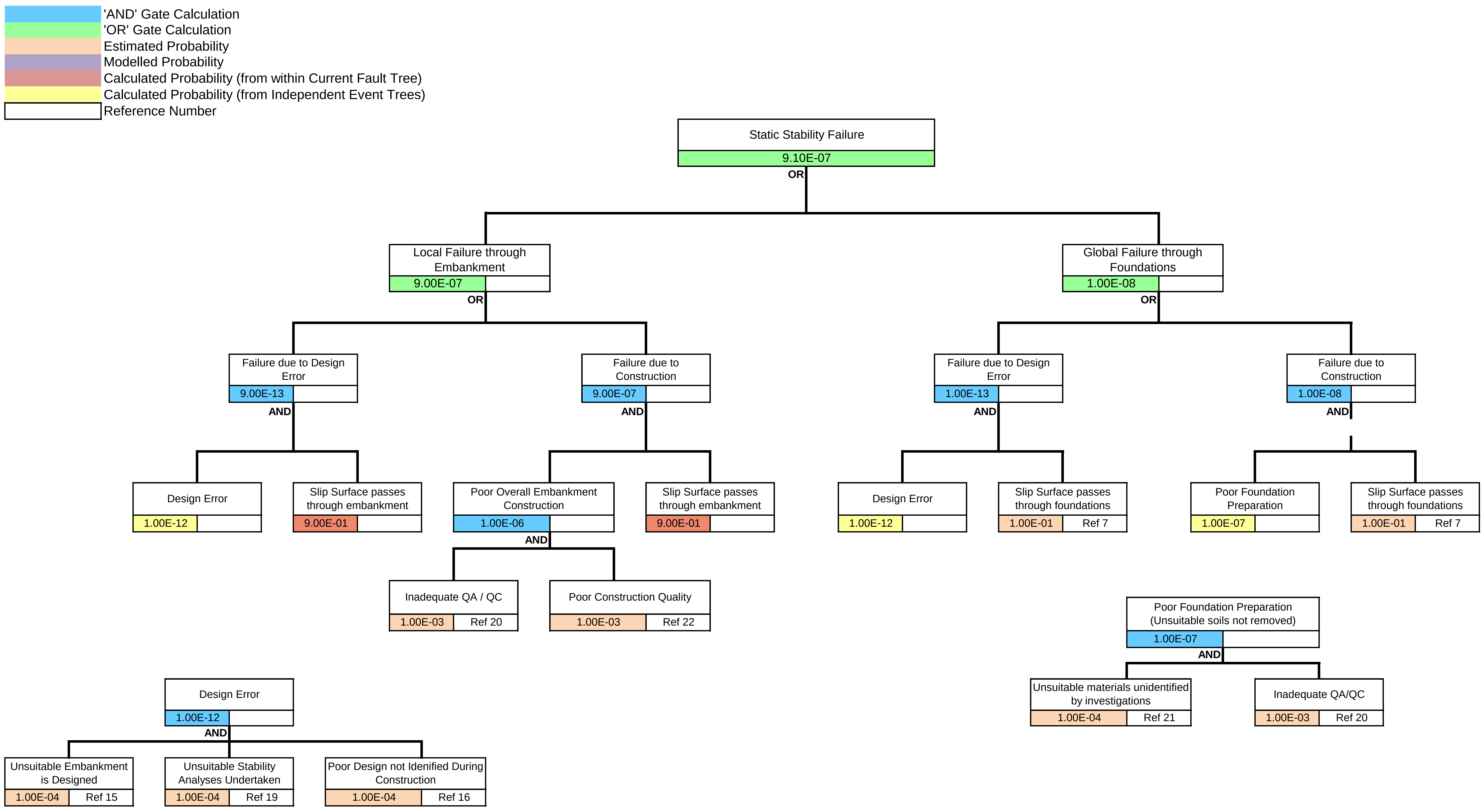
BULONG TSF ASSESSMENT

SEMI-QUANTITATIVE RISK ASSESSMENT & CONTROL ANALYSIS

FAULT TREE - OVERTOPPING FAILURE

Date:	20/09/2021	Job No	121085.01	FIGURE A1

K:\Projects\121\121085 DMIRS Abandoned Mines Program\01 Bulong TSF Assessment\Data and Calcs\Failure Modes\Fault Trees - Rev A Overtopping



