Scrivener Dam

Volume B: Dissipator Strengthening Concept Design Report

National Capital Authority

4 November 2021

→ **The Power of Commitment**

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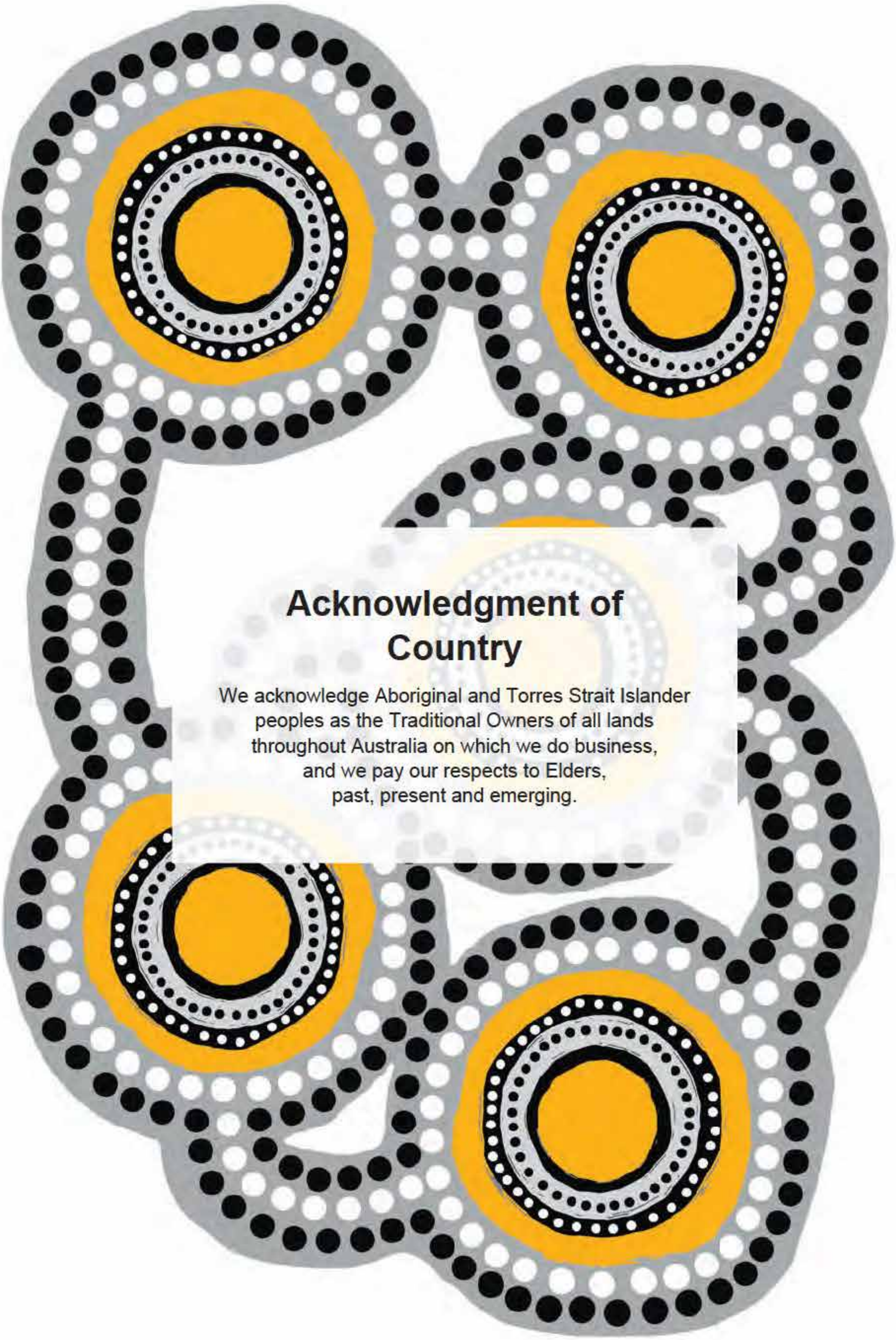

Acknowledgment of Country

We acknowledge Aboriginal and Torres Strait Islander peoples as the Traditional Owners of all lands throughout Australia on which we do business, and we pay our respects to Elders, past, present and emerging.

Executive summary

During a Design Review of Scrivener Dam in 2015-2016 (SMEC, 2016), it was identified that the stilling basin has several possible structural deficiencies, particularly relating to insufficient stability against uplift forces generated during spill events. The need to address these potential deficiencies was further supported by pre-existing concerns regarding the lack of waterstops in the stilling basin contraction joints, limited slab reinforcing and anchor lengths, the unknown condition of the anchors, and observations made of air-bubbling from the joints. A Physical Hydraulic Model study was subsequently developed to further explore and quantify the potential hydraulic forces acting on the stilling basin over a range of discharges (WRL, 2021).

GHD was engaged in August 2021 to progress the work undertaken by SMEC and WRL by undertaking an options assessment and developing a concept design to upgrade the stability of the Scrivener Dam stilling basin. During the Options phase, a broad range of upgrade options were identified and were reduced through an options workshop process to determine three preferred options for further development. The three preferred options comprised:

– Option 3 – Installation of a new anchored overlay slab, resulting in the new stilling basin invert being slightly higher than the existing arrangement.
– Option 4 – Retrofitting anchors into the existing slab to provide sufficient additional resistance.
– Option 9 – Partial demolition of the existing slab and reconstructing a new anchored slab to the original geometry.

Basic designs and preliminary cost estimates were prepared for these three options, and a multi-criteria assessment was undertaken to determine the preferred option to be taken through to concept stage. Through this process, Option 3 was selected as the preferred option. The option phase of the project is detailed in GHD (2021a).

This report details the concept development of Option 3. The physical scope of works developed in the concept design of the upgrade works on Scrivener Dam include:

– Preliminary works and Demolition - Removal of the existing baffle blocks and surface preparation of the existing slab for placement of the new overlay concrete;
– Anchoring works – Installation of approximately 670 No. 57.5 mm diameter double-corrosion protected passive anchors, on a grid of 2.4 m by 12.5 m deep upstream of the central baffles, and a grid of 2.9 m by 10 m deep downstream of the baffles (refer to Figure 1);

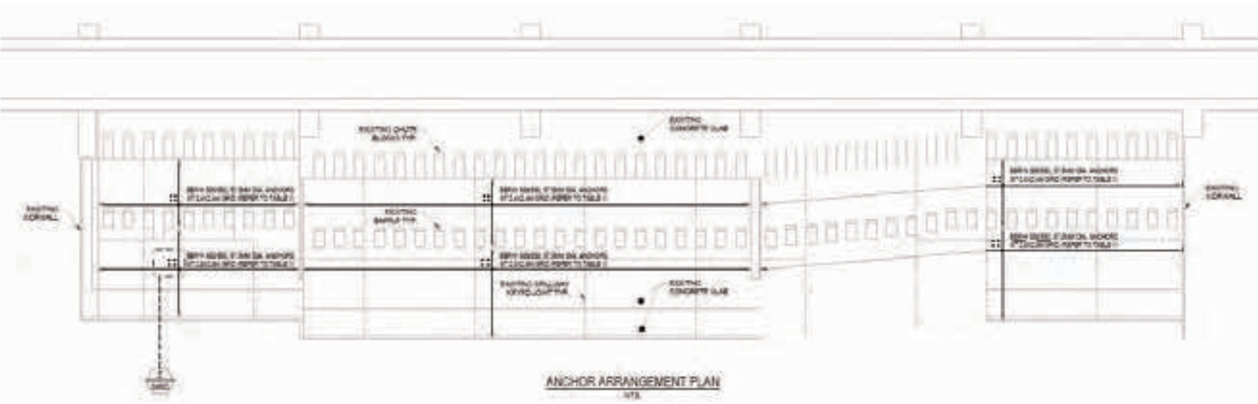

TABLE 1

BAY	LOCATION	OVERLAY SLAB THICKNESS	BBR-H BAR ANCHOR DIA.	ANCHOR GRADE	ANCHOR SPACING	EMBEDMENT LENGTH	BOND LENGTH	HOLE DIA.
		MM	MM	MPA	M	M	M	MM
BAYS 1 TO 5	UPSTREAM OF BAFFLES	500	57.5	500/550	2.40	12.5	4	175
	UPSTREAM OF BAFFLES	500	57.5	500/550	2.90	10.0	4	175

Figure 1 General Arrangement of proposed upgrade

– Slab works - Placement of a 500 mm thick overlay slab on the top of the existing slab, including construction of contraction joints with double waterstops and tie-ins to the existing structure. As part of these works, the existing chute blocks, baffle blocks and end sill will be raised by 500 mm. The raising will be achieved by complete demolition and reconstruction of the baffle blocks, however the chute blocks and end sill will be raised via a concrete overlay (refer to Figure 2).

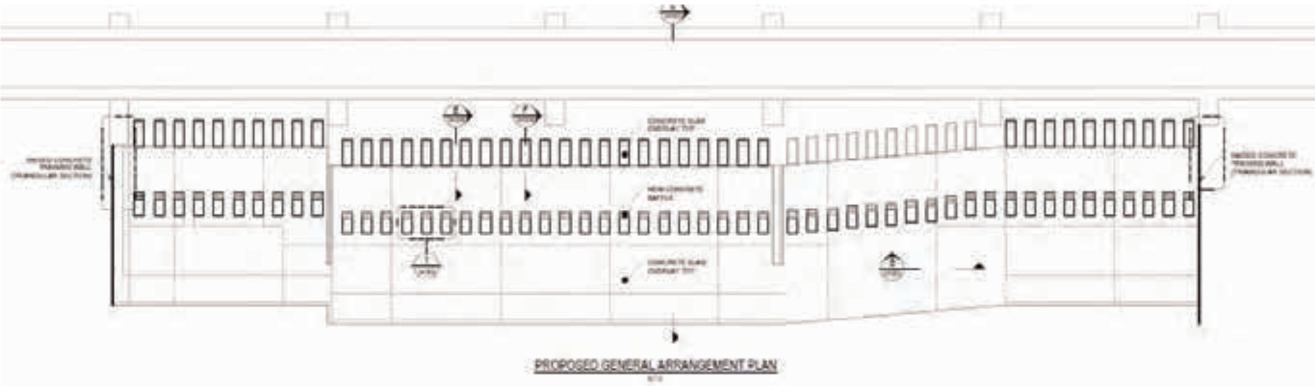

Figure 2 Stilling Basin Slab

– Training Wall extension - Extension of a short (triangular) section of the left and right side walls of the stilling basin to stop water impacting and eroding the abutments;
– Erosion armouring - Erosion protection of the left and right abutment slopes adjacent to the stilling basin, to minimise erosion of the abutments under unusual and extreme floods.

A number of other aspects have been investigated during the Concept Design, including:

– Review of the potential flood protection measures during construction – This review found that the likely flood protection measures will include a combination of temporarily lowering the lake level by around 0.5 to 0.75 mm and installing a 3.6 m high cofferdam.
– Potential impacts to the existing dam – The review found that there are no major impacts of the proposed stilling basin upgrade works on the existing dam which cannot be addressed as part of the proposed upgrade works.
– A constructability review of the project – which has provided further definition of the likely construction processes and methodologies required for the project, and has been used in the development of the proposed construction program and cost estimate.
– Development of a project risk register – which has identified a range of potential risks, with the key risks comprising geological conditions (various risks identified), cofferdam risks (a number of risks identified), the need for further hydraulic modelling (PHM or CFD), and the potential for excessive inflation/ escalation in construction works.
– Preparation of a cost estimate, including a Monte Carlo assessment of contingency amounts applied to the direct cost – The total expected cost for the project is summarised in Table 18.

Table 1 Summary of Concept Design Cost Estimates

Item No.	Description	Quantity	Amount ($ AUD)
DIRECT COSTS			
1	Preliminaries		[redacted]
2	Flood Protection/ Cofferdam		[redacted]
3	Stilling Basin Slab Upgrade		[redacted]
4	Stilling Basin Wall Raising and Erosion Protection		[redacted]
5	Miscellaneous		[redacted]
6	Minor Items		[redacted]
	Sub-total (Total Direct Cost)		[redacted]
TOTAL CONTRACTOR'S ESTIMATE			
	Contractor's Margin	[redacted]	[redacted]
	Contractor's Estimate (excl contingency)		[redacted]
	Contingency allowance		
	– Planned Risks Contingency		[redacted]
	– Unplanned Risks Contingency		[redacted]
	Indicative Contractor's Estimate (excl. GST)		[redacted]
OTHER INDIRECT COSTS			
	Owner's Indirect Costs (excl contingency)		[redacted]
	Contingency allowance on Owner's Costs	[redacted]	[redacted]
	Indicative Other Indirect Costs (excl. GST)		[redacted]
	Total Indicative Cost Estimate (exc. GST)		[redacted]

- A Safety in Design assessment – A safety in design register has been prepared for the project. The key risks identified during this process include site personnel and vehicle interaction, impacts on the Zoo, and working from heights/ crane risks.
- Recommendations for future investigations, studies and assessments – A number of key future studies were identified in addition to the standard design development works. These recommended studies include:
  - Undertaking geotechnical investigations and modelling
  - Undertaking a detailed Construction Flood Study
  - Preparing the preliminary detail for the downstream culvert design
  - Further development of the erosion protection works
  - Undertaking a noise and vibration study
  - Commencing stakeholder engagement
  - Assessing potential procurement methods and approaches
  - Carrying out dewatering trials on the stilling basin.

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1. Introduction

1.1 Purpose of this report

The NCA engaged GHD in August 2021 to undertake an options assessment and develop a concept design to upgrade the stability of the stilling basin at Scrivener Dam. The project builds on a culmination of several years of work which has involved investigating and to an extent, quantifying the possible deficiencies in the existing stilling basin related to the potential for large differential uplift pressure to develop in the structure. Under certain hydraulic conditions, these uplift pressures may lead to instability of the stilling basin slabs. Combined with pre-existing concerns regarding the lack of waterstops in the stilling basin contraction joints, limited slab reinforcing and anchor lengths, the unknown condition of the anchors, and observations made of air-bubbling from the joints, the need to address stability concerns is a prominent focus in the NCA's dam safety program.

The options assessment phase of the project is completed and has been reported in Volume A of the Scrivener Dam Stilling Basin Upgrade Project – Options Assessment GHD (2021a). This report (Volume B) covers the Concept Design phase of the project. The key purpose of the concept design phase of works is to further review, develop and refine the preferred option, and to prepare key documents to support the application for funding of the project. These documents include a Class 4 cost estimate (in accordance with AACE guidelines), other various assessments which aid the concept development including constructability review, risk assessment and safety in design review. The key scope of work covered in the concept design phase is discussed in more detail in the following sections.

1.2 Scope of this report

The scope of this report is as follows:

- Develop the concept design of the stilling basin upgrade with specific details of the anchors, concrete slab, contraction joints and baffle blocks, to meet the design and performance criteria.
- Investigate the potential flood protection works in further detail
- Develop the concept design for protection works required to either contain the flow within the stilling basin or to protect the adjacent embankment from erosion
- Develop the scope of works for the project in more detail than presented in the options phase
- Review the advantages and disadvantages of the works
- Assess the constructability of the upgrade works
- Review the Safety in Design aspects of the project
- Review the risks associated with the works
- Prepare a Class 4 cost estimate for the project, in accordance with AACE International guidelines.
- Provide an overview of the required early works and investigations work required to progress the project.

The key scope of work is presented in this report, and was presented in a Concept Design presentation workshop.

1.3 Limitations

This report: has been prepared by GHD for National Capital Authority and may only be used and relied on by National Capital Authority for the purpose agreed between GHD and National Capital Authority as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than National Capital Authority arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

Any reports, drawings, memos, or other deliverables produced by GHD shall be produced in a traditional and generally accepted format. Accessible reports, drawings, memos, or other deliverables can be provided by GHD at an additional cost if necessary.

If the GHD document containing the disclaimer is to be included in another document, the entirety of GHD's report must be used (including the disclaimers contained herein), as opposed to reproductions or inclusions solely of sections of GHD's report.

GHD has prepared the preliminary cost estimate set out in section 7 of this report ("Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD and discussed in section 7.

The Cost Estimate has been prepared for the purpose of informing budgetary funding for the project, and must not be used for any other purpose.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the [works/project] can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

GHD has prepared this report on the basis of information provided by National Capital Authority and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.4 Assumptions

A number of assumptions have been made during the development of the concept design for the stilling basin at Scrivener Dam. These assumptions include:

– The dimensions used in the development of the concept have been based on existing drawings and survey data. It is assumed that this information is suitable for the development of the concept.
– The design loads proposed for the stilling basin are based on the assumption that the dam is a High C consequence category. It is noted that this consequence category has recently been reduced from a High B, based on work recently undertaken by SMEC (2021).
– The hydraulic loads used in the development of the concept have been based on data provided in the physical model study report. It is understood that the physical hydraulic model was suitably calibrated and data has been adequately reviewed (WRL, 2021).
– The tailwater rating used in this concept design has been based on that which was developed by SKM (2011) and used in the physical hydraulic model study report (WRL, 2021).
– The development of the concept has been based on the existing gate operating rules. It is noted that alternate gate operating rules may be adopted in the future.
– It is understood that debris loading (trees, logs etc. being flushed through the spillway) on the structure is not a significant issue at the site.

- It is assumed that the upgrade works will be constructed without fully draining the storage (or with minimal drawdown).
- Specific assumptions relating to the development of cost estimates are described in Section 7.
- The concept has been developed on the understanding that there are no significant environmental, heritage of approvals requirements for the project.

1.5 Reference Documents

A suite of reference documents have been provided to inform the development of upgrade options. These documents are summarised in Section 11.

2. Stilling Basin Concept Design

2.1 General

Three options were developed as part of the Option Development phase of the project. These options comprised:

– Option 3 – Installation of a new, anchored overlay slab, resulting in the new stilling basin invert being slightly higher than the existing arrangement;
– Option 4 – Retrofitting anchors into the existing slab to provide sufficient additional resistance.
– Option 9 – Partial demolition of the existing slab and reconstructing a new anchored slab to the original geometry.

Option 3 was subsequently selected during the option assessment phase as the preferred option. Details on the selection process and the merits for selecting Option 3 are provided in GHD (Oct 2021).

The key features of Option 3 include:

– 500 mm thick, anchored overlay slab on the top of the existing slab, including minor surface preparation, installation of anchors, construction of contraction joints and tie-ins to the existing structure;
– 500 mm vertical raising of the chute blocks, baffle blocks and end sill. The raising will be achieved by complete demolition and reconstruction of the baffle blocks, however the chute blocks and end sill will be raised via a concrete overlay;
– Extension of the left and right side walls
– Anchors to stabilise the stilling basin slab against dynamic uplift forces
– No transverse (cross valley) contraction joints for the slab, other than the one at the upstream end of the stilling basin, adjacent to the dam toe, at the chute blocks
– Longitudinal (U/S-D/S) contraction joints are at a minimum of 9.0 m and maximum 12.75 m spacing
– PVC Waterstops and Hot Dipped Galvanised dowels at the contraction joints for the overlay slab
– Erosion protection of the left and right abutment slope, adjacent to the stilling basin

Further details on the key features of the concept are provided in the following section, and a suite of sketches detailing the concept are provided in Appendix A.

2.2 Key Features of Concept and Scope of Works

2.2.1 Slab Arrangement

The preferred arrangement comprises the construction of a 500 mm anchored, reinforced concrete slab on top of the existing slab. The anchored slab has been designed to withstand the design loads summarised in Table 2. The uplift design loads are based on a linear distribution of uplift pressure beneath the stilling basin ranging from reservoir level at the heel of the dam to tailwater level at the downstream end of the stilling basin. The downward pressure above the slab has been based on the transient pressure data collected with the physical hydraulic model study. The downward load detailed in Table 2 represents the mean pressure transient minus two times the standard deviation for the critical case (i.e. case which produces the maximum head differential). A diagram of the loads is presented in Figure 3.

Table 2 *Design Loads for Stilling basin anchored slab*

Bay	Location	Critical Load Case	Uplift Head acting upwards on underside of existing slab (m)	Design Head on top of existing slab (m)
Bay 2, 3 and 4	Upstream of Baffles	900 m^3/s with normal TWL	15.4	-7.3
	Downstream of Baffles		13.6	-7.7
Bay 1 and 5	Upstream of Baffles		12.5	-4.5
	Downstream of Baffles		10.6	-4.4

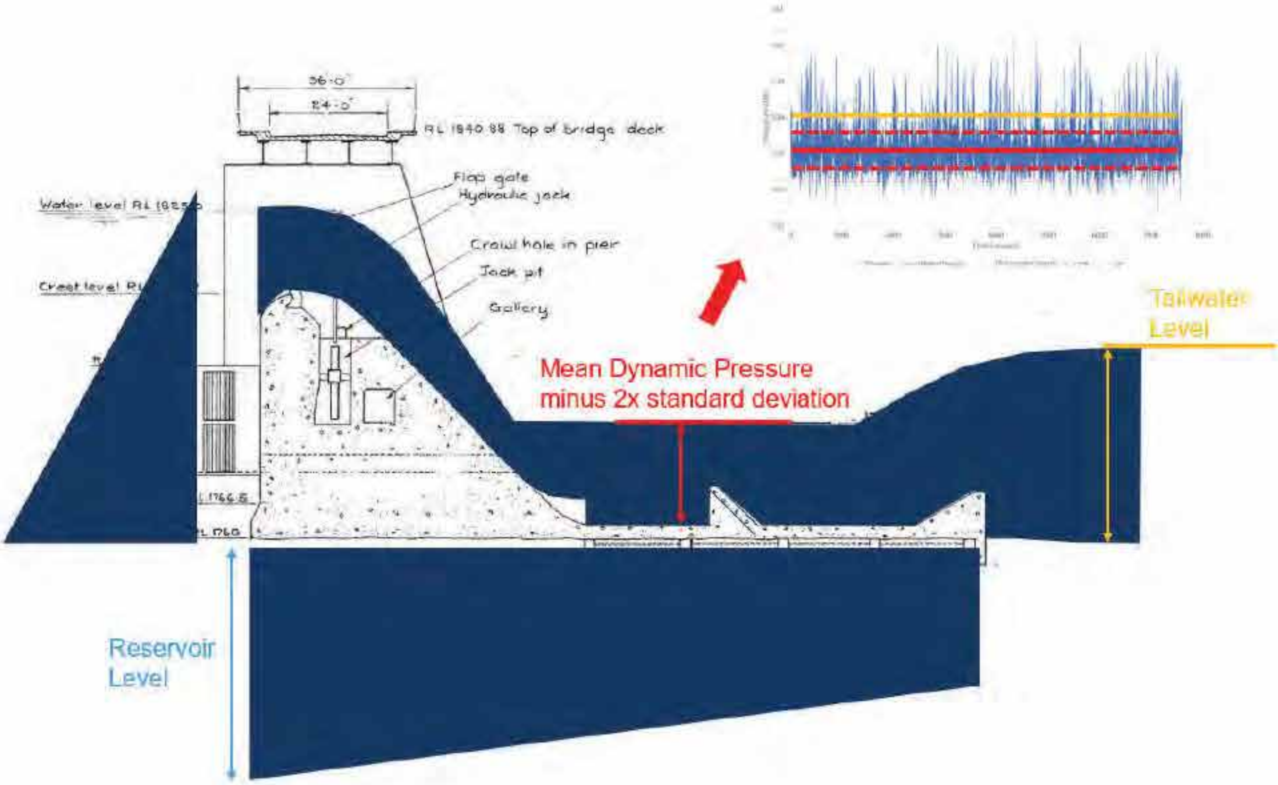


Figure 3 *Load Diagram for Hydraulic Loads*

In order to provide adequate section capacity to embed the anchor heads and resist punching shear, the minimum thickness of the concrete slab will need to be in the order of 500 mm. While the thickness of the slab could be increased from its current proposed 500 mm, it was determined that increasing its thickness was a less efficient design than relying on the anchors to resist the majority of the head differentials, and as such, 500 mm has been adopted for the slab thickness. A plan view of the proposed arrangement for the stilling basin upgrade is provided in Figure 4.

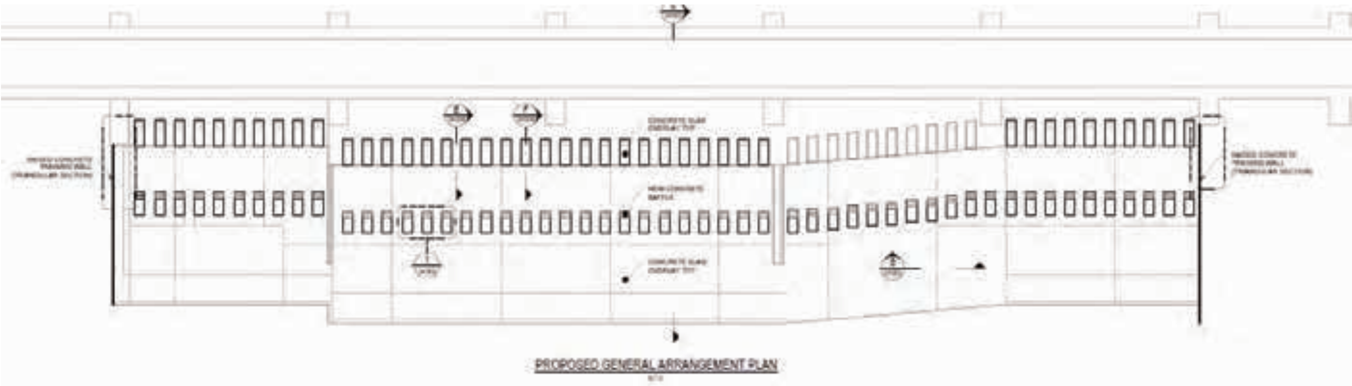


Figure 4 Stilling Basin Slab

The existing slab is around 900 mm thick but only includes a single top layer of very light reinforcement comprising 12 mm diameter bars at approximately 300 mm spacing. The new overlay slab, although thinner in section than the existing slab, includes considerably greater reinforcement. The current design assumes N24 bars at 200 mm spacing, top and bottom, and each way. The final arrangement of reinforcing will need to be optimised and detailed in future stages of the project.

Prior to placing the overlay slab, the surface of the existing slab will be prepared as a cold joint by removing the surface paste to expose the top of the coarse aggregate and cleaning the existing surface (i.e. preparation treatment consistent with a standard cold joint surface treatment). There is no additional allowance in the design for connecting the existing and new concrete together with dowels, as the design has assumed that the new anchored slab is structurally capable of resisting the design loads without aid from the underlying slab. Nevertheless, the aim will be to achieve a degree of bonding between the old and new slab through careful surface preparation.

The existing slab incorporates both transverse and longitudinal contraction joints. The proposed overlay slab arrangement aims to minimise the number of contraction joints by deleting the central cross-valley contraction joint, resulting in only one cross-valley contraction joint, which is unavoidable and occurs between the toe of the dam and the new slab. Contraction joints orientated in the upstream-downstream direction will generally be at a similar spacing to the existing arrangement, however, will be intentionally offset from the original joints to ensure that there is almost no ability for water pressure above the slab to penetrate through any defective joints through to the foundation.

The first line of defence in minimising the transmission of pressure through contraction joints will be via a double PVC waterstop configuration. For all contraction joints between ‘new and new’ concrete, the proposed waterstop arrangement comprises a bottom rearguard waterstop, and an upper centrebulb waterstop, as shown Figure 5.

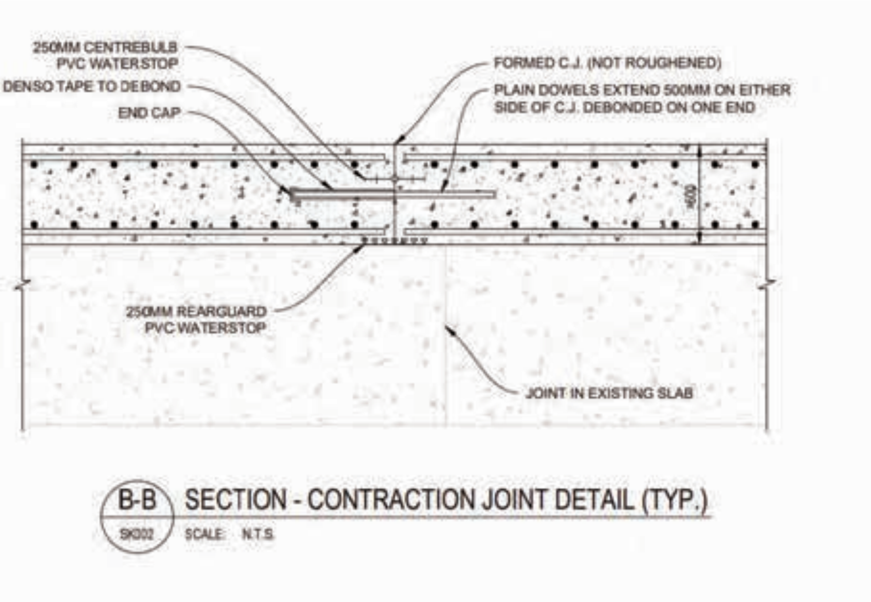


Figure 5 ***Typical waterstop arrangement (upstream-downstream orientated contraction joints)***

Waterstops at contraction joints between old and new concrete components (such as the toe of the existing dam) will most likely comprise PVC waterstops which are epoxied to the existing concrete and affixed in place with a continuous plate bolted through the flange of the waterstop, with half of the waterstop cast into the new concrete placement, similar to details shown in Figure 6. Waterstop arrangements around baffle blocks, chute blocks and the end sill are discussed in the following section. All contraction joints between new concrete components will be constructed with a straight joint, with a shear dowel located midway through the section, in accordance with USBR Design Standard No. 14 (2014). The shear dowels will be debonded on one side with Denso tape (or similar).

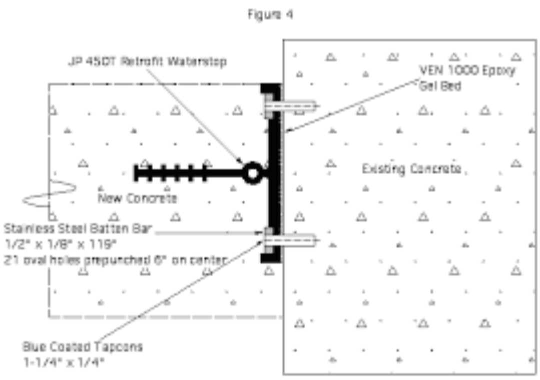


Figure 6 ***Typical waterstop detail between existing and new concrete works***

The anchor bar arrangement in the slab differs between the upstream and downstream sides of the central baffles, according to the relevant design loads. The anchor bars selected for the project comprise double-corrosion protected Grade 500/550 MPa, 57.5 mm diameter BBR H bars. The bars have also been designed with a free-length and embedment length. The anchor assembly comprises an outer grout zone, a corrugated sheathing, an inner grout zone, and BBR H Bar. In the free-length of the anchor, the BBR H bar will be encased in a smooth, snug-fit greased sheathing. Centralisers will be required along the length of the assembly to keep the anchor central within the corrugated sheathing and within the drilled hole. The top of the anchor will include an anchor plate, which will be held in place with top and bottom nuts, as shown in Figure 7.

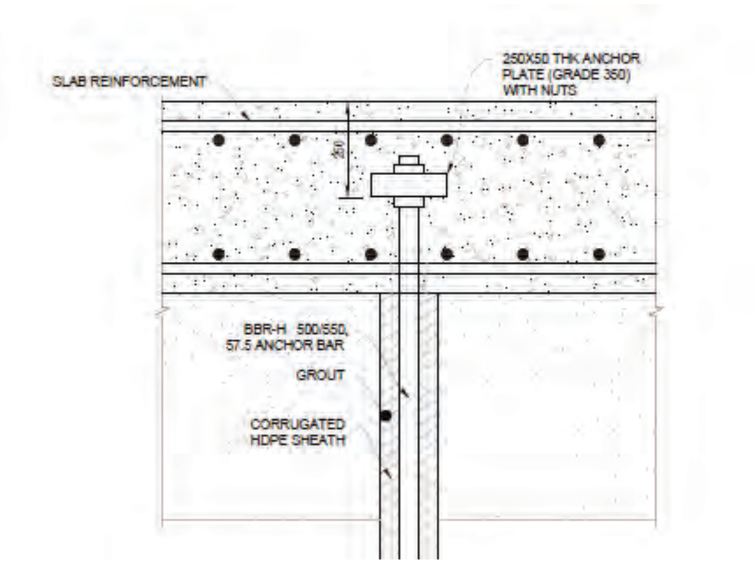


Figure 7   ***Anchor assembly and anchor head detail***

The anchor capacity has been assessed for four different failure modes, namely steel bar failure, rock-wedge failure, rock-grout failure and grout-bar failure. The steel bar failure mode defined the size, grade and spacing of anchors, while the rock-wedge and bond failure modes defined the bond length and embedment lengths for the anchors. A safety factor of 2.0 was used for the anchor bar failure and rock-wedge failure, while a safety factor of 3.0 was used for the grout-rock and grout-bar failures. Buoyant density was used to calculate the rock-wedge mechanism.

The current proposed layout for the anchors comprises a 2.4 m grid upstream of the baffles and a 2.9 m grid downstream of the baffles. In order to achieve the required resistance at this spacing, an embedment length (beneath the underside of the existing slab) will be 12.5 m and 10.0 m respectively, upstream and downstream of the baffles. A plan view of the proposed anchored slab is provided in Figure 8 and a typical cross-section of the design is provided in Figure 9.

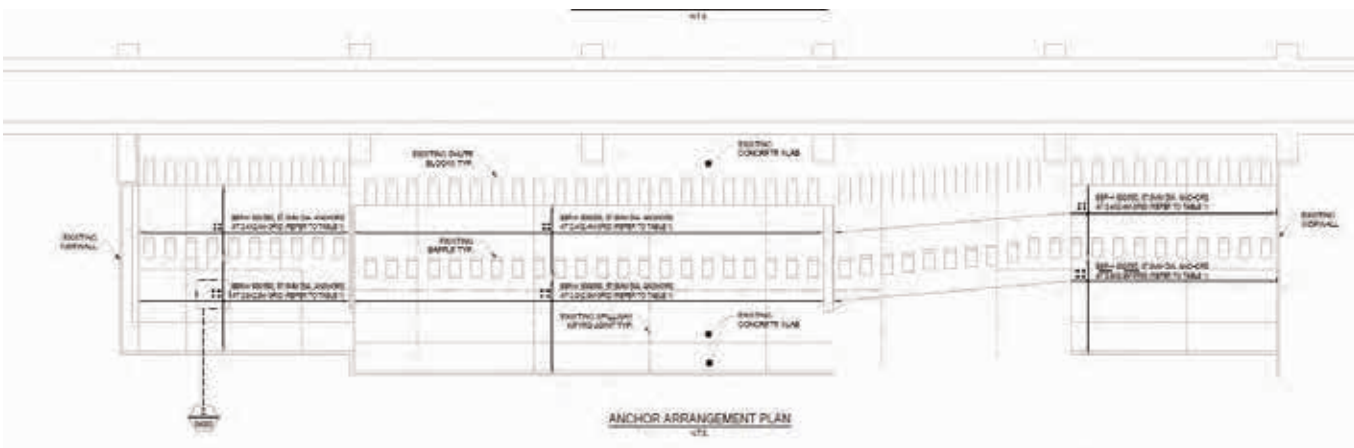


TABLE 1

BAY	LOCATION	OVERLAY SLAB THICKNESS	BBR-H BAR ANCHOR DIA.	ANCHOR GRADE	ANCHOR SPACING	EMBEDMENT LENGTH	BOND LENGTH	HOLE DIA.
		MM	MM	MPA	M	M	M	MM
BAYS 1 TO 5	UPSTREAM OF BAFFLES	500	57.5	500/550	2.40	12.5	4	175
	UPSTREAM OF BAFFLES	500	57.5	500/550	2.90	10.0	4	175

Figure 8   ***Plan view of anchor layout***

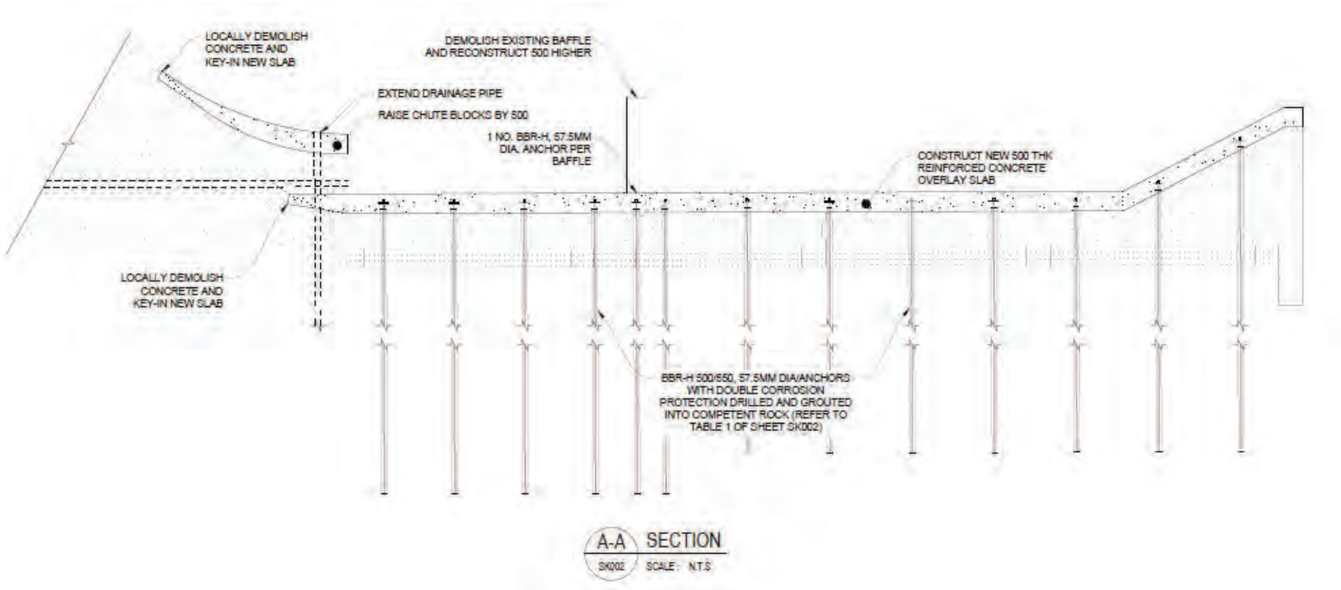


Figure 9 Typical cross-section of anchored slab

2.2.2 Baffles, End Sill and Chute Blocks

With the current 500 mm slab overlay, the design has assumed that the chute blocks, central baffles and end sill also need to be raised by 500 mm. There are various ways of achieving the 500 mm raising. For the upstream chute blocks, it has been assumed that a 500 mm overlay slab will be placed on top of the existing blocks. Surface preparation of this area will be similar to the slab overlay. Starter bars/ dowels will be required to connect the existing and new concrete. At this stage it is assumed that no anchor bars will be required through this overlay slab, however this will require further assessment in the next stage of the project. To avoid a feathered edge, the upstream end of the chute block overlay will need to be recessed into the existing dam face by locally excavating into the existing concrete. The edge between the existing and new concrete in this area will need to be profiled so that the new concrete is keyed into the existing concrete. The existing vertical and sub-vertical drains through the chute blocks will need to be raised to the new surface of the chute blocks. The top of the vertical drain will be capped, similar to the current arrangement, to prevent the ingress of debris and pressurised water into the drains.

The central baffles can be raised in a number of ways. Two key options have been considered, namely:

– Option 1 (preferred) - Completely demolishing the baffles and reinstating with new baffles. The new baffles would be cast integrally with the new overlay slab, thus avoiding any cold joints between old and new concrete at the base of the baffles. The new baffles would include skin reinforcement and would include anchors similar to the overlay slab.
– Option 2 - Constructing a 500 mm thick skin of concrete on the upstream face and top of the baffle. No new concrete would be applied to the sides or downstream face of the baffle. In order to 'tie' the new skin to the existing concrete, dowels would be drilled into the existing concrete and cast into the new skin. In order to prevent water pressurising through the joints along the sides and downstream end of the baffles, a post-fixed waterstop (most likely double waterstop) would need to be installed, similar to the arrangement previously shown in Figure 6.

During the option phase, concern was raised regarding the significant cost and potential environmental impacts of complete demolition of the baffles. However, during the concept design, further assessment was undertaken of the complete demolition option (Option 1), and the following was concluded:

– While complete demolition of the baffles through mechanical means would like result in problematic noise, vibration and dust issues, it is judged that a suitable demolition methodology can be achieved through diamond wire-cutting the base of the baffles and potentially removing the baffles in one piece.

- The removal of the baffles is considered to have significant benefits from a constructability staging perspective, as the removal improves the ability for equipment to move between the upstream and downstream sections of the slab without needing cranes to lift equipment between these sections of the slab.
- The complete demolition and reconstruction of the baffles, to be integral with the overlay slab construction, is considered to provide a significantly more robust technical solution as it removes vertical construction joints between existing and new concrete members, removing the risk of pressurising the foundations through such joints.

After consideration for these additional aspects, it was decided to adopt Option 1 as the preferred solution for the baffle design, as shown in Figure 10 and Figure 11.

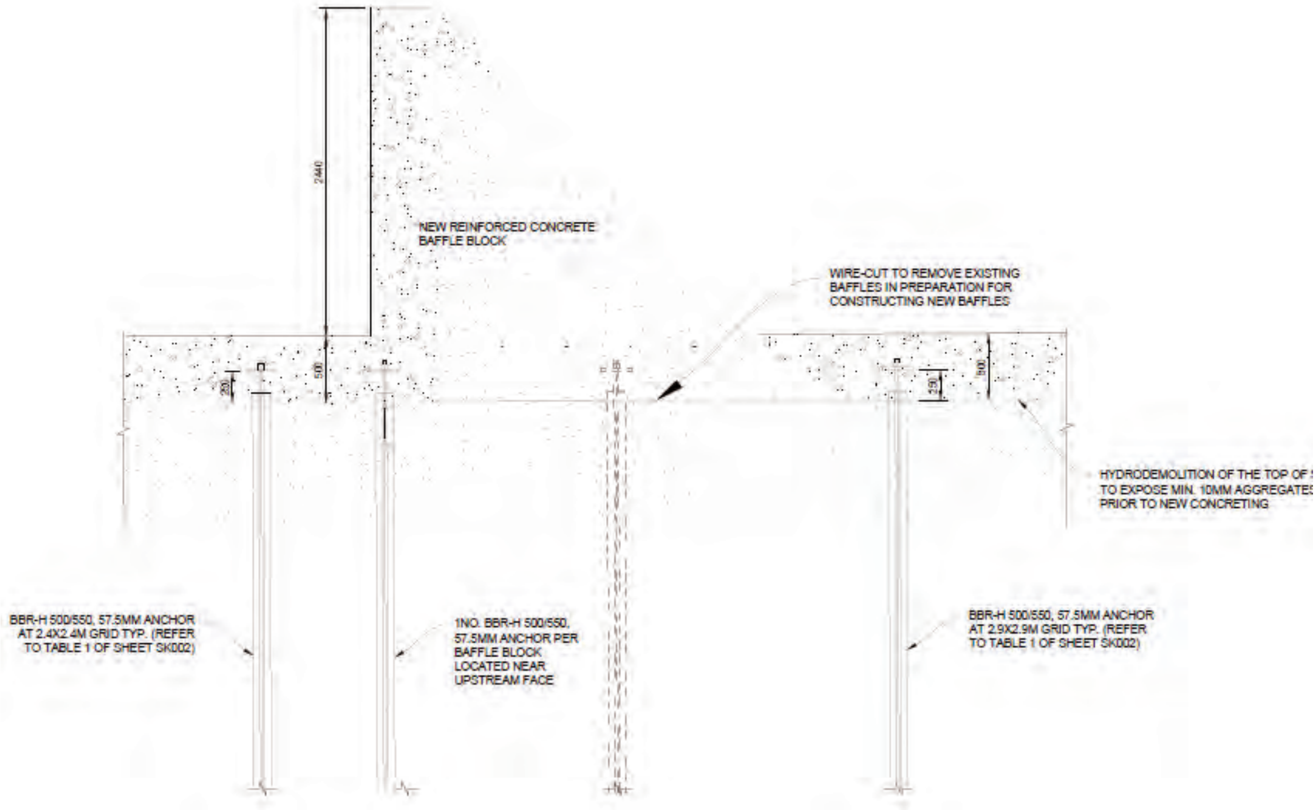


Figure 10 Details of central baffle raising

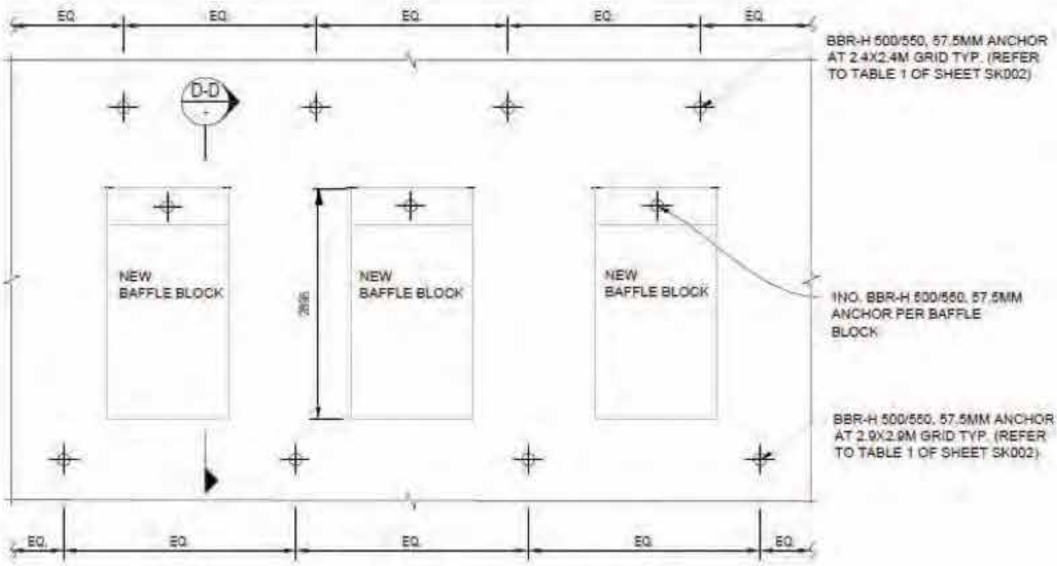


Figure 11 ***Plan view of typical baffle block raising works***

The downstream end sill would be raised by 500 mm as part of the overlay slab works. New anchors would be installed through the end sill to tie the new overlay slab to it in the same manner as the rest of the overlay slab. Details of the proposed raising of the end sill were previously shown in Figure 9.