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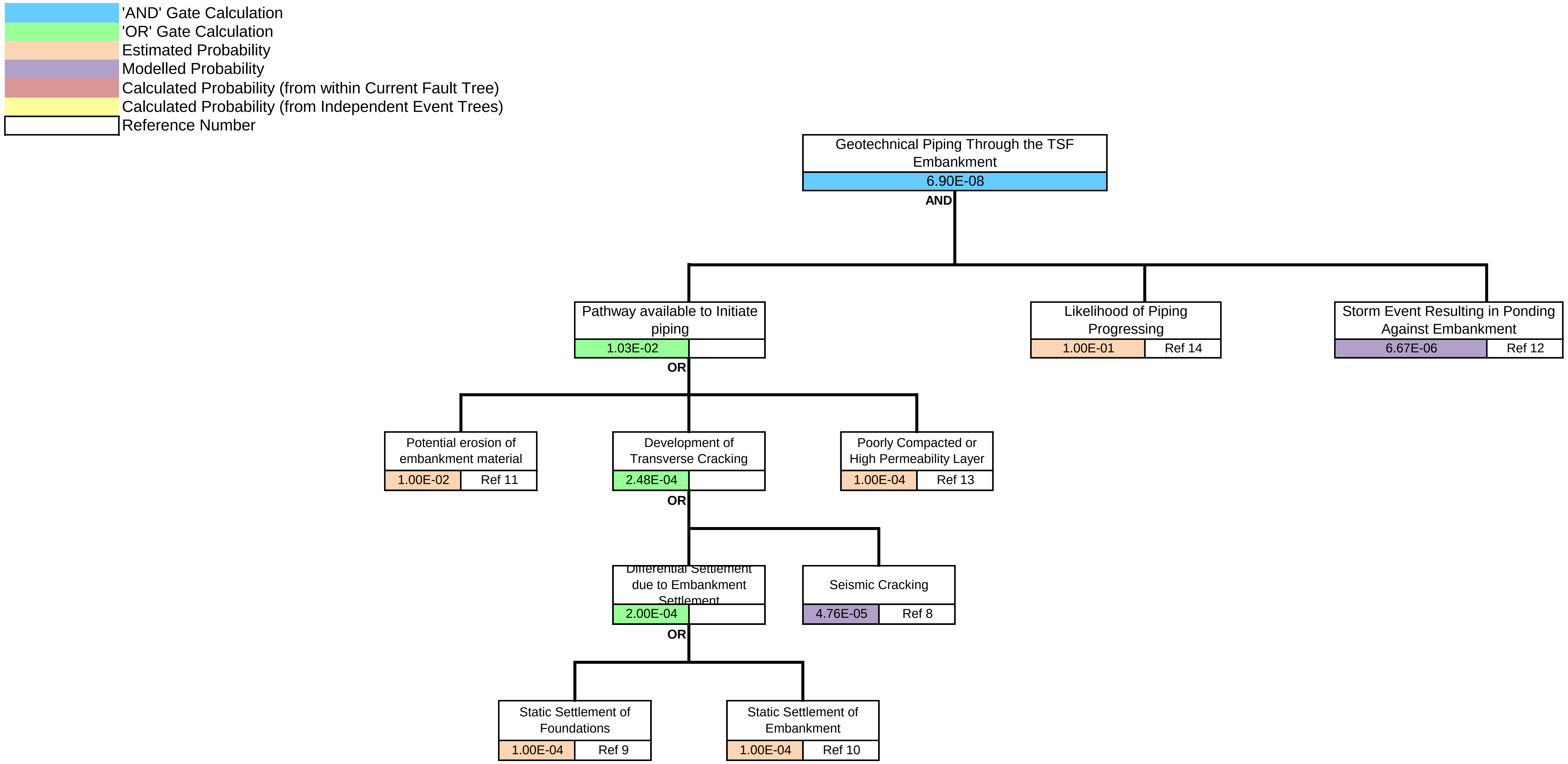
BULONG TSF ASSESSMENT

SEMI-QUANTITATIVE RISK ASSESSMENT & CONTROL ANALYSIS

FAULT TREE - STATIC STABILITY

Date:	20/09/2021	Job No	121085.01	FIGURE A2

K:\Projects\121\121085 DMIRS Abandoned Mines Program\01 Bulong TSF Assessment\Data and Calcs\Failure Modes\Fault Trees - Rev A Static Stability



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BULONG TSF ASSESSMENT

SEMI-QUANTITATIVE RISK ASSESSMENT & CONTROL ANALYSIS

FAULT TREE - FAILURE DUE TO PIPING THROUGH THE EMBANKMENT

Date:	20/09/2021	**Job No**	121085.01	**FIGURE A3**

K:\Projects\121\121085 DMIRS Abandoned Mines Program\01 Bulong TSF Assessment\Data and Calcs\Failure Modes\Fault Trees - Rev A Piping Through Embankment