2.2.3 Training Wall Extension

During the options phase, it was identified that the profile of the existing end training walls is relatively compact compared to the typical water surface profile for flows through the spillway, particularly when the gates are partially open. Although Figure 12 shows spillway flows passing the piers, it is noted that geometry of the end training walls on the stilling basin is the same as the pier geometry. Figure 12 demonstrates that under certain gate openings, the water surface profile passing the spillway extends beyond the geometry of the piers/training walls and spreads laterally where it is not confined by the concrete walls, therefore having the tendency to impact outside the training walls at either end of the spillway. It is proposed that modifications be made to the two end training walls to better confine flows exiting the spillway and prevent flows impacting outside the stilling basin.

Figure 12 ***Water surface profile relative to the shape of the piers and end training walls***

A number of options are possible for modifying the two training walls to better confine the flow. The current proposed arrangement comprises extend the end training walls with a triangular shaped wall extension. The approximate dimensions of this wall would be around 4.5 m long at the base and around 11 m high. The wall extension would be a standard reinforced concrete wall with starter bars connecting it to the existing piers. The proposed profile of the wall extension is shown in Figure 13.

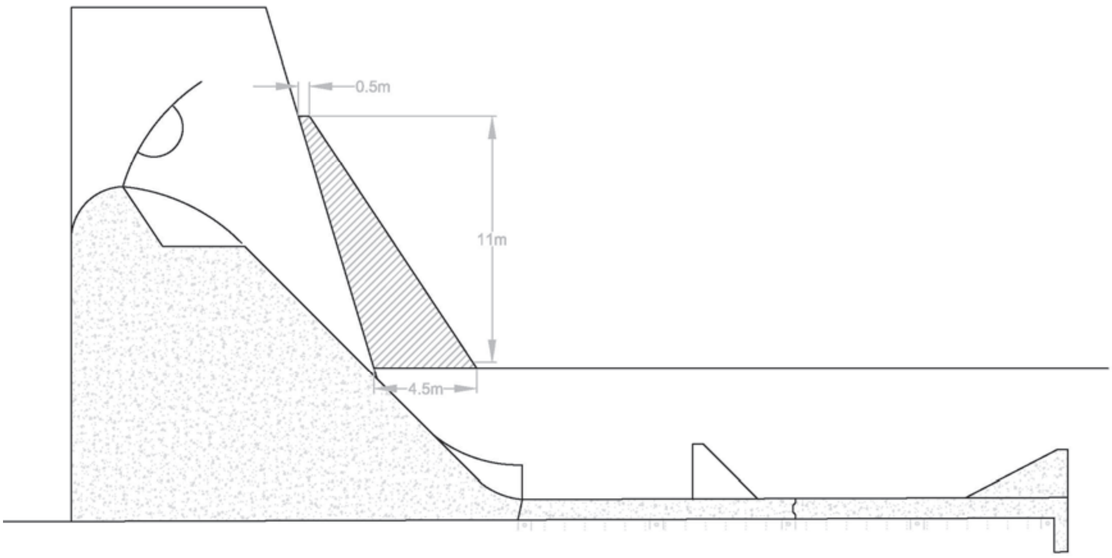


Figure 13 ***Proposed training wall extension***

2.2.4 Erosion Protection

The existing end walls on the stilling basin have a top level of around EL548.3m, which is well below the estimated tailwater level for the design flood. As such, under large floods, water in the stilling basin will overtop the end walls and potentially erode the earthfill material flanking the non-overflow section and potentially erode the toe of the embankment. The physical modelling of the stilling basin showed that flow on the abutments outside the stilling basin typically occurs in a circulating pattern, with water leaving the stilling basin circulating back onto the abutments and back into the stilling basin, as shown diagrammatically in Figure 14.

Figure 14 *Diagram of flow pattern*

While the water velocity in the unprotected abutment area is not overly high, there is potential that the flows will start to erode the abutments and scour back towards the non-overflow section of the dam. SMEC's Design Review (SMEC, 2016) assessed that the non-overflow section meets stability criteria without reliance on the stabilising effects of the downstream fill, however protection of this area is important to prevent erosion scouring towards the embankment sections.

During the option phase, it was proposed that the two end walls on the stilling basin be raised to contain the flow, however the height of wall raising required to contain the design flood would be excessive. As such, during the concept phase it was determined that a more appropriate solution would be to protect the area with rip rap erosion protection. The erosion protection would comprise a 1 m thick layer comprising a transition layer placed against the prepared surface, and a rip rap layer on the surface. Figure 15 shows the approximate extents of the erosion protection proposed on the abutments of the dam.

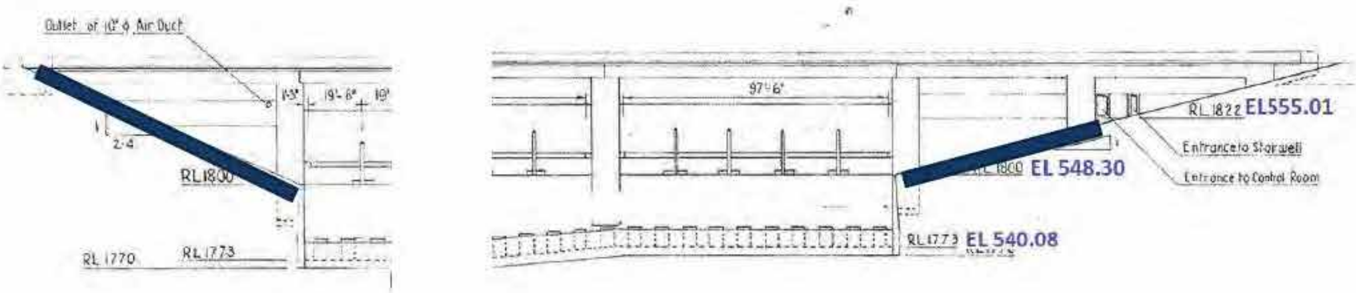


Figure 15 *Elevation of Dam showing extent of erosion protection*

2.3 Advantages and Disadvantages

After developing the key details for the concept design, and in order to confirm that Option 3 continues to be the preferred solution to upgrade the stilling basin, the advantages and disadvantages of Option 3 were again reviewed against the previously eliminated options (namely Option 4 and 9). A summary of the advantages and disadvantages of Option 3 compared with Option 4 and 9 are summarised in Table 3.

Table 3 Summary of Advantages and Disadvantages

Options	Advantages	Disadvantages
Option 3 (Preferred Option)	1. Meets the requirements of the performance criteria; 2. High quality and durable concrete will be used for the top slab (design life of 100 years expected); 3. Provides ability to minimise the number of contraction joints; 4. Anchors will have double-corrosion protection, providing a substantial improvement on the existing arrangement; 5. New slab will have significantly greater reinforcement than the existing slab (greater durability); 6. Waterstops will be installed in contraction joints, minimising the potential for high pressure water to pressurise the joints; 7. All the existing defects on the slab will be covered and protected by the overlay slab; 8. Arrangement means that the existing slab is left in place during construction, providing flood protection in the case of spillway flows during construction.	1. The option is potentially more expensive than Option 4 in terms of capital expenditure, but is likely to have less on-going OPEX costs as the upgrade resets the design life of the structure (i.e. the option does not rely on incorporating a slab which is already 60 years into its design life). 2. There will be an extensive amount of drilling works, leading to concerns regarding impacts of noise and vibration on the nearby zoo. It is noted that the extent of drilling works is no greater than other options (in fact, Option 4 requires more drilling), however this aspect needs further assessment in the next stages of the project.
Option 4 (Previously Assessed option)	1. The solution is likely to have the shortest construction program, resulting in less overhead cost, and shorter duration of impacts to the community. 2. This solution was found to be the cheapest solution.	1. Option 4 requires larger (deeper) anchors than Option 3 and 9 as the design loads are greater due to the need to allow for open contraction joints in the slab. 2. Option 4 assumes that no waterstops will be retrofitted into the contraction joints. While the design loads have been developed to account for the potential increase in head differential through transmission of pressure through the joints, there remains concern that the lack of waterstops in the joints provides a less robust solution than Option 4 and 9 which both include full PVC waterstops. 3. In order to provide adequate development of the anchor head, the retrofitted anchor head will need to be embedded into the existing slab by excavating a pocket into the top of the slab, installing the anchor, and then reconstructing the slab around the anchor head back to the original slab level. The detailing around this area of the anchor is particularly complex, and will require careful construction techniques. There is concern that the area around the anchor head will not be sufficiently robust, and if not adequately detailed or constructed, could lead to ongoing failures of the anchor heads. 4. Option 4 relies on using the existing slab. Existing defects (scouring/ cracks) in the existing slab will need to be addressed through patch repairs. These patch repairs will not have the same robustness as the new slab in Option 3 and 9. Furthermore, the life of this slab is already 60 years, and therefore will not achieve the same 100 year design life as for Option 3 and 9 which both include construction of a new slab.

Options	Advantages	Disadvantages
Option 9 (Previously Assessed option)	1. Same advantages to Option 3 with the exception of point '8'	1. This option continues to be significantly more expensive than Option 3 and 4. 2. The partial removal of the existing slab will result in extensive vibration, noise and dust emission, and these factors are likely to have a significant adverse impact on the nearby National Zoo and Aquarium. 3. There are significant dam safety concerns regarding the ability to safely pass a major flood with a partially demolished stilling basin slab. In addition, the partial demolition of the stilling basin slab will result in a temporary situation where the slab will have less resistance to uplift forces under normal operating conditions (non-flood conditions). 4. Option 9 will require the longest construction program, which will incur additional overhead costs, creates a longer exposure time from a flood risk perspective, and increases the length of time where the reservoir needs to be temporarily lowered (i.e. impact on community).

Based on the review of advantages and disadvantages following the development of the concept design, Option 3 continues to be the preferred option for the following key reasons:

– There is concern that Option 4, while cheaper, does not provide sufficient robustness particularly in terms of the anchor head arrangement, and does not achieve the overall intent of the project. As such, Option 4 should be eliminated from further consideration;
– Option 9 has similar advantages to Option 3, but is significantly more expensive and creates a flood risk during construction due to the need to partially demolish the existing slab. As such, Option 3 continues to be preferred over Option 9.

It is therefore recommended that Option 3 continue to be progressed as the preferred option.

3. Flood Protection and Cofferdam

3.1 General

Scrivener Dam is currently operated to maintain a very tight control over the upstream reservoir level. Under normal operating conditions, the upstream reservoir level is maintained to a range of +/-150 mm from the normal pool level (Full Supply Level). All minor inflows to the storage are passed via the low level outlet sluices. These sluices are each able to pass around 20 m^3/s, and can collectively discharge up to 60 m^3/s. In cases where larger floods occur, the spillway gates are opened. The spillway gates are not able to regulate small flows, and therefore are only opened when releases exceed about 80 m^3/s.

During the construction phase of the upgrade works, it will be necessary to manage discharges so that the construction area remains dry, while maintaining an operational storage. From a constructability perspective, it would be preferable to drain the storage so that any inflows can be captured in the storage without having to make releases. Draining the storage, however, is not an option due to its the significant aesthetic and recreational value to Canberra. As such, a balance needs to be achieved between what is reasonable from a drawdown perspective (e.g. how much value is gained from temporarily lowering the full supply level by a small amount) versus the benefits of installing a cofferdam in the stilling basin to protect the works.

During the options phase of the project, it was determined that a combination of cofferdamming the work site and lowering the reservoir by up to about 1.0 m (but preferably less) would be the preferred solution. The cofferdam would be arranged to split the stilling basin to two sections, with the cofferdam protecting one side of the stilling basin for the first part of construction, and then being flipped to the alternate side to allow completion of construction.

It may also be possible to operate the reservoir so that the lake surcharges up to 150 mm above the Full Supply Level, however this option has not been explored in detail, and would need to be assessed as part of a more detailed flood study.

This section provides a summary of the review of flood hydrology related to the construction works (i.e. more frequent flooding as opposed to extreme floods), the potential benefits of temporarily reducing the upstream full supply level, and the potential arrangement for the downstream cofferdam. Further refinement on this work will be required in future stages of design.

3.2 Review of Construction Flood Hydrology

A review of flood hydrology has been carried out using the Scrivener Dam Sluice Operations spreadsheet, which has data recorded for key parameters relevant to Scrivener Dam including lake levels, flow per sluice, rainfall and total gate flow. Data has been recorded from July 2000 to present day, although it is noted that there are some data gaps, including the lack of gate flow data which was not consistently recorded until July 2008.

Reservoir Levels have been very stable since 2000, having remained almost entirely within 150 mm above or below the reservoir Full Supply Level (FSL) of 555.93 mAHD, apart from a small number of occasions where it has dropped below the FSL, as per Figure 16. Key points in time where the reservoir level dropped below the typical range occurred between December 2011 and August 2013 where the reservoir level was kept at approximately 555.45 m for a 21 month period while upgrade works occurred on the gate hinges. For higher resolution graphs refer to Appendix B.

Figure 16 *Reservoir Level (2016-2021)*

The reservoir levels recorded over the last 20 years have been processed into a 'reservoir level exceedance curve', as presented in Figure 17. This curve confirms the consistency of the reservoir levels. It can be seen that a reservoir level of EL 556 m was exceeded less than 1% of the time from 2000 until present day, and that it was kept within 150 mm of the FSL for approximately 83% of the time.

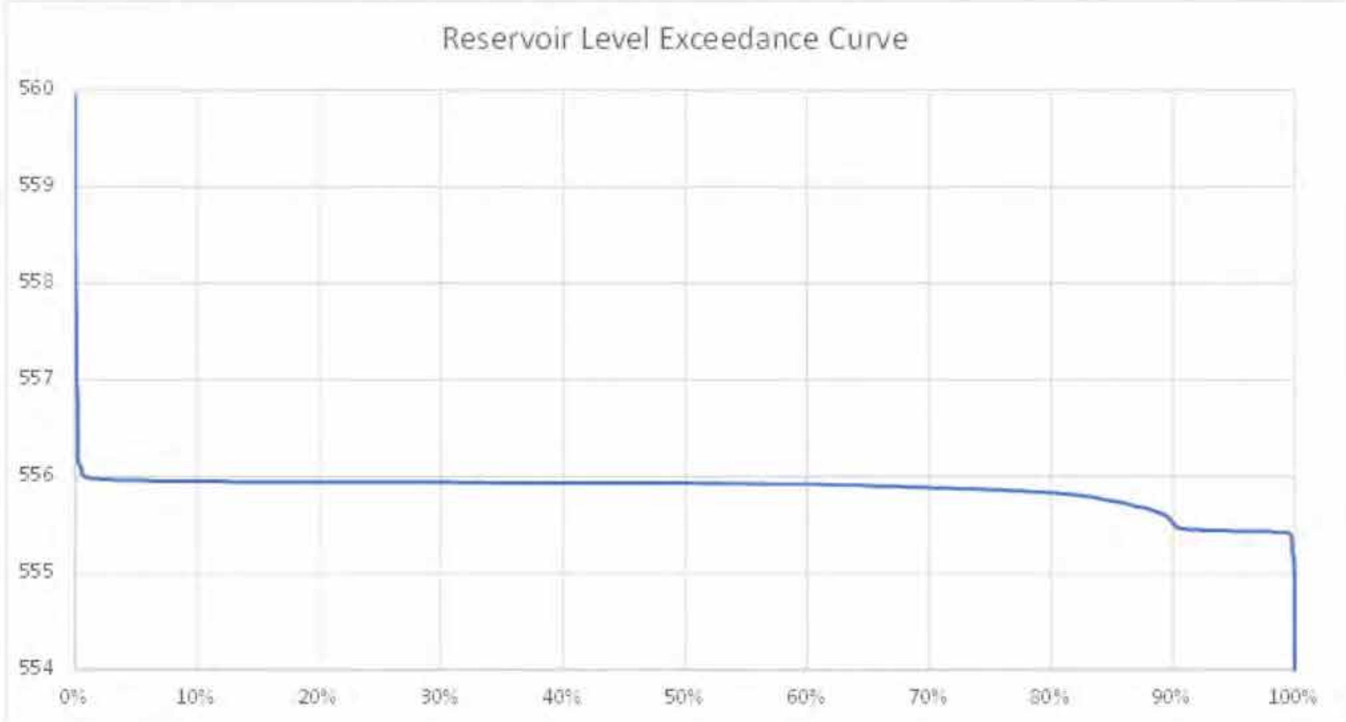


Figure 17 *Reservoir Level Exceedance Curve*

The data indicates that the dam's gates have been opened 19 times since July 2008, although this is sporadic in nature as can be seen in Table 4 which indicates that in six of the fourteen years the gates were not opened while in 2010 and 2016 the gates required opening 5 times each.

Table 4 *Gate Openings per Year Summary*

Year	No. of Gate Openings	Year	No. of Gate Openings
2008	0	2015	0
2009	0	2016	5
2010	5	2017	0

Year	No. of Gate Openings	Year	No. of Gate Openings
2011	2	2018	1
2012	2	2019	0
2013	1	2020	1
2014	0	2021 (Year to date)	2

A review was also undertaken of the typical frequency that the sluices are operated, and also the typical volume and flows passed through the sluices and spillway gates. Similar to the reservoir level exceedance curve, the 20 years of operational data was used to assess historical gate and sluice operation. Specifically, the 20 years of record included details of the average sluice flow rates (at 8 am every day) and also estimates of the total volume (ML) of water passed by the sluices and spillway gates every day. This data was processed into exceedance curves for the following outputs:

– Total combined volume (ML) discharged from the Sluices and Spillway Gates; and
– Total combined flow rate (in m^3/s) at 8am every morning from the Sluices and Gates. It is noted that due to the considerable fluctuations in flow rate over the day, the estimates of discharge at 8am every morning (the frequency with which the data is currently captured in the spreadsheet) does not provide a complete understanding of total discharge, and therefore emphasis has been placed on the total volume of discharge (previous dot point) as opposed to flow rate at 8am.

These exceedance curves are presented in Figure 18 and Figure 19.

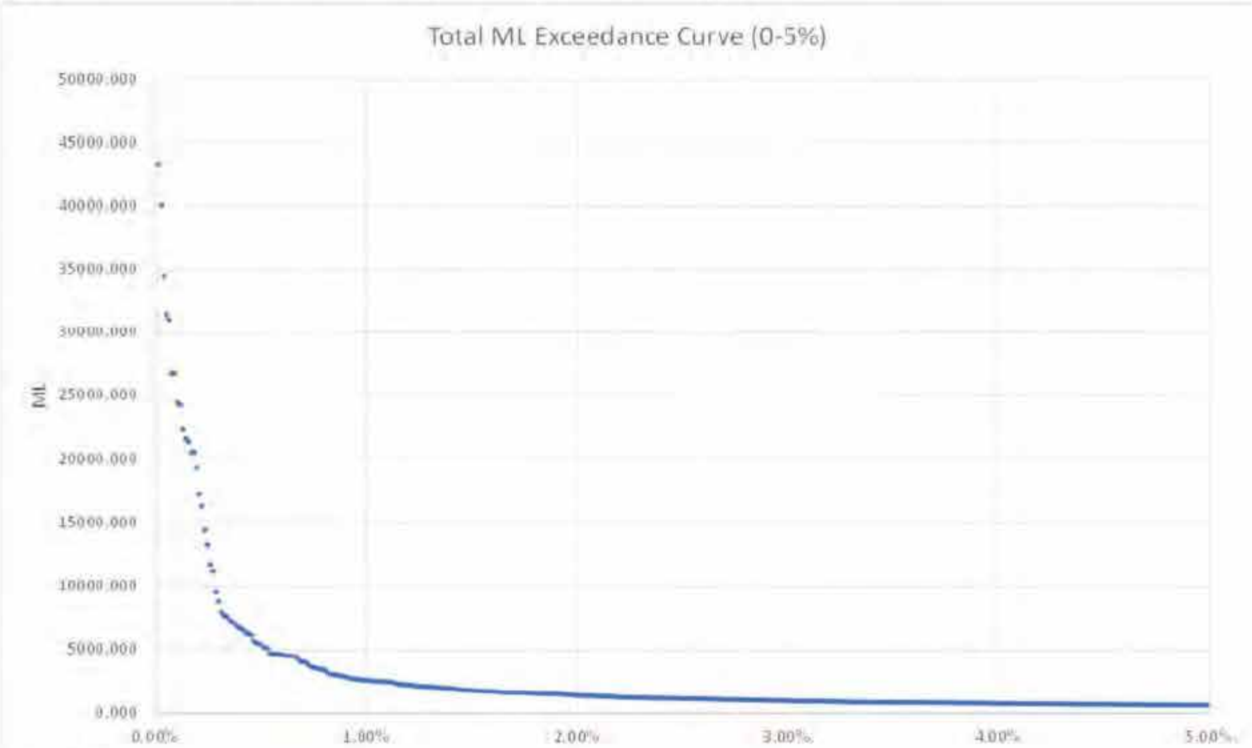
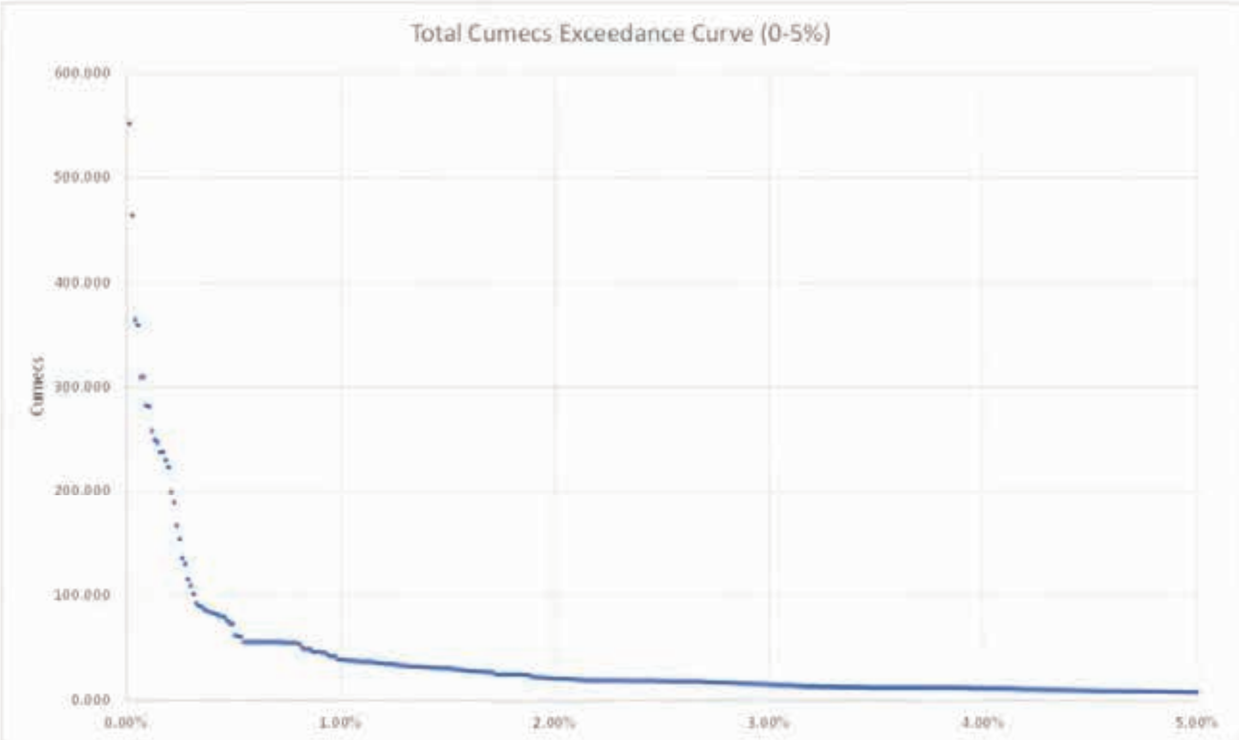


Figure 18 ***Total Sluice and Gate Daily Flow (ML) exceedance curve***



Notes: Gate discharges presented in this plot have been calculated from the average flow rate over a 24 hour period. Actual peak discharges may be higher than represented in the plot.

Figure 19 ***Total Sluice and Gate Flow Rate (m^3/s) Exceedance Curve***

These exceedance curves indicate the following:

- Around 0.5% of the time, the storage passes a total volume of 5,000 ML or more, as shown in Figure 18. Conversely, this means that around 99.5% of the time, the total volume needing to be passed through the dam is less than 5,000 ML. Based on the historical data, a total volume of 5,000 ML or more has been experienced 14 times since 2008, an average of 1.1 times per year, although 8 of these times occurred in 2010 and 2016, meaning the probability of needing to pass this volume is less than once per year.
- Around 99.5% of the time, the total flow discharged from the dam is less than 68 m^3/s, as presented in Figure 19. As previously mentioned, due to the fact that records are only taken at 8 am every day, there is a high chance that using flowrate records as the key data for determining flood risk is skewing the results. Estimates of total volume (previous dot point) is likely to be a better basis for determining the appropriate flood protection measures.

Using the sluice operations data since the 1st of July 2008, the following information was ascertained based on the number of sluices that operate every day.

Table 5 ***Sluice Operations Information***

No. of Sluices Operating	Number of Days	% of Days
0	1771	37%
1	1598	33%
2	838	18%
3	573	12%

Table 5 shows that 70% of the time, since July 2008, either no sluices or one sluice were operating. Conversely, more than one sluice is operated 30% of the time, although only on 1.9% of time are flows greater than 20 m^3/s, meaning that 98.1% of time, flow can be accommodated through only one sluice.

The review of operation of the sluices and spillway gates indicates that regular flows need to be passed through the dam. For the construction of the stilling basin upgrade works, it would be beneficial to reduce the frequency with which larger flows need to be discharged through the dam. As such, an analysis was undertaken to determine the benefits of temporarily lowering the Full Supply Level of the storage to provide 'some' airspace for storing flows and releasing water in smaller discharges. Using the reservoir storage-elevation curve, the volume of water capable of being stored in the upper portion of the lake was interpolated for relevant reduced reservoir levels, as can be seen in Table 6. This analysis was undertaken to determine what volume of flood inflows could be 'stored' in the upper portion of the storage if the FSL was temporarily lowered by various depths ranging from 250 mm up to a 1500 mm reduction on FSL.

The last column in Table 6 relates the total volume of water able to be stored in the 'airspace' with the exceedance curve for total volume of water passed by the storage (refer to previous Figure 18). For example, if the full supply level was temporarily reduced by 500 mm, it would be possible to store around 3,700 ML of water in the zone between the temporary lowered level and the original Full Supply Level. Based on the exceedance curves, only 0.7% of the time is the volume of water needing to be passed through the dam greater than 3,700 ML. Similarly, if the reservoir level was temporarily lowered by 750 mm, the exceedance curves show that only 0.5% of the time is the total volume of water needing to pass the storage more than the volume that can be stored in the temporary airspace. The results of Table 6 are also shown graphically in Figure 20. The analysis highlights the significant reduction in the discharge rate that can be achieved by storing some of the inflows and releasing them over a longer period of time.

Table 6 ***Reservoir Storage-Elevation Volumes***

Lake Level Range	Volume of Water Stored in Lake Level Range (ML)	Percentage Exceedance of Volume Stored (%)
FSL to -250mm	1,899	1.4%
FSL to -500mm	3,755	0.7%
FSL to -750mm	5,559	0.5%
FSL to -1000mm	7,305	0.4%
FSL to -1250mm	8,984	0.3%
FSL to -1500mm	10,590	0.3%

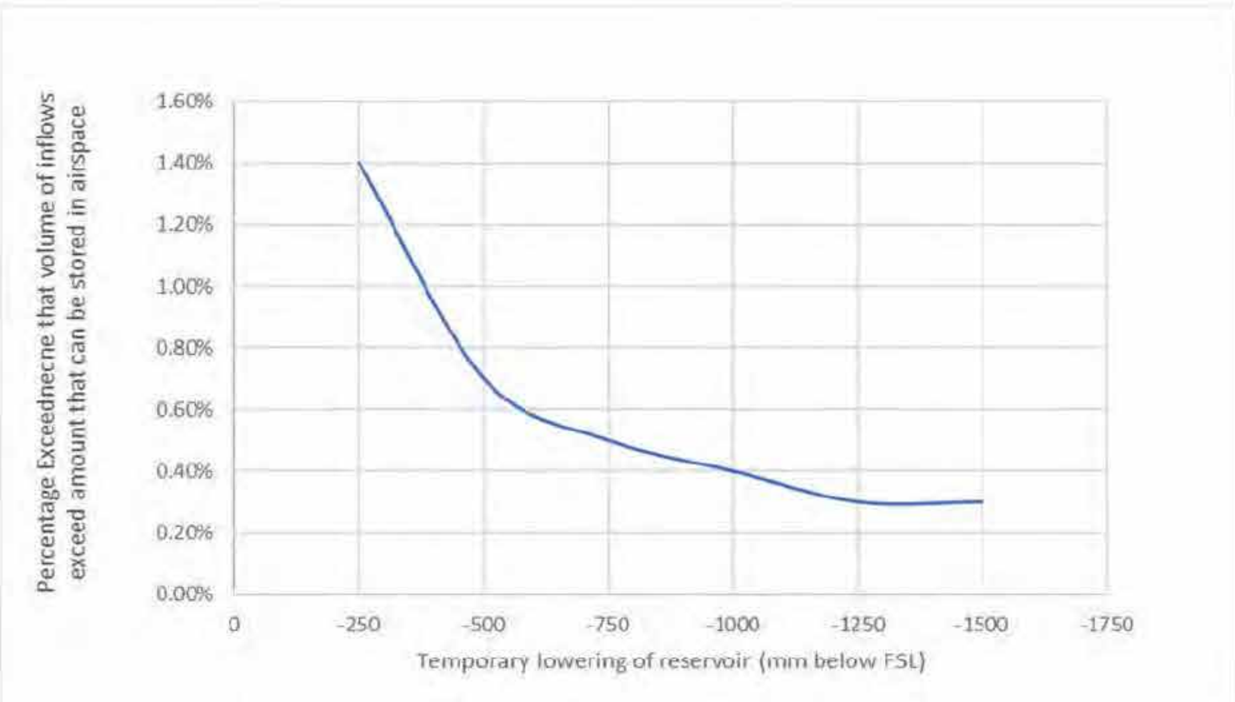


Figure 20 ***Ability for volume of inflows to be stored in temporary lowering of FSL (percentage exceedance)***

The final analysis undertaken on the hydrology of the storage was to assess the height of the potential downstream cofferdam. The review of construction flood hydrology and merits of temporarily reducing the upstream reservoir level suggests that the key flows which will need to be released through the storage would be achieved by releases through the sluices (as opposed to the spillway gates). Using the Scrivener Dam Tailwater Rating Curve (SKM, 2011), the approximate tailwater levels relative to the peak discharge capacity of one, two or three sluices operating, as well as one spillway gate open at the first increment, is provided in Table 7. Table 7 shows that in order to accommodate a flow rate output of 80 m^3/s, a cofferdam of 3.57m would be required in the lowest bays of the stilling basin (i.e. stilling basin invert level of 537.03 mAHD). It is noted that the invert level of the stilling basin will change as the upgrade works are constructed.

Table 7 Tailwater Elevation per Flow Rate

	Flow Rate (m^3/s)	Tailwater Elevation (mAHD)	Required Maximum Cofferdam Height (m)
1 Sluice Operating at Maximum Capacity	20	539.6	2.6
2 Sluices Operating at Maximum Capacity	40	540.0	3.0
3 Sluices Operating at Maximum Capacity	60	540.3	3.3
Single Gate Minimum Opening	80	540.6	3.6

3.3 Proposed Flood Protection

Based on the review of construction flood hydrology, it is proposed that a combination of a cofferdam and lowering of the reservoir level is used to provide additional flood protection during construction works.

As previously discussed, lowering the lake level by 750 mm provides an additional 5,000ML of water storage. Using the exceedance curves, this amount of storage results in considerably reducing the peak discharges from the dam. Even reducing the full supply level by 500 mm would provide a substantial reduction in flood risk, with the volume of inflows exceeding the airspace approximately 0.7% of the time (as opposed to 0.5% of the time with a 750 mm lowering of full supply level). Given that there will be major disruption to lower the full supply level by any amount, consideration should also be given to the benefits of reducing the storage by smaller amounts (say 250 mm), however based on the analyses undertaken to date, there appears to be a step change in risk between lowering by 250 mm versus 500 mm with double the chance of exceeding at the 250 mm lowering (i.e. 1.4% chance of exceedance at 250 mm versus 0.7% at 500 mm). Future analyses should be undertaken to consider the cost-benefit of temporarily lowering the reservoir versus constructing a taller cofferdam.

Due to the need to discharge flows during construction, a cofferdam has been proposed so that a single sluice and/or a single gate opened at the first increment are able to discharge at all times during construction. In order to have a single sluice or gate operable at all times, a cofferdam arrangement that will split the stilling basin in two has been proposed (refer to Figure 21 for an example). This means that works can be carried out on the 'dry' side of the stilling basin that is protected by the cofferdam, while the 'wet' side sluice and gate can operate to discharge flows. Once the works on 'half' the stilling basin have been completed, the cofferdam would be relocated (flipped) to protect the alternate side of the stilling basin, allowing works to be carried out on the remaining unconstructed zone.

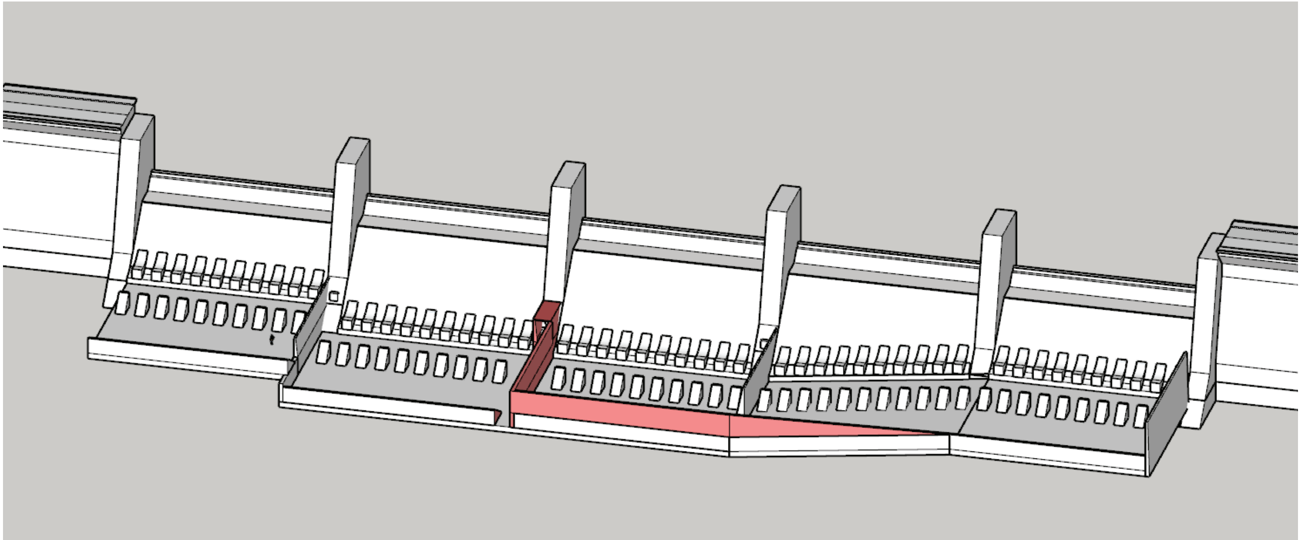


***Figure 21** View of proposed cofferdam (Stage 1)*

In order to keep the cofferdam compact, it is proposed that the cofferdam comprise a steel truss structure, with a steel skinplate, and custom waterstops at the base and sides. The steel cofferdam would need to be temporarily anchored to the concrete base of the cofferdam. An example of the typical cross-section of the cofferdam is provided in Figure 22.

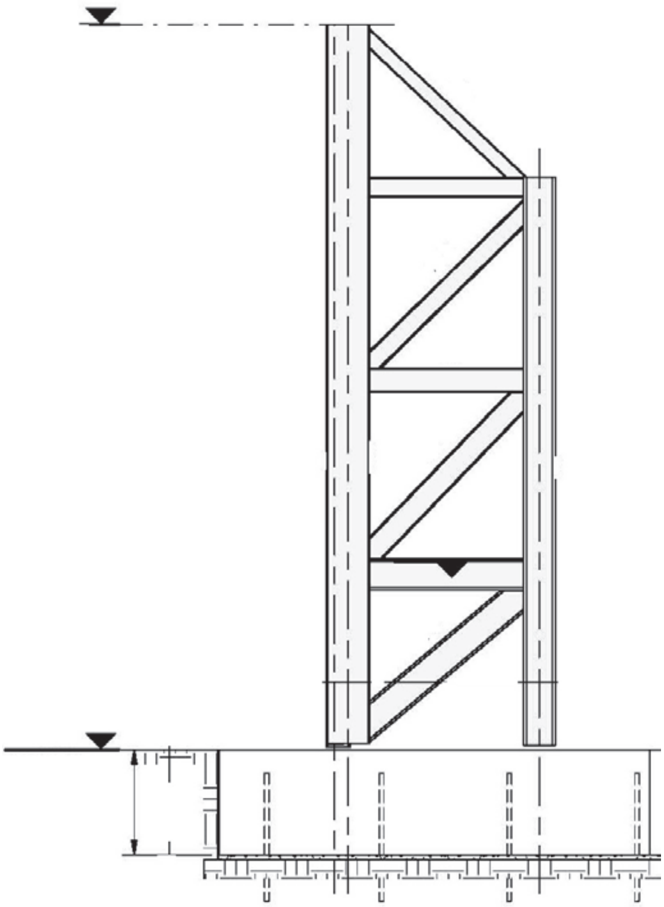


***Figure 22** Typical cross-section of steel truss cofferdam*

The minimum flow rate of a single gate opening is 80 m^3/s and as a result, the cofferdam would need to have a minimum height of 3.57 m based on the tailwater elevation for a flowrate of this level.

A combination of a cofferdam and lowering the lake level by 750mm will considerably reduce the probability that flows passing the dam will exceed the cofferdam height. Irrespective, the flood hydrology highlights that there remains a relatively high probability (in the context of dam engineering), that the cofferdam may be overtopped during the construction phase. Furthermore, it remains possible that a major flood may occur during the construction phase which could require all spillway gates to be operated. In this situation, the worksite will be completely flooded. The construction contract and specification will need to incorporate clear flood monitoring, flood evacuation preparedness and planning, and flood communication protocols, to allow the maximum possible time for the contractor to remove equipment from the worksite if a major flood occurs.

Risk cost modelling, for various lake drawdown and cofferdam height alternatives, should be undertaken to identify the level of risk and potential optimum configuration of lake drawdown and cofferdam height. This study should also investigate the allocation of flood risk between the contractor and the NCA.

4. Impacts to existing dam

From a dam safety perspective, the upgrade works on the stilling basin will have an overall beneficial impact on the safety of the dam insofar as reducing the potential for the existing stilling basin slabs to become dislodged and 'plucked' from the basin (thus creating a potential for erosion of the toe of the dam). While these upgrade works provide a clear benefit in this regard, it was acknowledged that there may be other aspects of the stilling basin upgrade works which adversely impact the existing structure, such as adversely changing the loading on the dam, or impact the main subsurface drainage system of the dam. As such, during the development of upgrade options to the stilling basin, consideration was given to the potential impacts on the dam as a result of the upgrade works. The following key questions were posed in this regard:

- Will the preferred stilling basin upgrade works have an adverse (or positive) impact on the structural integrity or durability of the existing structure, including:
  - The concrete spillway section
  - Spillway gates
  - Concrete non-overflow section
  - Embankment dam
  - Sluices
- Will the preferred stilling basin upgrade works have an adverse (or positive) impact on the ability to operate and maintain the dam?

Table 8 provides a systematic review of the potential impacts in relation to these two key questions.

Table 8 Summary of Review of impacts to existing dam

Component	Potential Changes/ Impacts to Components	Assessment Outcome
Impact on Structure integrity or durability of structure		
Concrete Spillway	Changes in geometry	N/A – The stilling basin does not impact the geometry of the existing structure.
	Impacts on material properties	N/A – The upgrade works will not impact the existing material properties.
	Impacts on loadings and load cases	The 0.5 m raising of the stilling basin is likely to increase the tailwater height on the downstream face of the dam (providing a slight increase in stabilising forces on the dam). There will be no changes to the tailwater levels downstream of the dam, and therefore the design uplift profile beneath the dam will remain the same. All subsurface drainage currently installed in the dam will be retained. The outlets from the current drainage curtain which pass through the chute blocks will release above the new stilling basin slab (i.e. not impacted).
	Overall impacts on stability or strength	No impacts on the strength of the dam. Minimal impacts on the stability of the dam (note previous comments regarding a potential increase in stabilising pressures from the tailwater within the basin).
	Overall impacts on durability	N/A – No perceived impacts.
Spillway Gates	Impacts on loadings and load cases	N/A – The stilling basin does not impact the geometry of the existing structure.
	Overall impacts on structural integrity	N/A – No impacts on the structural integrity of the spillway gates
	Overall impacts on durability	N/A – No perceived impacts.