REF No.	EVENT	ASSIGNED PROBABILITY	DESCRIPTION	JUSTIFICATION/CALCULATION METHOD
OVERTOPPING				
Ref 1	Storm Event to Overtop Embankment	1.00E-06	Crest at Design Level	Storage capacity / rainfall estimates
Ref 2	Storm Event to Overtop Embankment	3.33E-06	Crest 200 mm lower than design due to static settlement from poor construction	Storage capacity / rainfall estimates
Ref 3	Storm Event to Overtop Embankment	2.00E-06	Crest 150 mm lower than design due to seismic deformation	Storage capacity / rainfall estimates
Ref 4	Embankment Crest Settlement	1.00E-01	200 mm static settlement due to poor construction (assumed 2% settlement of max dam height - 9m)	Occurances of the condition or event are observed in the database.
Ref 5	Seismic Event to Cause Deformation	1.00E-04	1 in 10,000 AEP seismic event assumed to induce up to 150 mm settlement	Refer main report for details
Ref 6	Water overtopping TSF embankment causes erosion and a cascading failure	1.00E-01	Water overtopping the TSF crest causes significant and ongoing erosion of the embankment material that cannot be rectified in time, which cascades into a breach failure of the TSF embankment	Occurances of the condition or event are observed in the database.
STATIC STABILITY FAILURE				
Ref 7	Slip surface passes through foundations	1.00E-01	A static slip failure more likely to pass through the embankment, foundation material is expected to be stronger.	Occurances of the condition or event are observed in the database.
GEOTECHNICAL PIPING THROUGH THE TSF EMBANKMENT				
Ref 8	Seismic Cracking	4.76E-05	Development of transverse cracking across Zone 2 that will then drive piping through Zone 3. Equal to the AIR of the seismic event to cause significant cracking	Deformation Analysis
Ref 9	Static Settlement of Foundations	1.00E-04	Significant settlement of the embankment foundations cause transverse cracking across Zone 2	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 10	Static Settlement of Embankment	1.00E-04	Significant settlement of Zone 2 cause transverse cracking across the width of the zone	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 11	Potential Erosion of Embankment Material	1.00E-02	Internal erosion of the Zone A low permeability facing into the downstream mine waste rock	The occurance of the condition or event is not observed, or is observed in one isolated instance, in the available database several potential failure scenarios can be identified.
Ref 12	Storm Event resulting in ponding against the embankment	6.67E-06	Storm event causes water to pond against the embankment (above the tailings at RL 330.5 m).	Storage capacity / rainfall estimates
Ref 13	Poor Compacted or High Permeability Layer	1.00E-04	A poorly compacted or highly permeability layer creates a pathway for piping to iniate	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 14	Likelihood of Piping Progression	1.00E-01	Based on Fell. Et al 'Geotechnical Engineering of Dams' Table 8.17	
INDEPENDENT EVENT TREES				
Ref 15	Unsuitable Embankment Design	1.00E-04	An embankment design or foundation preparation that is beyond what is typically accepted is initially designed and not addressed during the review process	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 16	Poor Design not Identified During Construction	1.00E-04	Poor overall embankment design or foundation preparation methodology is not identified and addressed during construction	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 17	Insufficient Compaction	1.00E-03	Insufficient compaction is performed for significant portions of construction such that a weak zone is created	The occurance of the condition or event is not observed in the available database. It is difficult to think about any pluasible failure scenario; however, a single scenario could be identified after considerable effort.
Ref 18	Unsuitable Materials	1.00E-03	Low quality material used for signifcant portions of construction such that a weak zone is created	The occurance of the condition or event is not observed in the available database. It is difficult to think about any pluasible failure scenario; however, a single scenario could be identified after considerable effort.
Ref 19	Unsuitable Stability Analyses Undertaken	1.00E-04	The stability analyses undertaken were insufficient and potential critical stability issues were not discovered or addressed	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 20	Inadequate QA/QC	1.00E-03	Site engineer fails to notice or intervene in the unsuitable methods of foundation preparation/embankment construction that are implemented. QA/QC records unknown.	The occurance of the condition or event is not observed in the available database. It is difficult to think about any pluasible failure scenario; however, a single scenario could be identified after considerable effort.
Ref 21	Unsuitable materials not identified by investigations	1.00E-04	Geotechnical Investigation was not sufficiently performed, and unsuitable Geological Features (such as alluvial soil seams, fault lines or significantly more weathered rock formations) are left in place through the foundations	The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.
Ref 22	Poor Construction Quality	1.00E-03	Poor construction methodology and execution leads to varying levels of earthfill compaction, variable materials etc. Embankment construction records not available.	The occurance of the condition or event is not observed in the available database. It is difficult to think about any pluasible failure scenario; however, a single scenario could be identified after considerable effort.

APPENDIX B – DAM BREAK INUNDATION FIGURES

No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D

SCALE:	1:10,000
JOB No.	121085.01
DATE	10.08.21
DESIGN	TL
DRAWN	TL
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DMIRS
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DAM BREAK ANALYSIS
OVERALL LAYOUT

DWG. No.

FIGURE B1

SHEET SIZE	A3	Rev.	A

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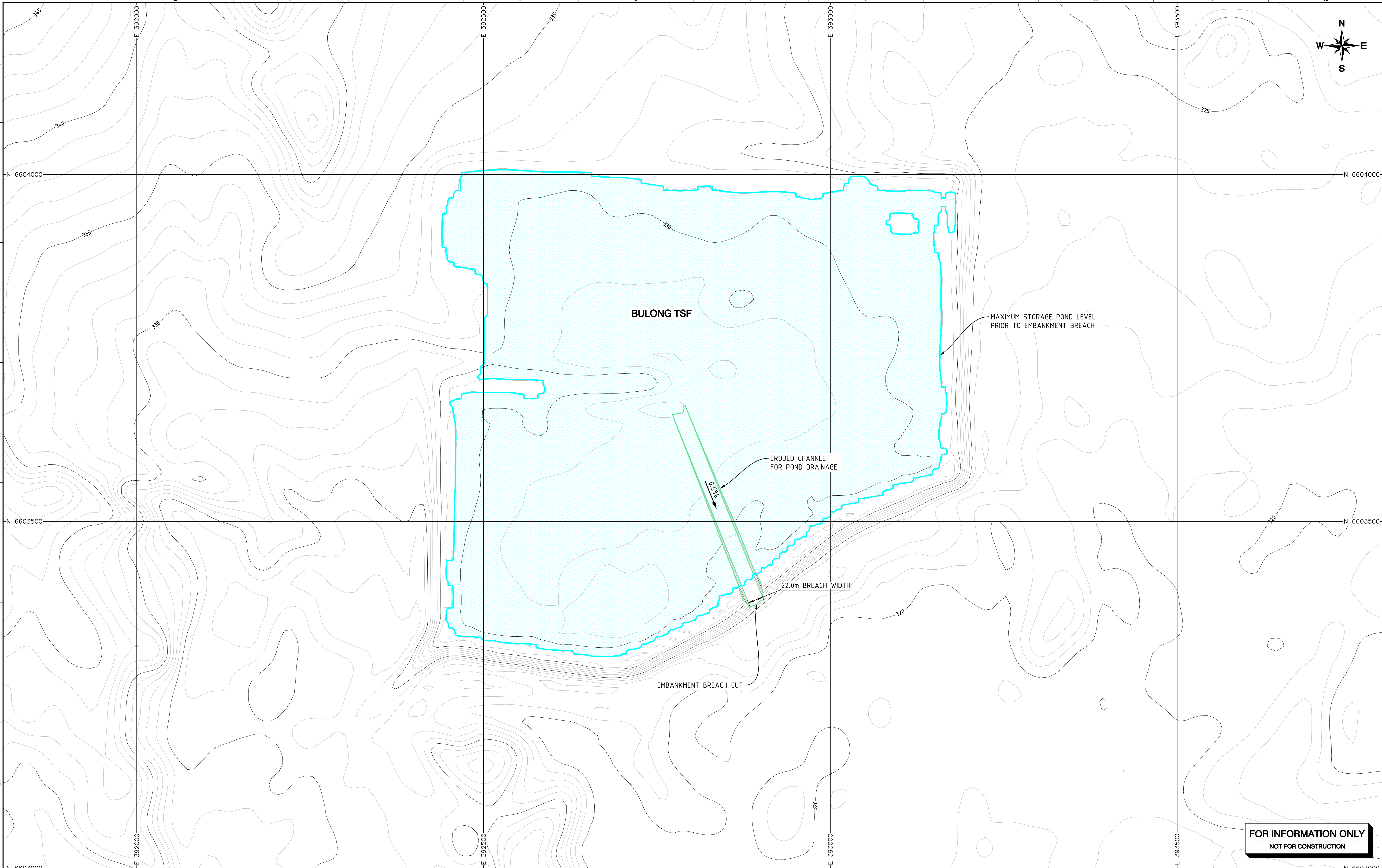

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No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D

SCALE:	1:5,000
JOB No.	121085.01
DATE	12.08.21
DESIGN	TL
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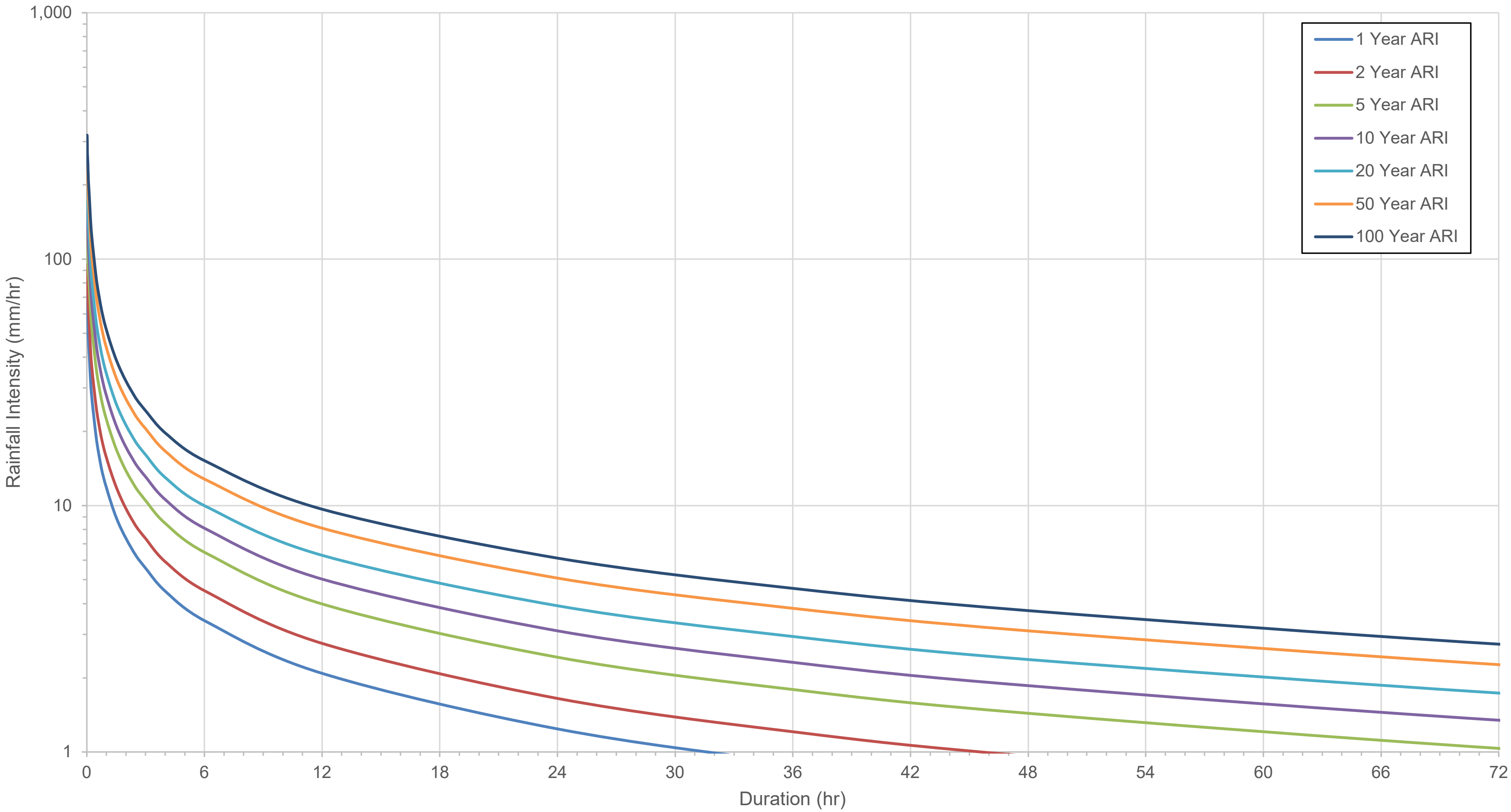
BULONG TAILINGS STORAGE FACILITY