Component	Potential Changes/ Impacts to Components	Assessment Outcome
Concrete non-overflow section	Changes in geometry	N/A – The stilling basin does not impact the geometry of the existing structure. The placement of erosion protection fill may slightly alter the geometry of the earthfill flanking the non-overflow section.
	Impacts on material properties	N/A – The upgrade works will not impact the existing material properties.
	Impacts on loadings and load cases	Placement of erosion protection material on the downstream face of the non-overflow section may have a slight stabilising effect, but would most likely be ignored in any assessments.
	Overall impacts on stability or strength	Refer to comments under 'Impacts on loadings and load cases'.
	Overall impacts on durability	Potential improvement in durability related to the placement of erosion protection on the downstream side.
Embankment Dam	Changes in geometry	Erosion protection placed on the embankment toe will alter (slightly) the geometry of the embankment.
	Impacts on material properties	No changes to the existing materials, but new erosion protection will be placed.
	Impacts on loadings and load cases	Placement of erosion protection on downstream toe will create an additional load at the toe of the dam. This zone is likely to have a slight stabilising effect on the embankment.
	Overall impacts on stability or strength	Refer to previous comments.
	Overall impacts on durability	Erosion protection is likely to improve the durability of the embankment.
Sluices	Impacts on performance of sluices	N/A – The stilling basin does not impact the geometry of the existing structure. It is possible that the sluice jets will impose slightly higher impacts loads on the basin floor due to the floor being 0.5m higher. This risk should be counteracted by careful selection of concrete strength/mix design.
Impact on ability to operate and maintain dam		
Operational Impacts	Access to stilling basin for surveillance	Access stairways will need to be reinstated or replaced (as appropriate) to ensure safe access to the basin.
	Gate Operation	It is proposed that the spillway gate operating rules are adjusted as recommended by SMEC. This change in operation should have a beneficial impact on the performance of the dam/stilling basin.
Maintenance Impacts	Dam subsurface drainage curtain	The drainage outlets from the dam's subsurface drainage system currently exit through the chute blocks. There is a vertical riser pipe in the chute blocks which is presumably used to maintain the pipes. This pipe will need to be extended to the surface to suit the raised profile.

In summary, the review of the impacts of the proposed stilling basin works has found that the proposed works will predominantly have a beneficial impact on the safety of the dam. The key items which will need to be addressed in the upgrade works include:

- Raising the existing vertical drains in the chute blocks to the proposed new surface level to enable long-term maintenance and monitoring of the drains,
- Reinstating access stairways into the stilling basin to enable long-term surveillance activities to continue.

Reviewing as part of a future hydraulic model study (potentially CFD) that raising the stilling basin invert by 500 mm does not substantially change the hydraulic performance of the stilling basin. Based on engineering experience and judgement, it is considered unlikely that such a small increase in invert level would have any major changes in hydraulic behaviour, but this should be checked in the next stage of design.

5. Constructability Review

5.1 General

Construction of the works involves managing several key disciplines that will need good overall site coordination and management to safely and efficiently deliver the works.

The locations of the works allow for good access to skill trades, general construction materials and support for construction activities. Additionally, the project requires a medium level of complexity for the site establishment and layout concerning providing safe and efficient access and work areas to complete the works.

A good principal contractor with experience in a similar type of work and with a good understanding of the project's risk and technical aspects will need to be engaged to deliver the works. Additionally, the procurement of suitably skilled and experienced subcontractors will be needed to deliver the scope associated with:

- Anchor installation,
- Concrete construction;
- Coordination with the NCA and impacted stakeholders;
- Noise Management; and
- Flood Management.

The following sections provide a constructability assessment for the identified key components of the works.

5.2 Site Establishment and Setup

5.2.1 General

The site lends itself well to the development of temporary site facilities to construct the works, with a preliminary site layout illustrated in Figure 23, including access roads, site compound, storage and handling areas and cranes.

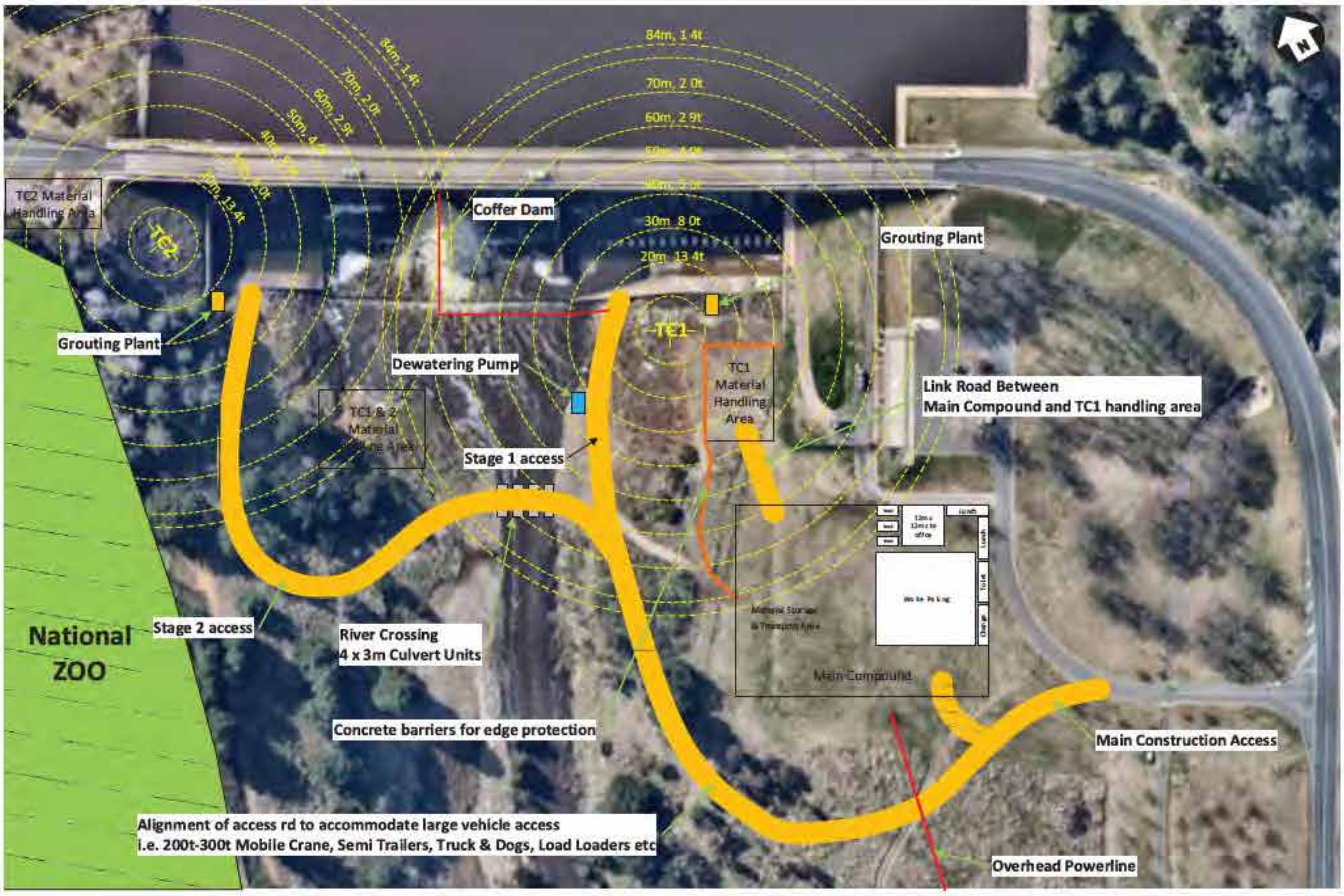


Figure 23 Preliminary Construction Site Layout

It is estimated that during the peak of the construction works, the following resources will be on-site:

- Anchoring Contractor: 8 -10-person crew (Drill operators, installation and grouting crews);
- Slab Construction: 16 -20 persons (Form workers, steel fixers, concrete placement and finishers, specialist trades (water stop install etc.);
- Baffle Blocks: 4-person crew (Form workers, steel fixers, concrete placement and finishers);
- Chute blocks: 4-person crew (Form workers, steel fixers, concrete placement and finishers);
- General Site Labour: 2-person crew (For site operations and general maintenance); and
- Craneage: 8-person crew (Tower cranes, riggers/dogman, telehandler operators).

To manage such a site and to take into consideration the technical nature of the works, the following management structure would be envisaged;

- Project Manager;
- General Site Superintendent (Senior Site Supervisor);
- Project Engineer;
- Site Foreman x 2;
- Site Engineers x 2; and
- WHS Officer.

In summary, a total peak of 60 persons is likely to be required on site during the peak delivery phase of the works.

It is foreseen that the key resources of the project manager and general superintendent will need to have a good understanding of the project's technical challenges and the ability to collaborate well with the NCA to achieve good project outcomes for all parties.

An on-site design engineer representative would be a good addition to such a management team to ensure that technical issues can be simply resolved as they arise. Options exist if this would be a full time of part time position.

5.2.2 Services Connections

Existing services available on-site that could be used by the construction works include:

- HV Power (underground and overhead);
- Potable Water Supply; and
- NBN and Telstra.

No known sewer service is available on either the left or right abutment. Therefore this service will need to be engaged through pump-out arrangement

5.2.3 Site Compound

A site compound will be required to support the construction works comprising site offices, lunch sheds, ablution blocks, change rooms, and worker car parking.

A sufficient area will also be required to manage material deliveries, material and equipment storage, and areas for formwork and anchor assembly works.

5.2.4 Access Roads & Hardstands

Site access is foreseen by utilising the existing road network on the left abutment from Lady Denman Drive, as shown in the previous Figure 23.

Relatively minor earthworks will be generally required to form access roads from the left abutment down to the river and then to the spillway on either side.

Access roads will need to be constructed of suitable grade and condition to accommodate large equipment and plant movements such as mobile cranes, road trucks including semi-trailers, low loaders, truck and dogs and concrete boom pumps. It is foreseen that road formation grades lower than 10% will easily be achieved on this site.

The management of materials and equipment will be key to efficient on-site delivery; therefore, hardstands will need to be constructed on-site to accommodate the temporary storage of materials, grouting stations, plant and equipment turn around setup areas.

Hardstands on each side of the dam will be required to manage materials and for a staged delivery (required to suitably manage floods).

The construction of the hardstands will need to be engineered to both support the weight of the equipment using them, i.e. mobile cranes and concrete pumps, and also to withstand during a certain flood event, including assessment given to the hardstand on the left abutment being impacted by turbulent flows from flooding flows flowing over the right-hand side of the spillway. It is foreseen that this will be managed by constructing rockfill embankments that are caped with finer material to create a suitable working platform.

5.2.5 Traffic Management

Traffic management is foreseen to be relatively simple as convenient access can be simply achieved from the existing road network (Lady Denman Drive).

The works will see a significant increase in vehicle use of the intersection at Lady Denman Drive, with appropriate controls needed to manage this with the existing road users, including the cyclists using the designated cycle route running parallel with Lady Denman Drive.

No upgrade is foreseen to the existing intersection with Lady Denman Drive, although the construction work does present a risk to the integrity of the existing pavement. A risk allowance for the reconstruction or upgrade of this intersection may be required.

The interface of the construction pavement and the existing sealed road should be managed by installing a concrete driveway and asphalt lead into the construction work from the existing pavement. This works is to help prevent damage to the existing pavement.

The safe management of the cycle track (Canberra Centenary Trial) will require some consideration, as it is heavily used by cyclists and at times at speed due to the terrain of the cycle route.

5.3 River Crossing

A suitable river crossing will be required to provide access from the left abutment to the right to move materials, plant, equipment, and personnel efficiently.

The construction of such a crossing is foreseen as straightforward with no major restrictions from approval or planning, given the area is highly disturbed.

During a preconstruction flood study required for the construction works, a suitably sized culvert crossing will need to be designed for an anticipated flood event, i.e., 1 in 10 etc. This will be needed to ensure that the site can still operate during or soon after a certain type of flood event. Failure to suitably size the crossing could result in delays and rework during the delivery.

The crossing will most likely consist of large culvert units (Steel or Concrete) infilled with large rock then overlaid with a suitable pavement.

5.4 Craneage

The layout of the site, coupled with the construction work detailed in the design, requires sufficient craneage capacity. All works require the movement of materials, equipment, and plant that cannot be easily handled without mechanical means. This includes Steel Anchors, Drilling Rigs, Reinforcement Bars, Formwork Systems, Concrete, drill spoil etc.

It is foreseen that tower cranes will provide efficient serviceability to works as they provide capacity and the reach required to get materials from storage areas and hardstands to all locations on the dam.

Due to the geometry of the site and the need to erect the cranes in safe positions (outside potential flood impact zones), two tower cranes with 84 m reach have been proposed for the works (Noting these types of units are available from local craneage suppliers). Refer to the proposed layout of these cranes in Figure 24.

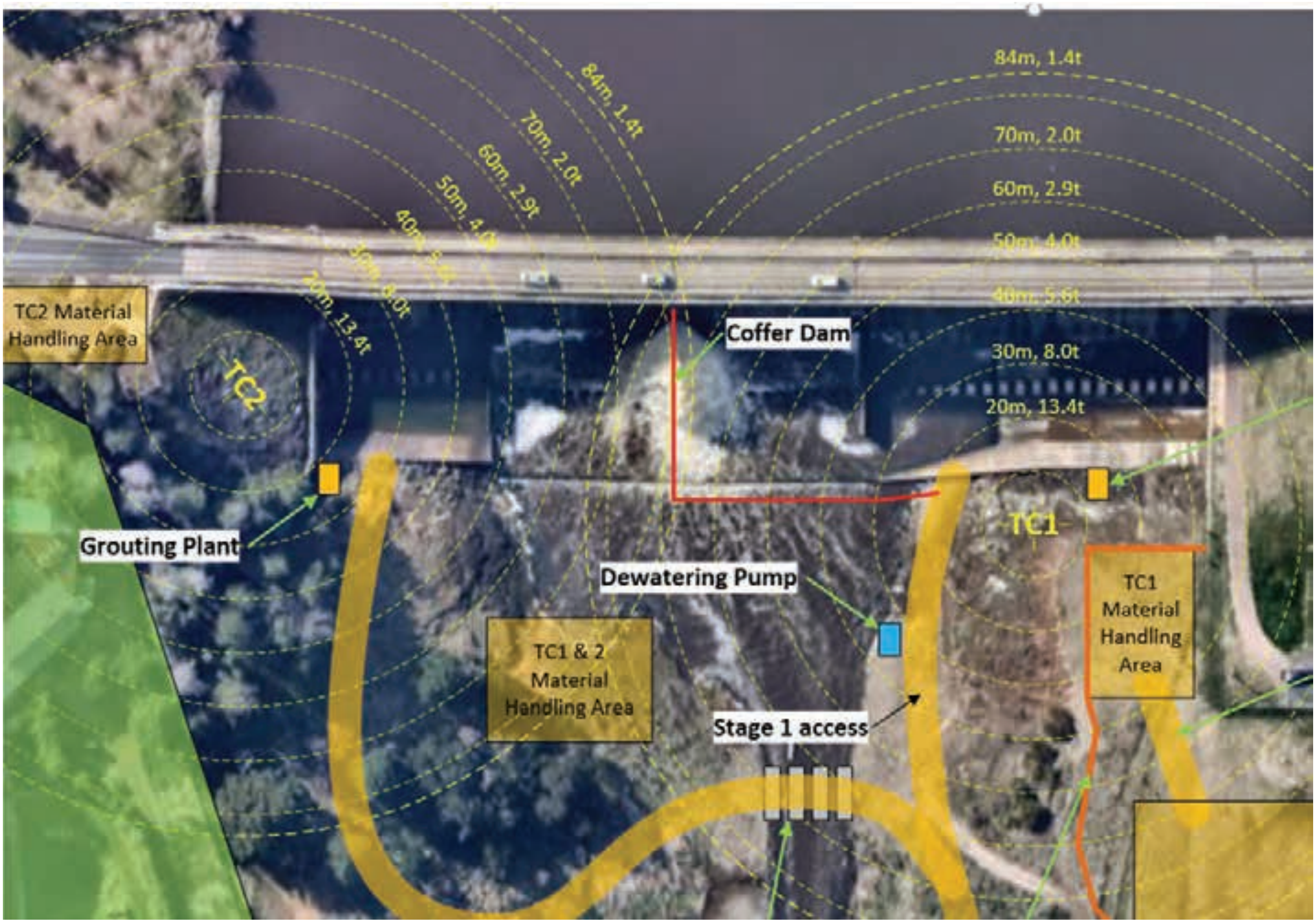


Figure 24 *Crane Layout Diagram*

To support these cranes, a general site cranage in the form of a telehandler and a Hiab truck will be required to help shift materials to and from the tower cranes.

To erect and dismantle the tower cranes, large mobile cranes will be required to access the site, i.e. 200-400 t units.

It is noted that when not in use, tower cranes "weathervane" as the wind changes direction. It is unknown if this will create issues with a tower crane on the right abutment (TC2 in the above image) as it would weathervane over the National Zoo and Aquarium.

Wind presents a delay risk to crane operation on-site, either as mobile cranes or tower cranes. Due to the location, they would set-up, mobile cranes present a lower downtime risk to tower cranes, although they would not provide the same level of service to the site.

A feasible alternate to tower cranes is crawler cranes established on-site. It is noted that tower cranes present a heightened industry relation risk to any project.

A hook analysis will provide optimisation of the crane demand and size, which could provide efficiencies to the current estimate.

5.5 Dewatering

The site's dewatering will be an ongoing task during construction and not limited to an initial pump down of the tailwater level downstream of the sill. The on-going nature of dewatering is due to the high likelihood of nuisance flows and other transmissions of flows under the dam and spillway. Further details on this aspect are discussed in Section 3.

A suitable dewatering system will need to be established to maintain a low water level both in the stilling basin and downstream of the sill to keep water outside the work area. Such pumping arrangement will need to include:

- 6–8-inch bulk dewatering pumps located downstream of the sill;
- 2–4-inch dewatering pumps located inside the work zone to maintain dry conditions;
- Puddle pumps located within the basin to remove small amounts of standing water; and
- Pump controls to be a mixture of automatic, i.e., float switches and manual on off.

Optimal performance for such a project will be high-capacity submersible pumps connected to either generators or site electrical supplies.

Ongoing maintenance of the pumps and pumping operation will be paramount to ensuring delivery is not adversely impacted by standing water levels.

A risk to the works is transmission flows running through/under the dam and out-letting in the work areas. These flows can create construction delays as they prevent concrete placement etc. If encountered, such flows will need to be managed on a case-by-case basis with solutions such as sealing, outlet controls, redirecting etc.

5.6 Cofferdam

A cofferdam will be required to provide flooding protection to the works and provide a dry work area. Such a requirement creates a staged delivery approach as only one portion of the works can be protected at any one time.

It is envisaged that the cofferdam will be bolted to the existing concrete elements (spillway slab and sill) with sealing between the elements achieved using rubber gaskets and sealants.

The cofferdam should be designed to consider the available lifting abilities of the site cranage to efficiently manage the installation, movement and removal of the dam.

A preliminary layout of the proposed cofferdam is provided in Section 3, however the overall size of the cofferdam will need to be refined following the completion of a more detailed flood study that will need to produce key information, including:

- Frequency and type of flows;
- Height of flows;
- Duration of flows and impacts on downstream operations; and
- Operational requirements for the dam operators for given current and forecast conditions and preparation requirements for the site.

5.7 Material Supply

The following details specifics on the major materials required for the project.

5.7.1 Concrete

The Canberra concrete industry will have sufficient capacity to provide concrete to such a project, with the concrete mix nominated to be a 32 MPa, 20 mm aggregate mix. However, the industry potentially lacks the infrastructure to support the hot and cold weather placement requirements for such a project, as no known batching cooling or heating facilities are available at any local plants.

It is foreseen that the cost of ice, chilled water, and heated water infrastructure will need to be covered by the project to have concrete delivered during either the winter or summer periods.

The concrete pours for the project, specifically the slabs, do not present a supply or delivery risk for the concrete suppliers available.

5.7.2 Reinforcement

The reinforcement bar for the work is standard in detail and size, with no specific concerns about getting materials to the site.

Processing of the bars would be performed offsite ready for installation.

Coupling of the reinforcement could be achieved using cutting treads onto the reinforcement bars or using externally threaded bars at connection points.

High pricing risk is associated with reinforcement steel, with significant increases in the purchase price occurring over the last 24 months. With current reports price volatility is expected for the coming 12 months.

5.7.3 Anchor Bars

The design incorporates a readily available bar system (BBR H Bar) that provides a high end engineered solution for this application. Unlike the previously considered Macalloy bars, the BBR-H Bars are not a proprietary system and therefore do not limit the buying capacity of the project through only one supplier being is available for this critical material.

Given the double corrosion protection detail nominated, the option exists for the anchors to be supplied to the project as:

- Bar and components only, to be fully assembled on-site;
- Bar and components assembled, to be installed and fully grouted on-site; or
- Bar, components and internally grouted, to be installed and grouting to the external sheathing only.

The successful contractor would need to determine the best approach weighing up quality, costs and on-site efficiency when selecting the supply option. This would require engagement and consultation with the proposed specialised anchoring subcontractor.

5.7.4 Waterstop

The water stop intended for use on the project does come with some supply concerns relating to time given that only one known supplier in Chile for the product. Lead times of up to 16 weeks for such material is likely.

There are four types of water stop foreseen to be incorporated into the works

- Standard Centrebulb;
- Standard Rearguard;
- Bolt-on Centrebulb; and
- Bolt-on Rearguard.

The installation of these types of water stops is relatively simple. However, critical care is needed when installing the water stop to ensure that they are correctly centred at the joint in the concrete and ensure correct alignment and encasement in the concrete, specifically the Centrebulb installed on a horizontal plane.

Site welding of the water stop is relatively simple, with no complex equipment or skills required.

5.8 Anchoring

The anchoring work will need to be carried out by a specialist subcontractor with relevant technical experience and resources to complete the works.

The anchoring works will be one of the initial stages in construction following the establishment of the site, services, cranes etc.

The anchoring design will require the use of a downhole hammer drill configuration which is required due to the diameter of the hole. This type of drill will help minimise noise generation as part of the works, but this is not the main reason.

Drilling is expected to generate high levels of noise i.e. up to 110 dBA (plus), within 10 m of the operation of the machine. This noise generation will create issues for the neighbouring stakeholders (National Zoo and Governor-General), and noise management needs to be considered to minimise disturbance from this activity. The noise generation will also create noise emission issues for workers, and delivery scheduling should allow anchoring works to progress enough to avoid following trades being exposed to such noise. It is noted that the sidewalls and steel cofferdam will likely bounce the noise around the stilling basing, making working conditions extremely poor.

The key risk associated with the anchoring work is summarised in Table 9. These risks are also captured in the Safety in Design Register (where relevant) and the project Risk Register (refer to Sections 6 and 8).