DAM BREAK ANALYSIS
TSF BREACH LAYOUT

DWG. No.
FIGURE B2

SHEET SIZE	A3	Rev.	A

SHEET 1 OF 1



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DMIRS

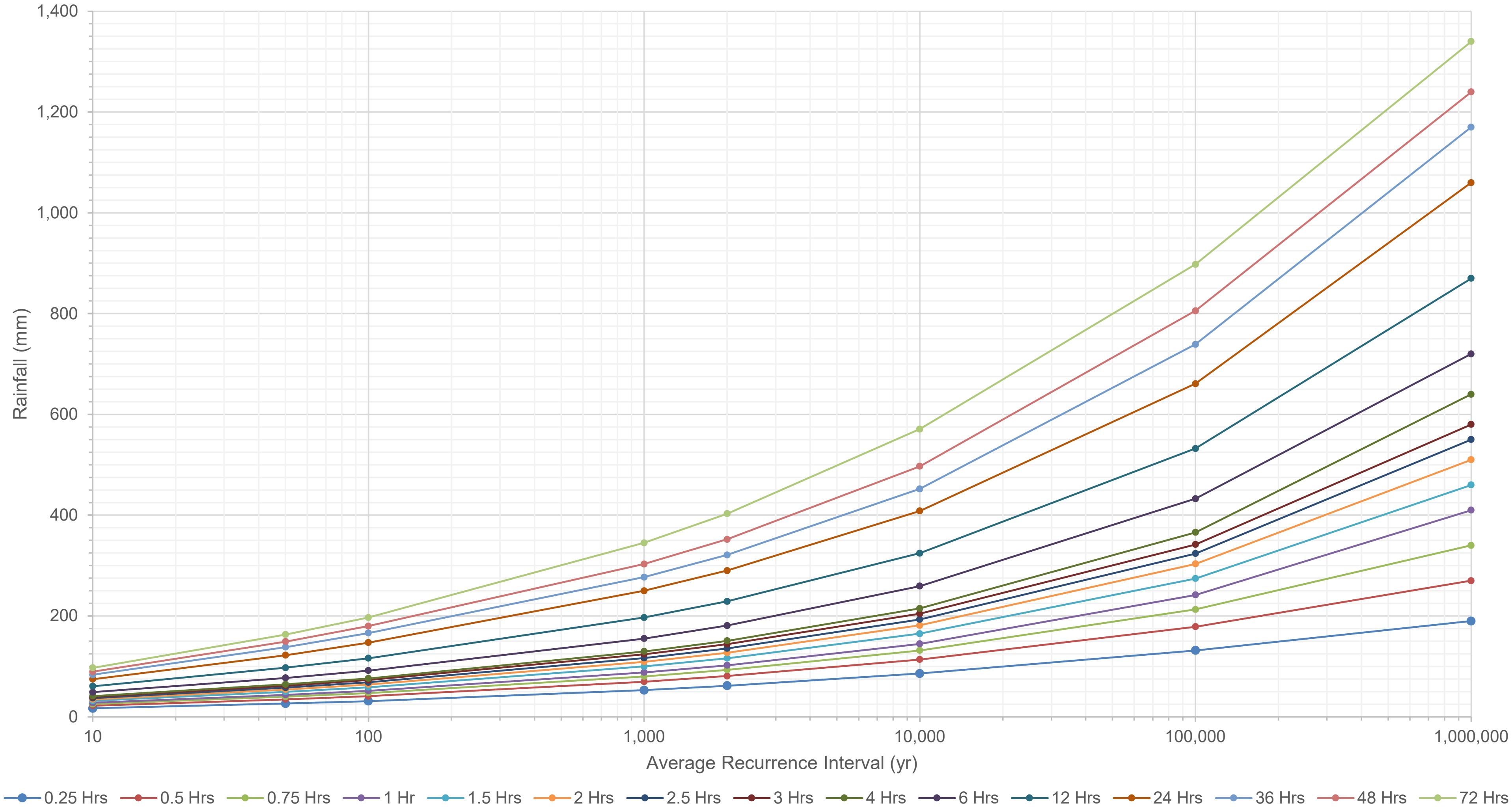
BULONG TAILINGS STORAGE FACILITY

GEOTECHNICAL ASSESSMNENT AND FINAL CLOSURE

Dam Break Study - Rainfall Intensity-Frequency-Duration Curves

Date:	16/08/21	**Job No:**	121085.01	**FIGURE B3**

K:\Projects\121\121085 DMIRS Abandoned Mines Program\01 Bulong TSF Assessment\Data and Calcs\Rainfall\PMP Estimate Bulong TSF.xlsx Fig3



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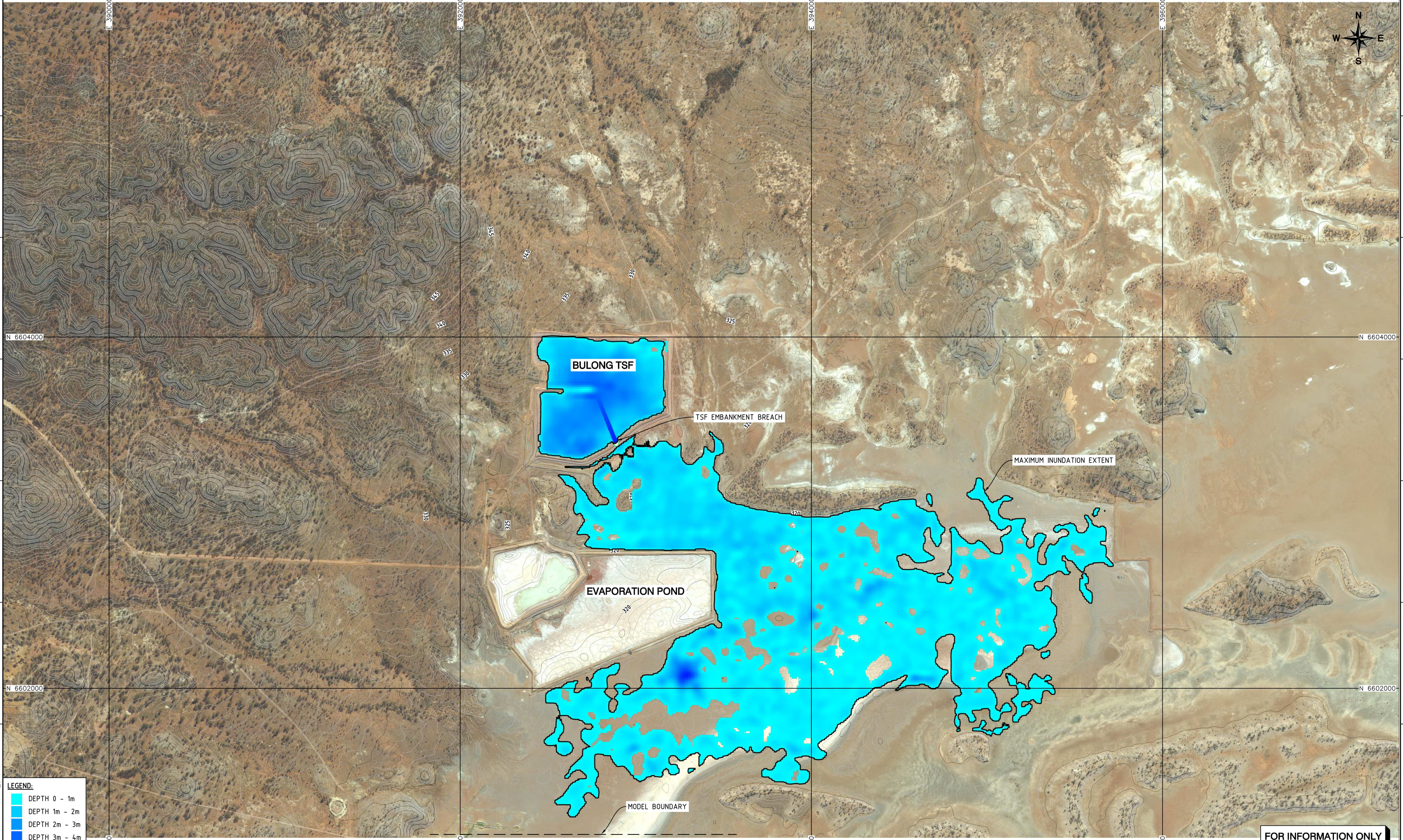
GEOTECHNICAL ASSESSMNENT AND FINAL CLOSURE

Dam Break Study - Estimation of Extreme Rainfall Events

Date:	16/08/21	**Job No:**	121085.01	**FIGURE B4**

K:\Projects\121\121085 DMIRS Abandoned Mines Program\01 Bulong TSF Assessment\Data and Calcs\Rainfall\PMP Estimate Bulong TSF.xlsx Fig4