Table 9 Key Risks for Drilling and Anchoring Works

Scope	Risk
Ground Conditions	Hard rock resulting in production delays and high consumable wear. Fractured rock mass creating anchor hole integrity issues, requiring conformance grouting works, i.e., drills, redrills etc. This adds cost and time, noting that this conformance work can delay the installation of other anchors due to access requirements for drilling rigs in a certain area. Intercepting groundwater connected to the reservoir results in the requirement to pressure grout.
Noise Generation	Very noisy scope of work. Impacts on adjacent stakeholders Impact on workers, and will drive the schedule of overlaying works to avoid exposing workers to such noise
Access	Access for drilling rigs will be limited. Craneage of drilling equipment will be required, especially to work on the area's u/s of the baffle blocks. The work needs to be carefully staged to ensure access is maintained to achieve both drilling and redrills
Material Handling	All equipment and materials associated with the works is heavy and will require craneage for all movements. The work will be very reliant on some form of craneage. i.e. anchor movements, movement of drill soil etc
Environmental Management	Grouting operations are inherently messy. Ongoing maintenance and clean-up of grouting areas and grouting stations will be required.

5.9 Slab Construction Works

The slab construction will require close attention to detail and quality assurance to ensure good construction is achieved.

After completing the anchoring works area, the existing surface will need to be prepared either using mechanic scabble, water blaster or a combination of both to suitably prepare the surface. The preparation work will also need to extend to the perimeter of the existing baffle blocks and sidewalls of the existing structure.

At the interface of the new slab, overlay with all existing elements of the spillway will need to be suitably prepared as described above.

Jointing of the slabs will need to be carefully planned and constructed to ensure the quality of the joint is achieved. Experienced concrete crews should be engaged to carry out this works, and not just any concrete subcontractor.

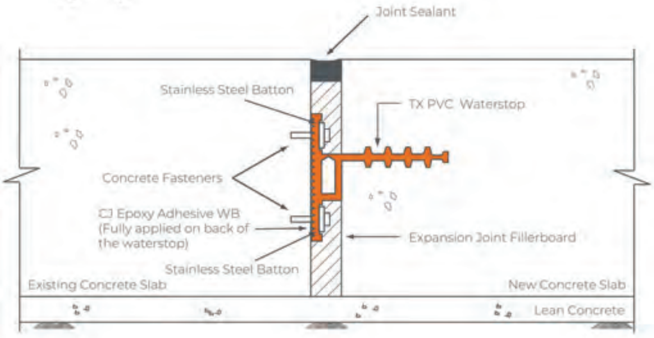
The installation of the reinforcement steel is relatively simple, although sufficient set-up steel will be needed to support the reinforcement cages before and during the placement of concrete. Dowel installation at the interface/ connection to the existing concrete elements will add additional scope to this work, but it is simply drilling a lot of holes.

The placement of concrete could be achieved using a concrete pump or crane and kibble. Given the reach requirements, the pump may be the most efficient in some cases if a concrete mix design can be accepted (high slump required). But in other situations, the crane will be the alternate solution.

A combination of roller screed and vibrative screeds is seen as the most suitable approach to finishing this concrete, coupled with large internal concrete vibrators. Placement of concrete on the sill will need consideration for worker access for placement and finishing, with a form of a temporary moveable walkway to be considered.

The key risk associated with the concrete work is summarised in Table 10. Similar to the drilling risks, the following risks are also captured in the Safety in Design register and the project Risk Register as appropriate.

Table 10 Key Risks associated with Concrete Works

Scope	Risk
Surface Preparation	Poor preparation leading to bond failure between the new and existing concrete.
Geometry of overlay	Pour layout needs to be carefully considered to ensure suitably placement, compaction, and concrete finishing can be achieved.
Connection to existing structural elements	A significant qty of dowels need to be drilled into the existing elements (Baffles, existing walls etc.) Timely and labour intensive task. Waterstop connection between the new and existing elements needs suitable detailing. These details and materials are not standard, nor are they readily available. A concept detail is shown below, noting no joint sealant or filler board would be used for the  scrivener application.
Waterstop	Particular care needs to be taken during the installation of the water stop and the placement of concrete. Poorly installed and supported water stops will move during concrete placement and result in significant quality issues.
Finishing	Poor and unplanned placement methods will result in poorly compacted concrete and poor surface finish that will compromise the life of the new overlay. Compaction must be achieved and not compromised for a surface finish on the US curve and the downstream sill. As slope and vertical curves can create quality issues relating to compaction
Curing	Water curing will be ideal for this work, and suitable resources and labour will be needed to implement this process. Water curing can have an impact on adjacent works if water management is not correctly controlled.
Inclement weather	Cold Weather impacts include frosting of the surface, lack of hydration temperature Hot Weather impacts include plastic shrinkage cracks, high internal hydration temperatures (Element thickness should not cause significant issues) Wind: Plastic shrinkage cracks.

5.10 Baffle Raising Works

The baffle blocks present an interesting challenge. It is assumed that the existing baffles will be completely removed using a wire-cutter to detach the baffles at the existing slab invert level. It is assumed that the baffles would be removed from the stilling basin with a crane, potentially in one or two sections.

The new baffles would then be cast integral with the new slab. The new baffles would include skin reinforcement, and incorporate an anchor through the centre of the baffle.

It is foreseen that the most efficient construction method for this extension work will be to manufacture bespoke steel formwork that incorporates an access scaffold to provide safe access for workers, including steel fixers, form workers and concrete placement crews.

Due to the large quantity of baffles and the detailed nature of the baffles' construction, a dedicated crew will be required for this work.

5.11 Chute Raising Works

The chute block raising works require detailed construction, including minor demolition, dowel installation, small reinforcement installation, and concrete placement and finishing on a shallow vertical curve.

Similar to the baffle blocks, it is envisaged a designated crew will be assigned to complete this work.

Custom formwork and access platforms would be ideal for managing the access and formwork requirements for these elements.

Traditional concrete placement methods will suitably achieve the placement and finishing of the concrete surface. No specific special tools or equipment are envisaged for this scope.

5.12 Scour Protection to existing abutments

The scour protection to either side abutment is intended to be riprap rock protection. Given the layout and the access roads to be constructed for the works, the construction of the rip rap protection is foreseen as a viable construction method.

On the left abutment, details for providing access to the existing maintenance door will be required using a concrete wall or other means to manage the interface between the rip rap-rock and the dam structure will be required, as shown in Figure 25.

Figure 25 ***Schematic of Erosion protection works (plan view)***

5.13 Demobilisation

Demobilisation will generally involve the removal of all temporary site works, including the site compound, site access roads and hardstands, cranes etc.

Progressive demobilisation and rehabilitation will be achievable as the project completes work on one side of the stilling basin and progresses to the other side.

5.14 Delivery Schedule

A preliminary detailed delivery schedule has been developed for the works and takes into consideration the following key elements:

- Preliminaries and planning, including developing key project plans including CEMP, Flood Management Plan, Noise Management Plan etc. Some of these could be taken on by the NCA pre-engagement
- Procurement of critical components, including materials (concrete, anchors, water stop, reinforcement) and specialised subcontractors. Noting the selection of suitable subcontractors is key to the success of the project.
- Site Establishment, including compound, access roads, site services, hardstands and site craneage setups.
- Staged delivery of the works, controlled around the installation of a cofferdam centrally located to allow for safe and dry construction on each side of the spillway at any one time.
- Sequencing of the works are generally as follows:
  - Anchor installation
  - Slab construction
  - Baffle and chute extensions
  - Scour Protection to the abutments

Specific critical allowances in this preliminary program include:

- Anchoring works must be sufficiently completed before starting other trades to minimise worker exposure to drilling rig noise.
- Stage slab construction allows for a 14 days curing period before a slab is placed adjacent to existing slabs.
- An early start on the right abutment works, given the elevated nature of the furthest right portion of the spillway, and an early start is envisaged before moving the cofferdam from protecting stage 1 of the works.

5.15 Noise Management

The works are expected to generate significant noise, especially but not limited to the anchor drilling operations. To manage the noise, the following methods should be considered:

- Use of downhole hammers to drill anchor holes;
- Use of hydro demolition for demolition of existing concrete sections; and
- Use of noise absorption materials/ structures around noise emitting operations.

A noise study will need to be carried out to completely understand the noise pollution from the works and its impact on the two sensitive receivers, noting that the existing terrain and structures observed will not provide sufficient noise emission control or muffling.

5.16 Construction Contract Considerations

The selection and development of the construction contract can significantly influence the outcome of the delivery of the project.

The type of contract relationship required for this project needs consideration when selecting the type of contract and specific of the delivery. A collaborative type of contract should be considered for the works, for a 'best for project' outcomes concerning overall successful delivery, including quality, time, cost, and stakeholder management.

The price structure of the contract will also need some consideration, with some key risks such as noise most likely best managed by the use of provisional sums or open-book pricing.

Works insurance for the project could present some risks concerning the value to establish insurance cover and the ability to obtain cover at all. This is due to recent adjustments in the insurance space with large payouts in Australia occurring (apartment building quality issues), and the high-risk nature of dam construction works. Whether the contractor or NCA establishes this policy needs to be considered.

6. Risk Register

6.1 General

A Risk Assessment of the concept designs has been undertaken, focusing on the following risk categories:

- Technical Aspects – Various technical aspects of the project may have risks, including assumptions made on geotechnical conditions, topographic input information, and material sources.
- Procurement – Risks associated with procurement activities include being able to adequately procure appropriate contractors, materials and the risk of inflation/escalation over the project.
- Construction – Construction risks include aspects which may impact the construction program, budget, and quality.
- Environmental and Social – Many factors relating to the stilling basin upgrade works have an interaction with environmental and social impacts, in particular public safety and environmental impacts both upstream and downstream of the re-regulating pond.

The Risk Assessment has been undertaken in accordance with ISO 30000 (2009) Risk Management standard, and includes the following aspects:

- Identification of the Hazard
- Potential causes of the hazard
- Consequences and impacts of the hazard occurring
- Likelihood that the risk will eventuate
- Risk rating
- Risk mitigation measures
- Residual risk

The Risk Assessment will need to be updated as the project progresses to ensure that management of the risk is being undertaken in an effective manner.

The Risk Assessment has also been used as one of the key tools to determine the contingent costs associated with the project. Further details on the expansion of the Risk Register to assess contingency costs is described in Section 7.

6.2 Risk Rating

The analysis of risks (i.e. likelihood and consequence) used in the assessment is summarised in the following matrix. Control measures have been nominated wherever possible in an attempt to reduce residual risks to a rating of 'medium' or lower.

Table 11 Risk Matrix

		Likelihood				
		Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Consequence	Catastrophic (5)	Medium	High	High	Extreme	Extreme
	Major (4)	Medium	Medium	High	High	Extreme
	Moderate (3)	Low	Medium	High	High	High
	Minor (2)	Low	Low	Medium	Medium	High
	Insignificant (1)	Low	Low	Low	Medium	Medium

Various descriptors have been developed to define the likelihood of occurrence, and the consequences for each risks. These descriptors are summarised in the following tables.

Table 12 Definition of Likelihood of Occurrence (base on ISO 31010)

Likelihood	Definition of Likelihood
5 - Almost Certain	There is evidence of certainty that this will eventuate; or occurs once a year, or has >80% chance of occurring
4 - Likely	The threat exists and it indicates high probability of occurrence; or occurs once every 1-5 years; or has a 20% to 80% probability of occurring
3 - Possible	The threat exists but the history of expectation of this type of situation indicates occurrence is moderately possible or occurs once every 5 to 20 years or has a 5% to 20% probability of occurring
2 - Unlikely	A slight threat is perceived from this source but the situation is unlikely to occur or is likely to occur once every 20 to 100 years, or has a 1% to 5% probability of occurring
1 - Rare	No perceived threat from this source of risk or occurs once every 100 years or has <1% probability of occurring

The consequence category for various risks was assessed using the measurement criteria summarised in the following table.

Table 13 Descriptors for Consequences of Risks

Consequence	Cost (AUD)	Program	Legal and Regulatory	Environment	Safety
5 - Catastrophic	Increase in Costs by >$20M	>12 weeks	The public bring a Class Action, major cost implications unable to be met by NCA, or major breach of regulatory or Common Law obligations that impacts on a region or suburb in the ACT	Significant environmental breach resulting in prosecution, total loss of eco-system	A single fatality or permanent impairment to one or more persons
4 - Major	Increase in Costs by >$5M to <$20M	>6 & <12 weeks	A public hearing (not Class Action), major cost implications that NCA will need to seek additional funding to cover	Major environmental breach, or major loss to eco-system	Hospital admission required
3 - Moderate	Increase in costs by >$0.5M to <$5M	>3 & <6 weeks	Moderate statutory penalty imposed, moderate cost implications absorbed by NCA	Moderate environmental breach, partial loss of eco-system	Serious injury or dangerous event
2 - Minor	Increase in cost by >$0.1M to <$0.5M	>1 & <3 weeks	Low statutory penalty, low cost implications, moderate non-deliberate breach of regulatory obligations	Fines imposed as a result of an environmental breach, isolated disruption to the eco-system	Medical treatment (doctor or medical facility) required
1 - Insignificant	Increase in cost by <$0.1M	<1 week delay	Minor, non-deliberate breach of procedural or regulatory obligations. Little or no cost implications	Non-compliance to environmental obligations. Little or no disruption to the eco-system.	Illness or injury (first aid treatment only)

6.3 Key Risks Identified

The preliminary risk assessment undertaken for the Stilling Basin is provided in Appendix D. It is noted that the risk assessment was based on the preferred concept, and not individual options. The risk register will need to be reviewed and updated through the project phases as further information becomes available.

Nearly all of the risks identified to date fall into the ‘medium’ to ‘high’ categories if mitigation measures are not adopted. None of the risks fall into the ‘Extreme’ category. The highest of these risks after mitigation measures are adopted include:

– Geological conditions – Two key risks identified relating to geology of the site remain in the ‘high’ category following mitigation measures. The first of these risks is that the geological conditions are substantially worse than expected. The second risk is that artesian pressures are encountered during the drilling works, required substantially greater work to address the seepage during construction.
– Cofferdam risks – Due to the nature of the flooding at Scrivener Dam, and the need to maintain an operational storage during construction, there are inherent risks associated with the cofferdam. The highest of these risks is the potential for the cofferdam to fail. These risks should be mitigated through the design process.
– Hydraulic modelling – Although it currently appears unlikely that the physical hydraulic model study will need to be rerun for the proposed upgrade solution, it remains a risk that a new model will need to be developed.
– Inflation/ escalation – It has been highlighted that the construction industry is currently experiencing significant inflation in a number of areas (both supply and resources). The rapid fluctuation in inflation remains a high risk to the project.
– Project doesn’t gain government funding – Similar to many projects, there is an inherent risk that the project will not gain government funding in the upcoming funding cycle. Associated with this risk is the potential for the project to be under-funded.

After implementing the mitigation measures, all but 6 of the 48 risks identified fall into the low to medium categories.

7. Cost Estimate

7.1 General

This Section presents the Class 4 cost estimates prepared for the concept design, and includes details of:

– Assumptions made, and limitations in preparing the cost estimates
– Direct costs on identified construction items
– Risk analysis undertaken to determine contingent costs
– Other Mark-ups and allowances in the cost estimates
– A summary of the estimates

A schedule of quantities and breakdown of the cost estimate is included in Appendix E.

7.2 Key Assumptions, limitations and accuracy

In addition to the assumptions previously described in this report, the following additional assumptions were made in the preparation of the preliminary cost estimates:

– The level of detail of the option designs and cost estimates of the present study correspond to a concept screening level study (or a 'Class 4 estimate in accordance with AACEi), which has been undertaken for the purpose of comparing options. This level of study is required where there is more than one business scenario, and it is necessary to determine which one is the best, both technically and financially.
– A preliminary construction program has been prepared, and has been used as a key basis for some components of the estimate. The program has been prepared using experience and engineering judgment.
– Indirect costs (engineering design, environmental and heritage studies, project management, supervision costs, etc.) are included as percentage mark-ups or lump sum items on the direct costs.
– The cost estimate is only for the implementation of the upgrade option and does not include any allowance for running or operational costs over the life of the dam.
– The estimates have been based on the chute blocks and end sill being largely retained in the upgrade works (not completely demolished). Incorporating these features in the upgrade works provides a significant reduction in the costs and environmental impact, associated with demolition works. Conversely, it has been assumed that the central baffle blocks will be completely removed, by wire-cutting, and reconstructed. The costs associated with these works are accounted for in the estimate.
– The current estimate assumes all anchors will have double corrosion protection and include a free-length.
– It is highlighted that the construction industry has experienced significant recent escalation in prices. For example, the price of steel has risen by around 12% in the last 3 months. The potential for on-going price escalation, and how to manage this risk, will need to be considered in future stages of the project. At this stage, escalation risk has been incorporated into the Monte Carlo assessment.

7.3 Direct Costs

A cost estimate for direct items has been prepared by GHD's specialist contractor advisor, Mr. Asher Trounce. The estimate has been developed using the following data:

– Quantities applied in the cost estimates were based on data provided by GHD, and calculated using the concept design arrangement.
– Unit rates were developed using:
  - Budget quotes from suppliers
  - Estimates from recent similar works
  - Industry unit rates in published data
  - Experience as a specialist cost estimator on large infrastructure projects.

- Time-factored rates were assessed based on a preliminary construction program prepared by Mr. Trounce. A copy of the preliminary construction program for all three options is provided in Appendix C.

The estimate was based on the Concept Design and is subject to change as the design develops. A contingency allowance as described below has been added to the estimated costs of the works described in this report.

7.4 Mark-ups and allowances

The direct costs have been estimated based on approximate quantities and selected unit rates. There are however a number of items that cannot be directly measured. For those items the following percentage mark-ups have been included in the cost estimates, based on past project experience:

- Contractor's supervision, site overheads and profit: [redacted] of direct cost.
- Minor miscellaneous items not measured: [redacted]
- Engineering design (no allowance has been made for physical hydraulic modelling or geotechnical investigations as it is assumed the recently undertaken investigations and current planned geotechnical investigations will be sufficient): [redacted] for all options.
- Environmental, planning and heritage approvals: Assumed lump sum amount of [redacted].
- Project management and construction phase services: [redacted] of the contractor's estimate.

These items are shown as separate line items in the cost estimate.

7.5 Risk and Contingency

A risk register was developed during the concept stage by GHD, and reviewed by GHD's constructability specialist. The Risk Register informed a Montel Carlo analysis which was undertaken in two components namely:

- Planned estimate risks (based on the Direct Costs)
- Unplanned estimate risks (based on the Risk Register prepared and discussed in Section 6).

The total risk of the planned and unplanned risk has been modelled and calculated using @Risk software. The Monte Carlo model has been simulated for 100,000 iterations.

Planned risks were generally modelled using triangular distributions. The extent of the variance has been presented by a probabilistic distribution after determining the appropriate range of unit ranges and quantities. In particular, the following was developed by GHD's constructability specialist as an addition to the cost estimate:

- Lower bound price (variance on quantity and unit rate)
- Expected unit rate (which has been used in the base estimate)
- Upper bound unit rates (variance on quantity and unit rate)

Figure 26 provides a summary of the distribution of planned costs determined with the Monte Carlo assessment.

[redacted]

Figure 26 Distribution of Planned Costs

The total construction costs for the P50 and P90 values are shown in Table 15. Total construction cost output information is attached in Appendix F for reference.

Table 14 Summary of Contingent Costs

Item	P50 Estimate	P90 Estimate
Planned Costs	[redacted]	[redacted]

A similar process was undertaken for the unplanned costs. Unplanned risks were based on the Risk Register. These risks were modelled as two-dimensional. One dimension is the risk consequence, and the other dimension is the likelihood. Each dimension is modelled independent of the other and can have a significant impact on the overall risk contingency.

Figure 27 provides a summary of the distribution of unplanned costs determined with the Monte Carlo assessment.

[redacted]

Figure 27 Distribution of Unplanned Costs

The total risk outputs for the P50 and P90 values are shown in Table 15. Total Risk output information is attached in Appendix F for reference.

Table 15 Summary of Contingent Costs

Item	P50 Estimate	P90 Estimate
Planned Costs (1)	[redacted]	[redacted]
Unplanned Costs	[redacted]	[redacted]
Total	[redacted]	[redacted]

Note (1) – The planned risk estimate has been calculated by subtracting the proposed direct costs from the cost estimate from the P50 and P90 estimates.

At this stage, the contingency amount included in the cost estimate is based on the P90 estimate.

It is noted that a contingency has also been applied to the indirect costs. In the options phase, the contingency applied to direct and indirect costs was [redacted] For this phase, given the further design development, it is proposed that a [redacted] contingency is more appropriate, and has been applied in the cost estimate for indirect costs.

7.6 Summary of Cost Estimates

A summary of the cost estimate prepared for the Concept Design to a Level 4 (AACE International) estimate is summarised in Table 16. A more detailed breakdown of this estimate is attached in Appendix E.

Table 16 Summary of Concept Design Cost Estimates

Item No.	Description	Quantity	Amount ($ AUD)
DIRECT COSTS			
1	Preliminaries		[redacted]
2	Flood Protection/ Cofferdam		[redacted]
3	Stilling Basin Slab Upgrade		[redacted]
4	Stilling Basin Wall Raising and Erosion Protection		[redacted]
5	Miscellaneous		[redacted]
6	Minor Items		[redacted]
	Sub-total (Total Direct Cost)		[redacted]
TOTAL CONTRACTOR'S ESTIMATE			
	Contractor's Margin	[redacted]	[redacted]
	Contractor's Estimate (excl contingency)		[redacted]
	Contingency allowance		
	– Planned Risks Contingency		[redacted]
	– Unplanned Risks Contingency		[redacted]
	Indicative Contractor's Estimate (excl. GST)		[redacted]
OTHER INDIRECT COSTS			
	Engineering design	[redacted]	[redacted]
	Environmental and planning approvals	[redacted]	[redacted]
	NCA's Management Costs (% of Contractor's Estimate)	[redacted]	[redacted]
	Owner's Indirect Costs (excl contingency)		[redacted]
	Contingency allowance	[redacted]	[redacted]
	Indicative Other Indirect Costs (excl. GST)		[redacted]
TOTAL PROJECT ESTIMATE			
	Indicative Contractor's Estimate (excl. GST)		[redacted]
	Indicative Other Indirect Cost (excl. GST)		[redacted]
	Total Indicative Cost Estimate (exc. GST)		[redacted]

8. Safety in Design

8.1 General

The ACT Work Health and Safety Act (WHSA) describes the duties of designers of plant, buildings and structures. These include that designers must ensure, so far as is reasonably practicable (SFAIRP) that the plant, building or structure is designed to be safe and without risks to health if it is used for a purpose for which it was designed. This condition applies to design, construction, operation and maintenance phases of the project.