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SCALE:	1:12,500
JOB No.	121085.01
DATE	12.08.21
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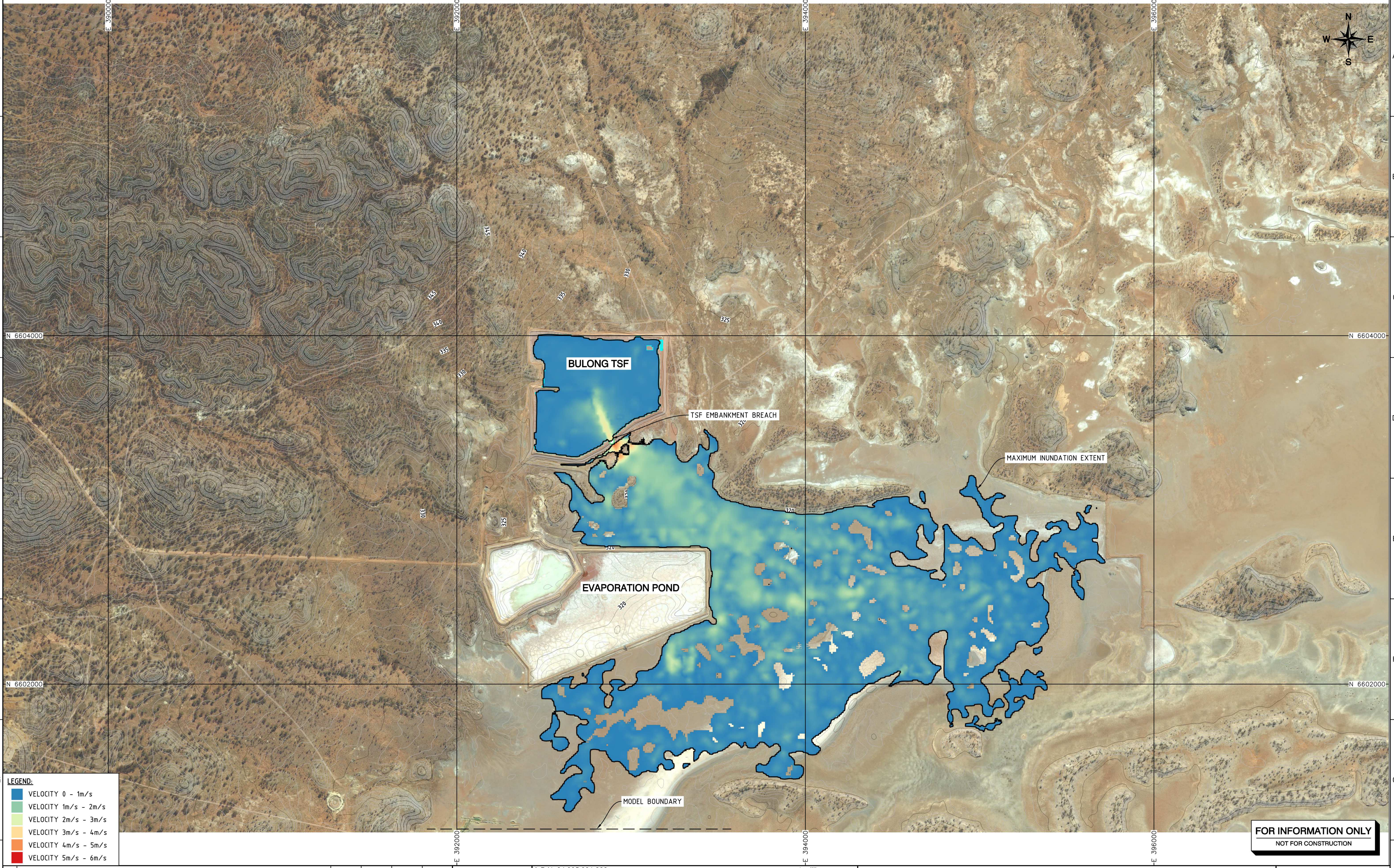
DAM BREAK ANALYSIS
MAXIMUM INUNDATION DEPTH

DWG. No.

FIGURE B5

SHEET SIZE	A3	Rev.	A

SHEET 1 OF 1



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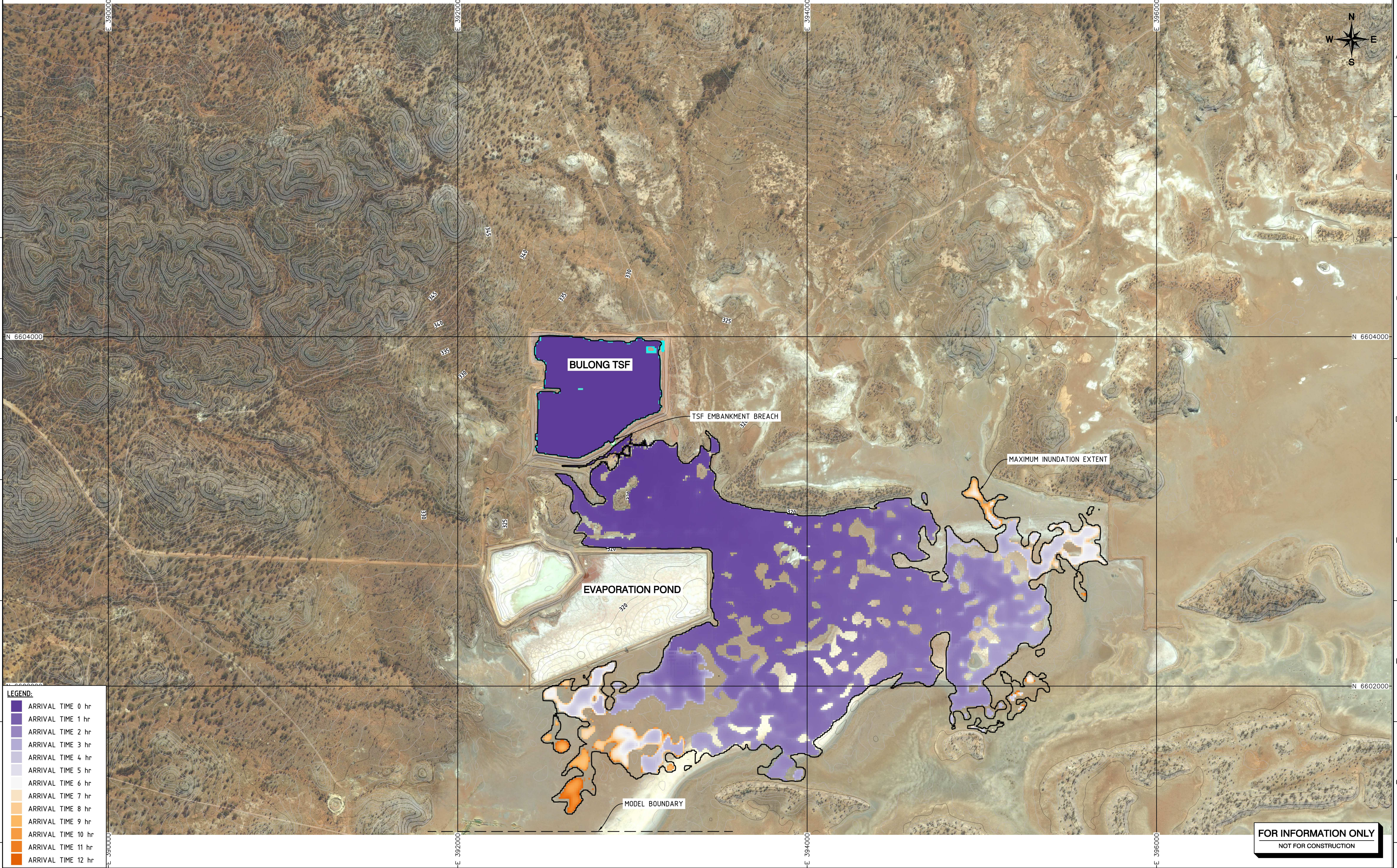
BULONG TAILINGS STORAGE FACILITY