What is ‘reasonably practicable’ in a given situation is to be determined objectively. The designer must do what a reasonable person would do in the particular circumstances by putting in place reasonably practicable measures. In determining what is ‘reasonably practicable’ account must be taken of:

– The likelihood of the hazard or risk concerned eventuating.
– The degree of harm that would result if the hazard or risk eventuated.
– What the person concerned knows, or ought reasonably to know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk.
– The availability and suitability of ways to eliminate or reduce the hazard or risk.
– The cost of eliminating or reducing the hazard or risk.

The methodology applied to the Scrivener Dam stilling basin upgrade project was developed to meet the objectives of the work with reference to these legislative requirements.

8.2 Safety in design process

It is typical to undertake a number of SiD assessment processes throughout the development of a project. The ability to influence safe outcomes on a project is often highest in the early stages of the project, as shown in Figure 28.

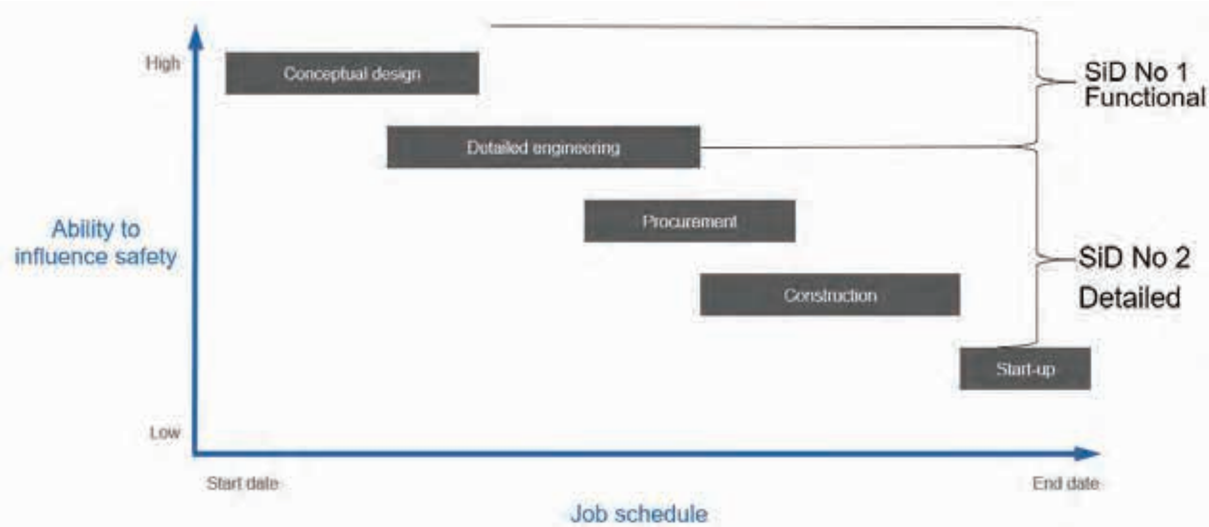


Figure 28 SiD1 ability to influence safety figure

For the Scrivener Dam project, a SiD assessment has been carried out as part of the concept development. This process comprised an internal workshop involving experienced personnel covering a broad range of disciplines. It is proposed that future SiD assessments include workshops with all relevant stakeholders.

The steps used to undertake the SiD process for the concept design are shown in Figure 29.

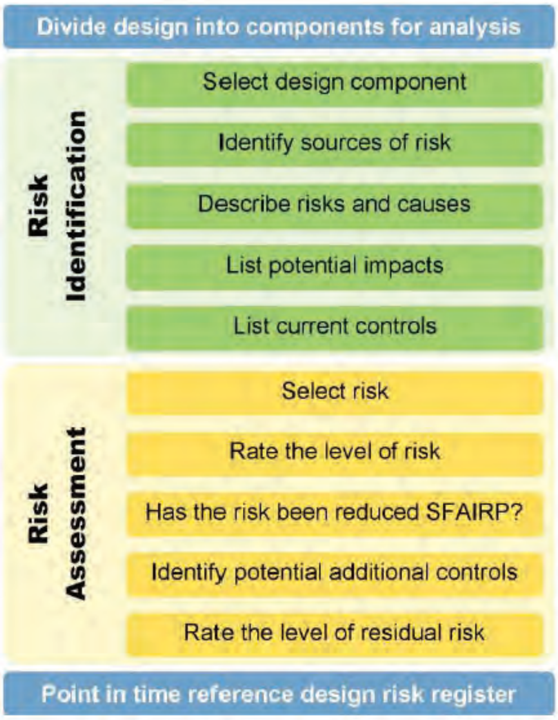


Figure 29 Safety in design methodology

The broad process for the SiD carried out as part of the concept design involved the following steps:

– Components for Analysis – The design was divided into logical components for analysis to focus the SiD assessment and to allow time for the key areas to be considered.
– Risk Identification – The objective of this step was to identify and describe the key risks related to each of the identified design components. The identification was undertaken as a brainstorming exercise with the workshop team. Guidewords were used with the participants as a reference to prompt thought and aid the identification process.
– Impacts and Causes – Each identified risk was further described by listing the cause(s), potential impact(s) and current control(s) in the risk register spreadsheet. The project team identified a number of safety in design risks prior to the workshop. The team reviewed these risks and updated them to reflect the knowledge of the team members. The remainder of the workshop identified additional risk scenarios associated with the design.
– Risk Identification – The aim of the assessment is to determine the risk level for each of the risks identified in the previous stage. The risk level was determined using the following process for each risk:
  - Identify the worst credible case consequence and assess the severity of this case using the defined severity classification.
  - Assess the frequency of that consequence (with the listed current controls in place).
  - Based on these values, obtain the risk rating from the agreed risk matrix.
– Assigning a Risk Level - Once assessed, the team determined if the risk level for each item had been reduced SFAIRP in the design. If not, additional control measures were identified and listed, and the residual risk (i.e., the risk level with the additional controls in place) were assessed. If no additional control measures were identified, then no residual risk assessment was required.
– Developing Control Measures – When selecting control measures to adopt in the design, the hierarchy of control was considered, as shown in Figure 30 (ordered from the most preferred at the top to least preferred at the bottom). The initial focus was on eliminating the hazard by design and controls lower in the hierarchy were only selected if elimination was not practical.

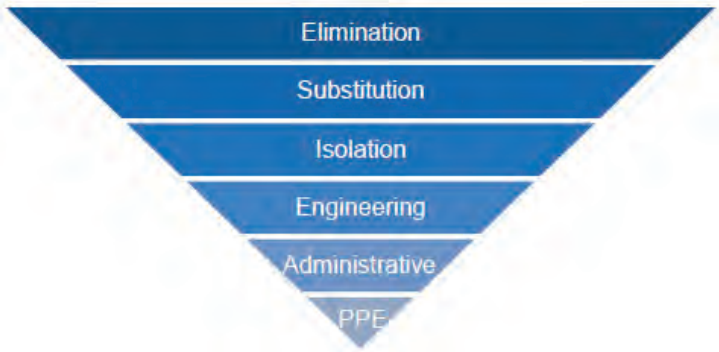


Figure 30 Hierarchy of controls

– Risk Register – The results of the risk identification and assessment process are captured in the risk register, which is a point in time Safety in Design risk register. The register should be kept live throughout the project and be updated to reflect any changes or modifications to the design that impact the risk assessment information. At the end of the Detailed Design phase, the register should be carried forward to the construction phase so it can continue to remain live throughout the asset life cycle.

8.3 Results of SiD Assessment

8.3.1 Summary of Risks

The first SiD assessment was facilitated by GHD as an internal workshop. A Safety in Risk Assessment was completed as part of the workshop and is provided in Appendix D. A summary of the risk ratings is shown in Table 17.

Table 17 Summary of risk ratings

Risk Ranking	Number of Uncontrolled Risks	Number of Residual Risks
Extreme	3	0
Significant	21	11
Moderate	2	13
Low	0	2
Total	**26**	**26**

8.3.2 Key recommendations

The intent of the SiD Risk Assessment is that it be maintained and updated regularly during the design and be used to record and communicate safety design information relating to the design. Some of the key SiD risk identified in the workshop included:

– Site personnel and vehicle interaction – There will be a number of site personnel on site undertaking various tasks over the duration of the construction works. In addition, the project will require the delivery of various materials, and support by various mobile plant. One of the greatest safety risks identified on the project was for injuries to staff through unsafe interactions with mobile plant and vehicles. This risk was initially identified as an ‘Extreme’ risk, but can be controlled to a ‘High’ risk to an extent with procedures, exclusion zones and PPE (high-vis jackets).

– Impacts on the Zoo – There is the potential for safety impacts on the zoo associated with noise, dust and vibration. While the consequences on staff and patrons at the zoo may be relatively low (i.e. not expected to cause serious injuries), there is currently very little known about the potential impacts on the behaviour of the animals kept at the zoo (impacts on breeding programs etc). As such, there may be major impacts from an environmental perspective. This risk was initially identified as an ‘Extreme’ Risk but is expected to be reduced to a ‘High’ risk through the environmental and approvals process, and subsequent CEMP procedures.

- Working from heights – Although the majority of work on the stilling basin will occur from the slab level, the baffles and chute blocks need to be raised by 0.5m. The baffles are currently approximately 2.0m. This means that all works on the baffles will be undertaken from height. These working from height risks can be controlled through procedures and work platforms. This risk was initially classified as an ‘Extreme’ risk, but is expected to be reduced to ‘Medium’ risk with procedures and equipment.

After mitigation measures, there are no ‘Extreme’ risks, however 11 ‘High’ risk items remain. The majority of the high risks relate to risks associated with vehicle movements, flooding risks, heavy lifts, and dropping objects from a height. While some of these risks can be mitigated to an extent during the design phase, many of them will need to be addressed through the construction phase.

9. Future Investigations, Studies and Assessments

During the development of the Concept Design, it has become apparent that there are a number of items which will specifically require further assessment in the upcoming phases of work in additional to the standard project/design development works. These key items specifically include:

- Geotechnical investigations – Although there is a significant amount of existing information on the geological characteristics of the site, it is noted that further investigations and geological modelling of the site will be required to better characterise the site. In particular, specific attention to be given to characterising the geological faults identified during the construction phase.
- Construction flood review – The development of the concept design has included a high-level review of the construction flood hydrology risks. Through this review, a preliminary arrangement for the cofferdam has been developed. Nevertheless, it is highlighted that the review of construction flood hydrology is preliminary in nature, and should be further explored as the project progresses through a specific construction flood hydrology review. This should include risk cost modelling for various lake drawdown and cofferdam height, alternatives, This study should also investigate the allocation of flood risk between the contractor and the NCA.
- Design of downstream culvert crossing for construction – As part of the constructability assessment of the project, it became apparent that downstream access will be required via a construction river crossing. At this stage, it is proposed that the river crossing combine a bank of culverts. The design of these culverts is particularly important, as not only will it serve an important access route for construction, but it will also be important to ensure that the culvert does not adversely impact the tailwater levels during construction. Any temporary increases in tailwater levels during construction are likely to have an exponential impact on the design and cost of the cofferdam.
- Design of access around erosion protection area – A preliminary design for erosion protection of the embankment has been prepared, however it is noted that additional details will be required to ensure that the erosion protection does not impede access through the existing training walls to the spillway gates. It appears likely that additional works (concrete erosion protection/ concrete retaining wall) may be required in this area to ensure that the access route remains open/clear, while allowing erosion protection to be placed against the embankment.
- Noise and vibration study – During the concept development, it became apparent that there may be significant impacts on the nearby properties. In particular, there is concern that the relatively loud drilling works required for the project may adversely impact the nearby zoo. It is understood that the zoo currently runs a number of internationally important breeding projects. It is unclear whether noise impacts have the potential to affect these breeding programs. Furthermore, there may be adverse impacts from noise and vibration on the number and experience of patrons to the zoo, particular the hotel accommodation facilities. These aspects need to be further understood, most likely initially through a specific noise and vibration study.
- Stakeholder engagement – Associated with the previous issue raised regarding noise and vibration, it is recommended that early engagement with stakeholders take place to identify potential issues, and develop strategies for managing these risks.
- Procurement approach – As discussed in the Constructability Review, it is recommended that NCA commence assessments of potential procurement approaches for the upgrade works. In addition to the items raised in the constructability review, it would also be prudent to consider whether there is benefit in early procurement of waterstops (due to their likely long lead-time) through a Principal Supplied Items mechanism in the contract.
- Dewatering trials – It is understood that NCA is about to embark on dewatering trials for the stilling basin. GHD supports these early trials so that issues can be identified and address early in the design phase.

10. Conclusion and Recommendations

The concept design of the stilling basin upgrade has been prepared based on the preferred option identified in the Option Phase of the project, namely Option 3. A number of refinements have been made to the concept since the options phase including:

– The proposed spacing of the anchors has increased from that which was proposed in the option phase
– Further refinement has been undertaken on the anchor assembly details
– Further refinement and assessment has been made of details associated with contraction joints, and raising the chute blocks, baffles and end sill
– Further refinement has been made on the training wall extension
– The proposed end wall raising works proposed at option stage have been revised, and now comprise erosion protection of the abutments in the form of rip rap project.

In addition to the updates to the concept design, a number of other aspects have been investigated in the Concept Design, including:

– Review of the potential flood protection measures - This review found that the likely flood protection measures will include a combination of temporarily lowering the lake level by around 0.5 to 0.75 mm and installing a 3.6 m high cofferdam.
– Potential impacts to the existing dam – The review found that there are no major impacts of the proposed stilling basin upgrade works on the existing dam which cannot be addressed as part of the proposed upgrade works.
– A constructability review of the project – The review has provided further definition of the likely construction processes and methodologies required for the project, and has been used in the development of the proposed construction program and cost estimate.
– Development of a project risk register – The Project Risk Register identified a range of potential risks, with the key risks comprising:
  - Geological conditions (various risks identified)
  - Cofferdam risks (a number of risks identified)
  - Hydraulic modelling (PHM or CFD)
  - Inflation/ escalation
  - Project doesn’t gain government funding (major project risk but doesn’t impact Monte Carlo assessment)
– Preparation of a cost estimate, including a Monte Carlo assessment of contingency amounts – The total expected cost for the project is summarised in Table 18.

Table 18 Summary of Concept Design Cost Estimates

Item No.	Description	Quantity	Amount ($ AUD)
DIRECT COSTS			
1	Preliminaries		[redacted]
2	Flood Protection/ Cofferdam		[redacted]
3	Stilling Basin Slab Upgrade		[redacted]
4	Stilling Basin Wall Raising and Erosion Protection		[redacted]
5	Miscellaneous		[redacted]
6	Minor Items		[redacted]
	Sub-total (Total Direct Cost)		[redacted]
TOTAL CONTRACTOR'S ESTIMATE			
	Contractor's Margin	[redacted]	[redacted]
	Contractor's Estimate (excl contingency)		[redacted]
	Contingency allowance		
	– Planned Risks Contingency		[redacted]
	– Unplanned Risks Contingency		[redacted]
	Indicative Contractor's Estimate (excl. GST)		[redacted]
OTHER INDIRECT COSTS			
	Owner's Indirect Costs (excl contingency)		[redacted]
	Contingency allowance	[redacted]	[redacted]
	Indicative Other Indirect Costs (excl. GST)		[redacted]
	Total Indicative Cost Estimate (exc. GST)		[redacted]

– A Safety in Design assessment – A safety in design register has been prepared for the project. The key risks identified during this process include:
  - Site personnel and vehicle interaction
  - Impacts on the Zoo
  - Working from heights/ crane risks
– Recommendations for future investigations, studies and assessments – A number of key future studies were identified in addition to the standard design development works. These recommended studies include:
  - Undertaking geotechnical investigations and modelling
  - Undertaking a detailed Construction Flood Study
  - Preparing the preliminary detail for the downstream culvert design
  - Further development of the erosion protection works
  - Undertaking a noise and vibration study
  - Commencing stakeholder engagement
  - Assessing potential procurement methods and approaches
  - Carrying out dewatering trials on the stilling basin.

11. References

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ANCOLD (2012) , Guidelines on Consequence Category for Dams, October 2012

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SMEC (2021), Scrivener Dam Model Study Report, Draft 7 May 2021

SMEC (2021), Scrivener Dam Hydrology, Dambreak and Consequence Assessment

SMEC (2019), Scrivener Dam – IDSI Report – Dewatering of Stilling Basin

WRL (2021), Scrivener Dam 3D Physical Model, March 2021

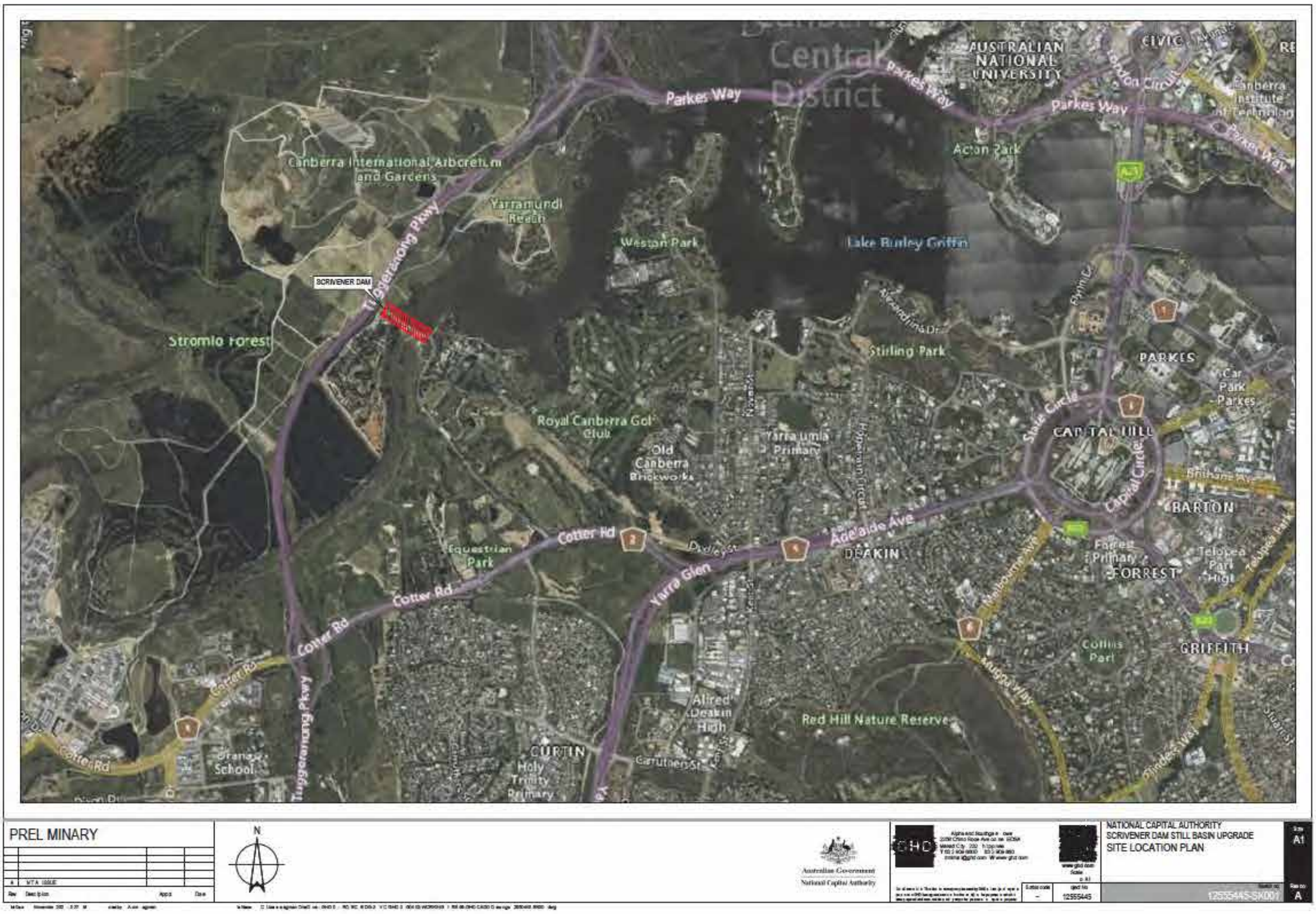
USACE (2005), Stability Analysis of Concrete Structures EM-1110-2-2100 – 1 December 2005.