DAM BREAK ANALYSIS
MAXIMUM INUNDATION VELOCITY

DWG. No.
FIGURE B6

SHEET SIZE	A3	Rev.	A

SHEET 1 OF 1



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JOB No.	121085.01
DATE	12.08.21
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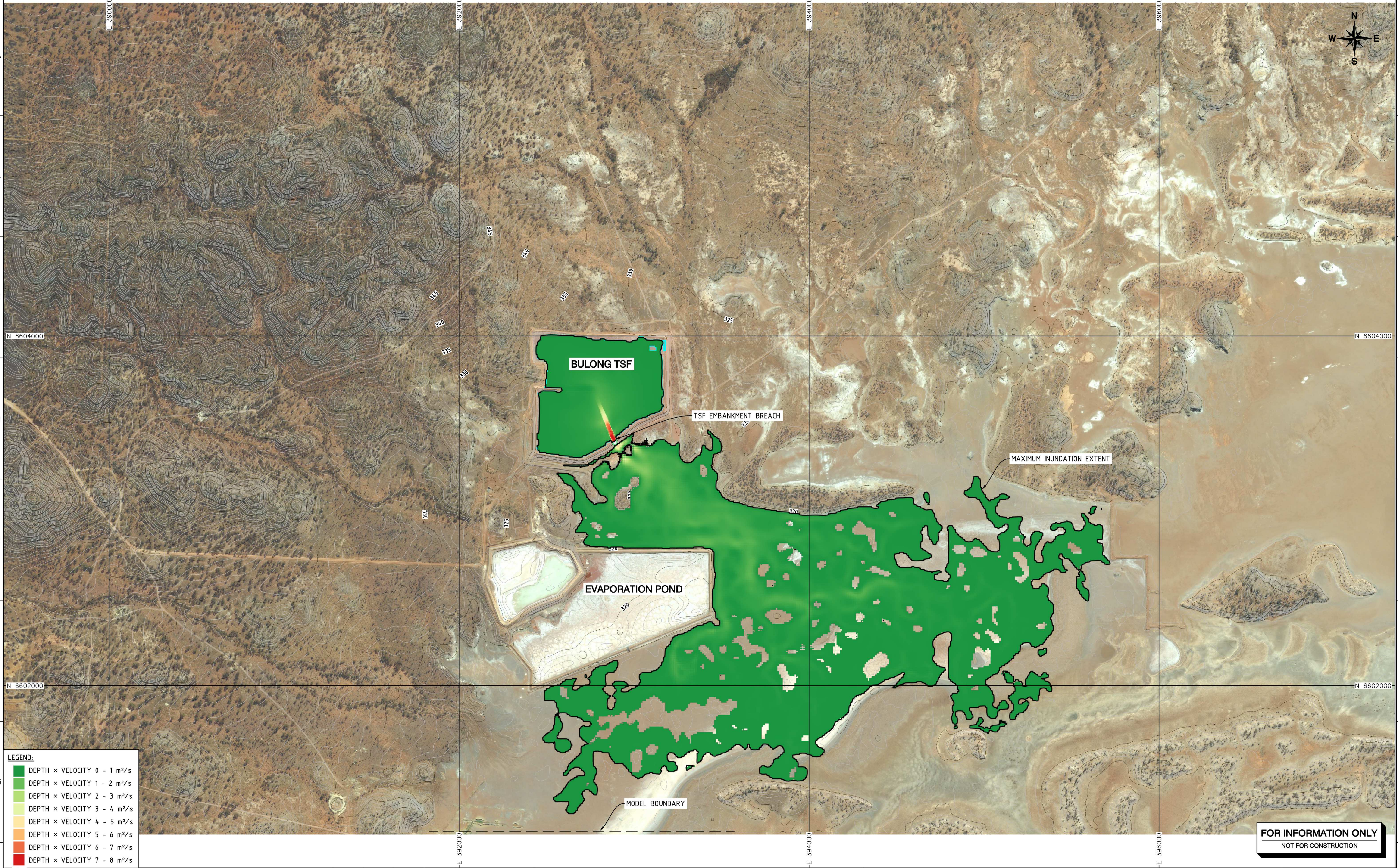
DAM BREAK ANALYSIS
INUNDATION ARRIVAL TIME

DWG. No.

FIGURE B7

SHEET SIZE	A3	Rev.	A

SHEET 1 OF 1



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No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D

SCALE:	1:12,500
JOB No.	121085.01
DATE	12.08.21
DESIGN	TL
DRAWN	CV
CHECKED	-
APPROVED	-

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DMIRS
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DAM BREAK ANALYSIS
INUNDATION DEPTH x VELOCITY

DWG. No. **FIGURE B8**

SHEET SIZE	A3	Rev.	A

SHEET 1 OF 1