Various Drawings and photos

Appendices

Appendix A

Concept Sketches


Central District
AUSTRALIAN NATIONAL UNIVERSITY
CIVIC
Parkes Way
Canberra International Arboretum and Gardens
Yarramundi Reach
Acton Park
Weston Park
Lake Burley Griffin
SCRIVENER DAM
Tuggeranong Pkwy
Stromlo Forest
Stirling Park
PARKES
Royal Canberra Golf Club
Old Canberra Brickworks
Yarralumla Primary
CAPITAL HILL
State Circle
Capital Circle
BARTON
Cotter Rd
Equestrian Park
Adelaide Ave
DEAKIN
Yarra Glen
Forest Primary
FORREST
GRIFFITH
Red Hill Nature Reserve
Alfred Deakin High
CURTIN
Holy Trinity Primary
Tuggeranong Pkwy
PRELIMINARY
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Australian Government
National Capital Authority
GHD
www.ghd.com
NATIONAL CAPITAL AUTHORITY
SCRIVENER DAM STILL BASIN UPGRADE
SITE LOCATION PLAN
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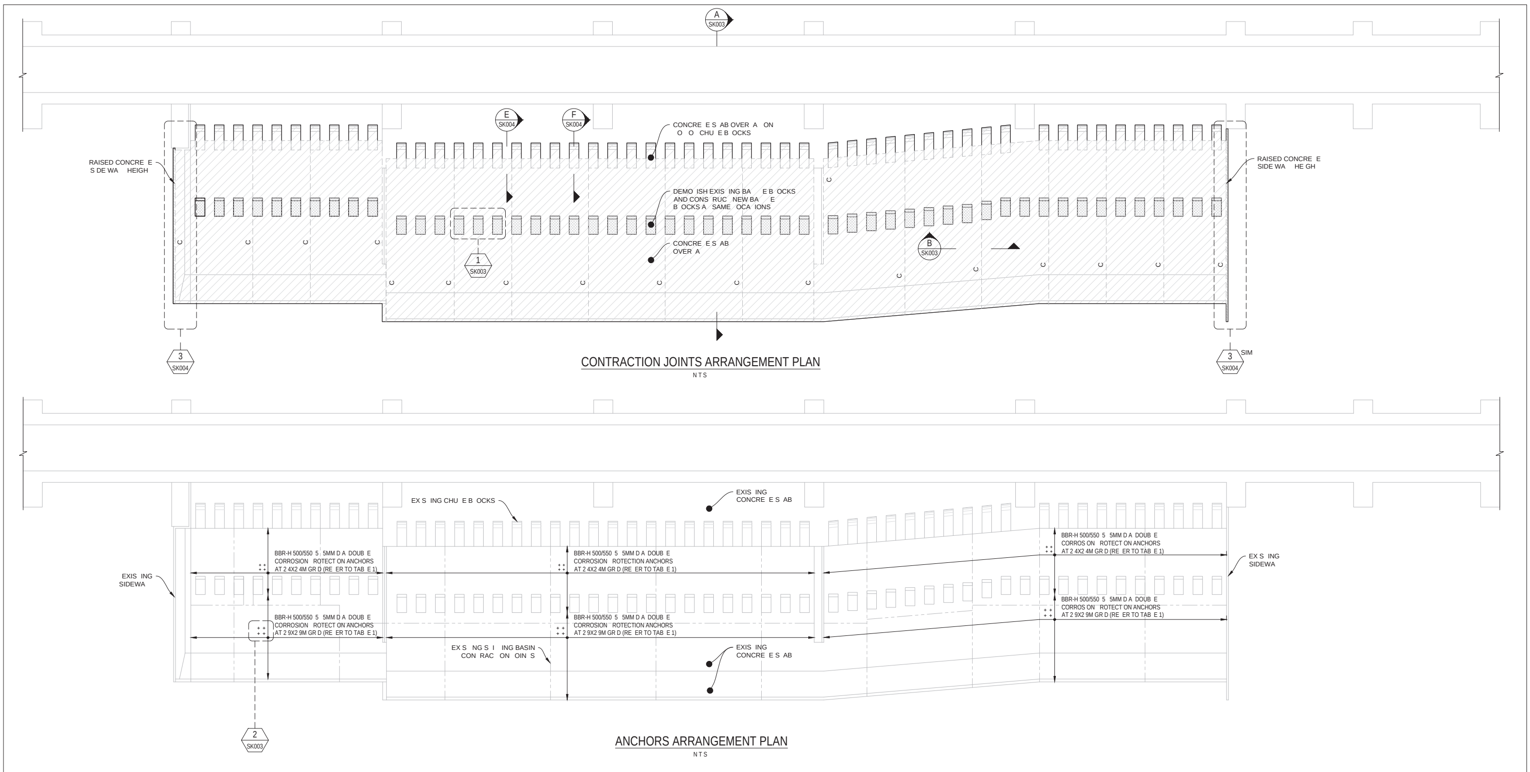


TABLE 1								
BAY	LOCATION	OVERLAY SLAB THICKNESS	BBR-H ANCHOR DIA.	ANCHOR GRADE	ANCHOR SPACING	EMBEDMENT LENGTH	BOND LENGTH	HOLE DIA.
		MM	MM	MPA	M	M	M	MM
BAYS 1 TO 5	UPSTREAM OF BAFFLES	500	57.5	500	2.40	12.5	4	175
	UPSTREAM OF BAFFLES	500	57.5	500	2.90	10.0	4	175

PRELIMINARY

N

NATIONAL CAPITAL AUTHORITY
SCRIVENER DAM STILL BASIN UPGRADE
GENERAL ARRANGEMENT PLAN

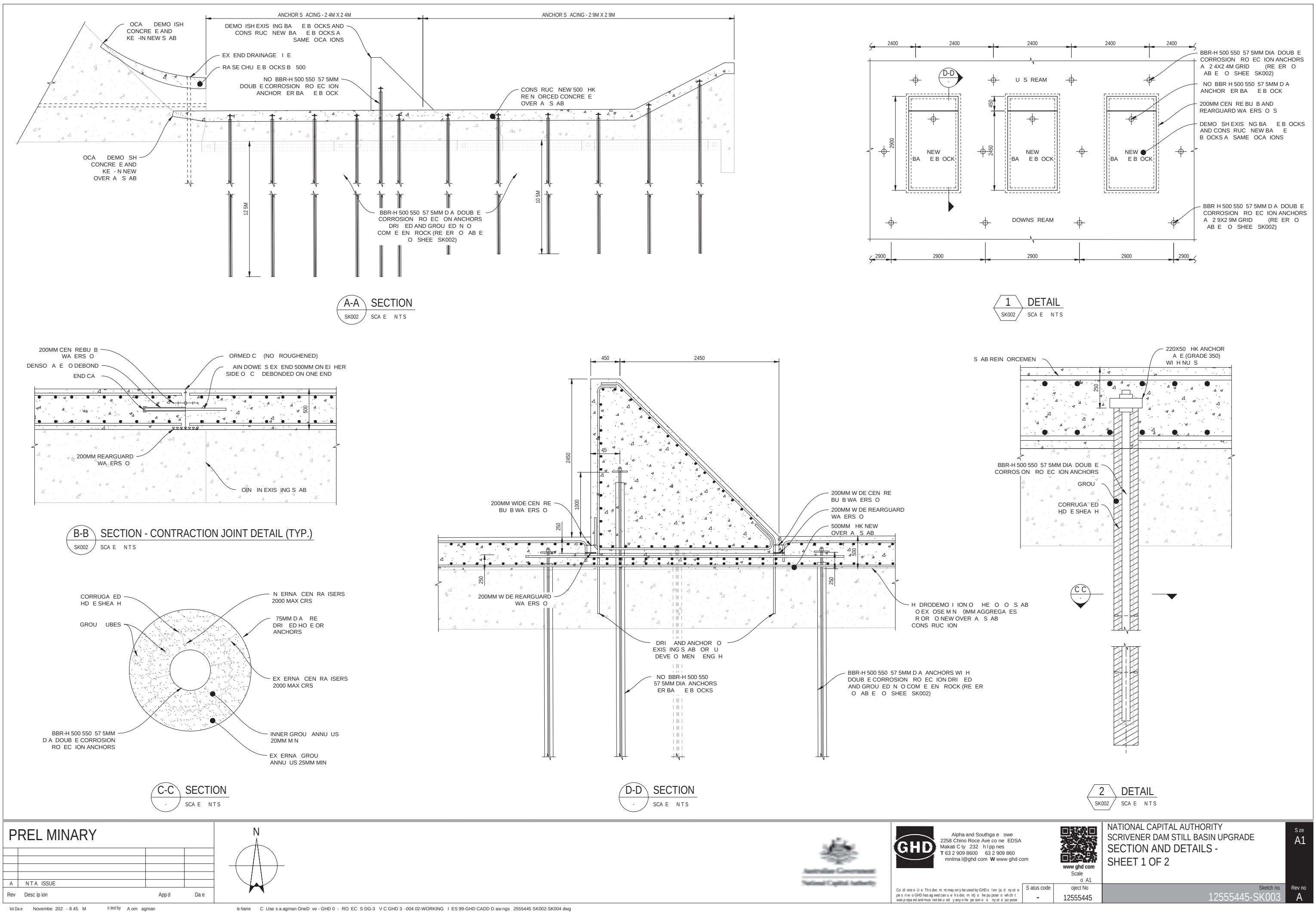
Size A1

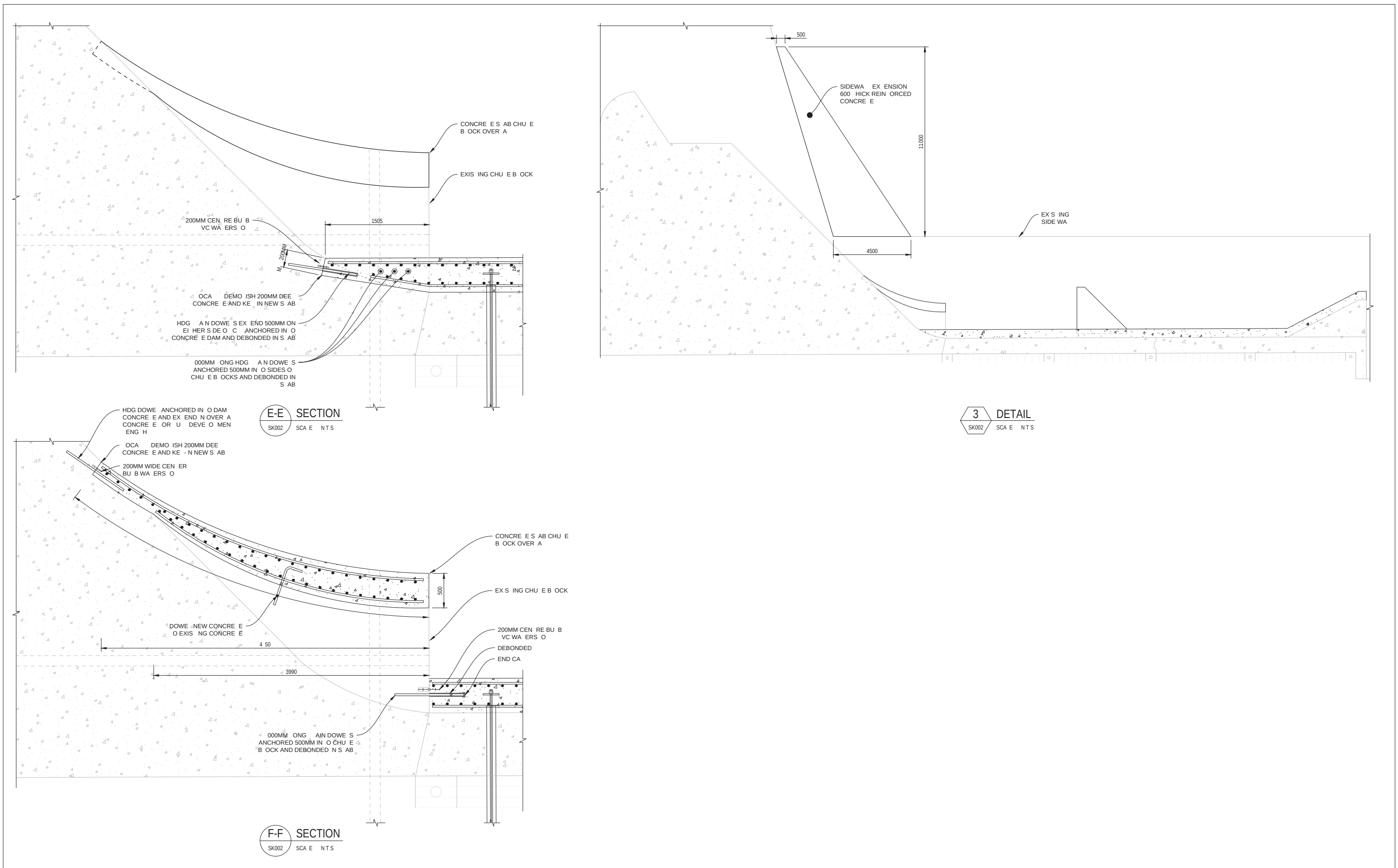
Project No 12555445

Sketch no 12555445-SK002-SK004

Rev no A

National Capital Authority—Scrivener Dam Dissipator Strengthening project
Submission 1 - Attachment 5





PREL MINARY

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mnlma l@ghd com W www ghd com

www.ghd.com

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NATIONAL CAPITAL AUTHORITY
SCRIVENER DAM STILL BASIN UPGRADE
SECTION AND DETAILS -
SHEET 2 OF 2

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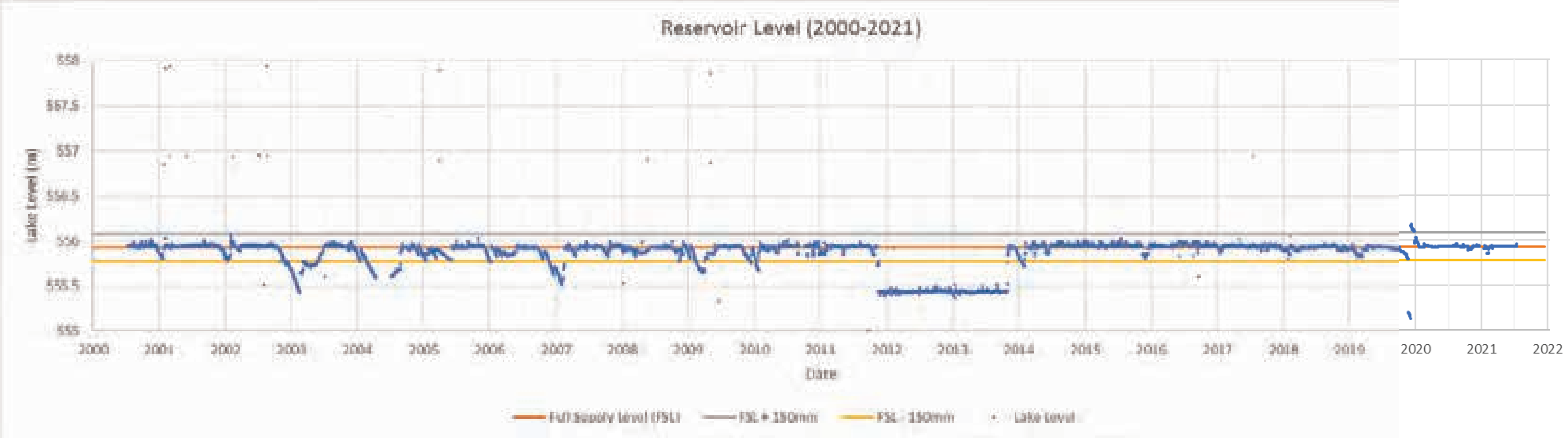
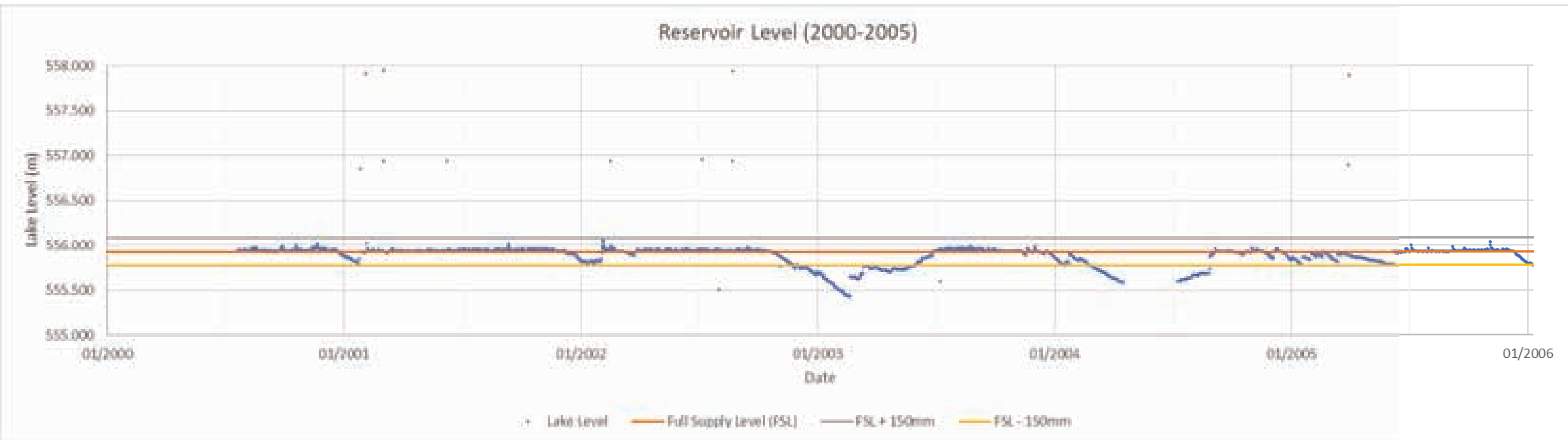
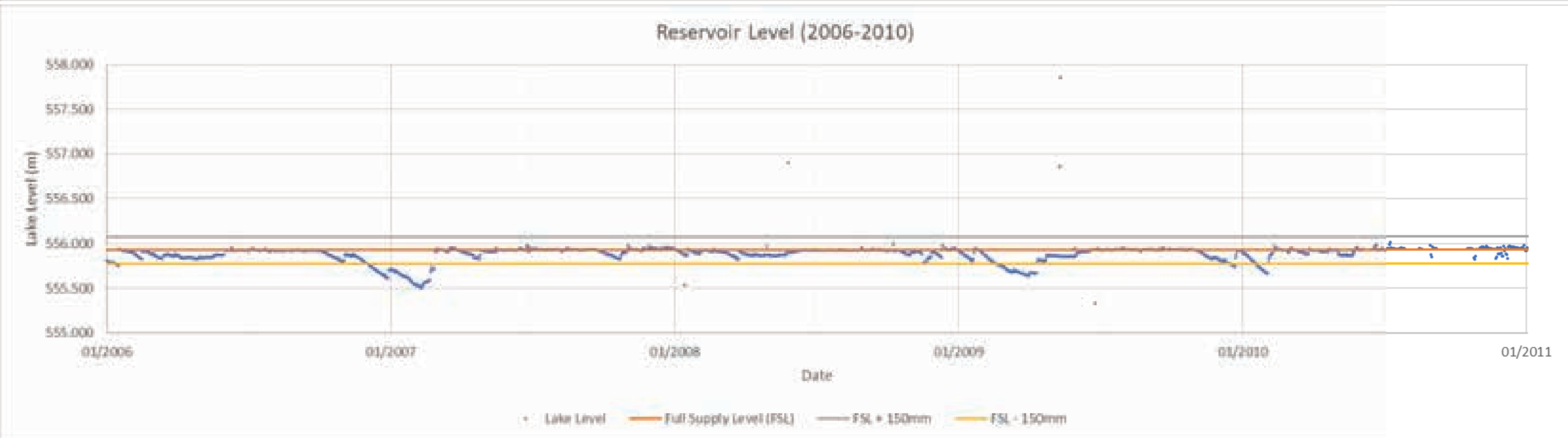
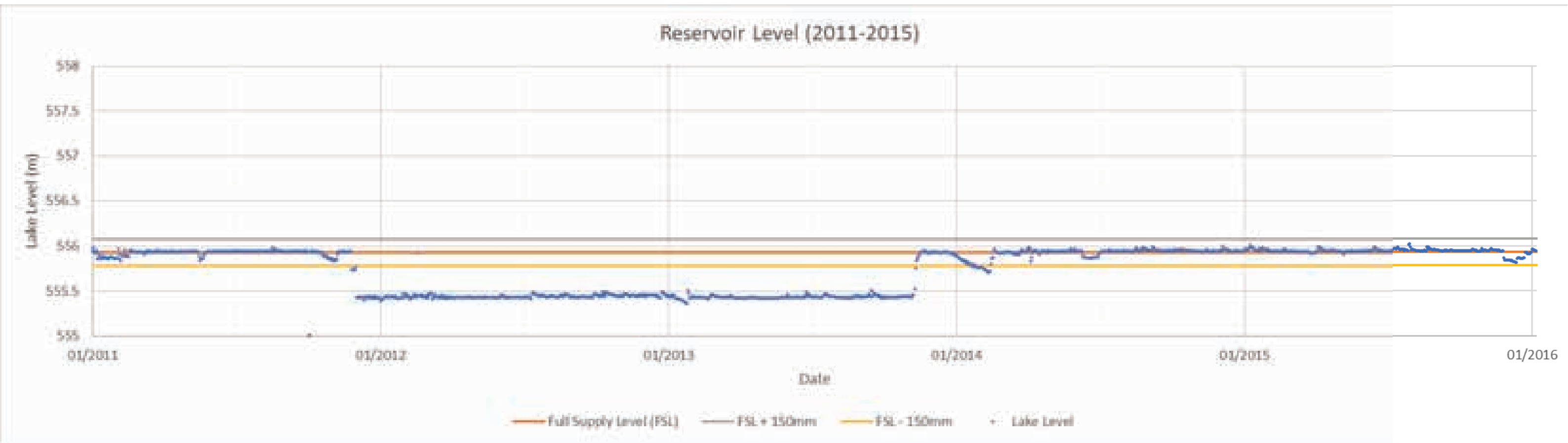
Appendix B

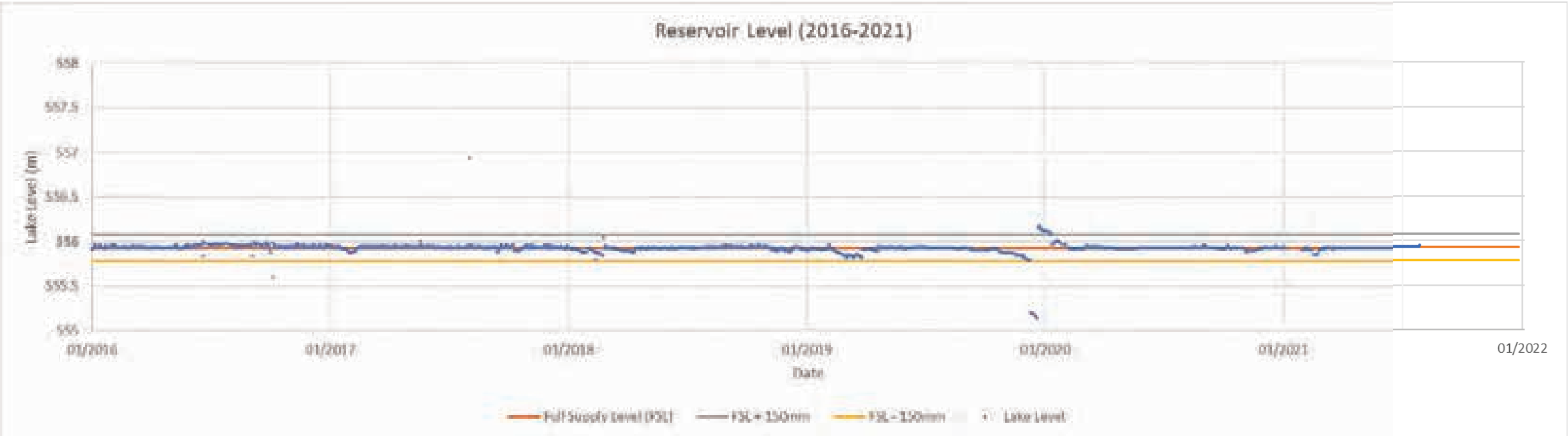
Construction Flood Hydrology

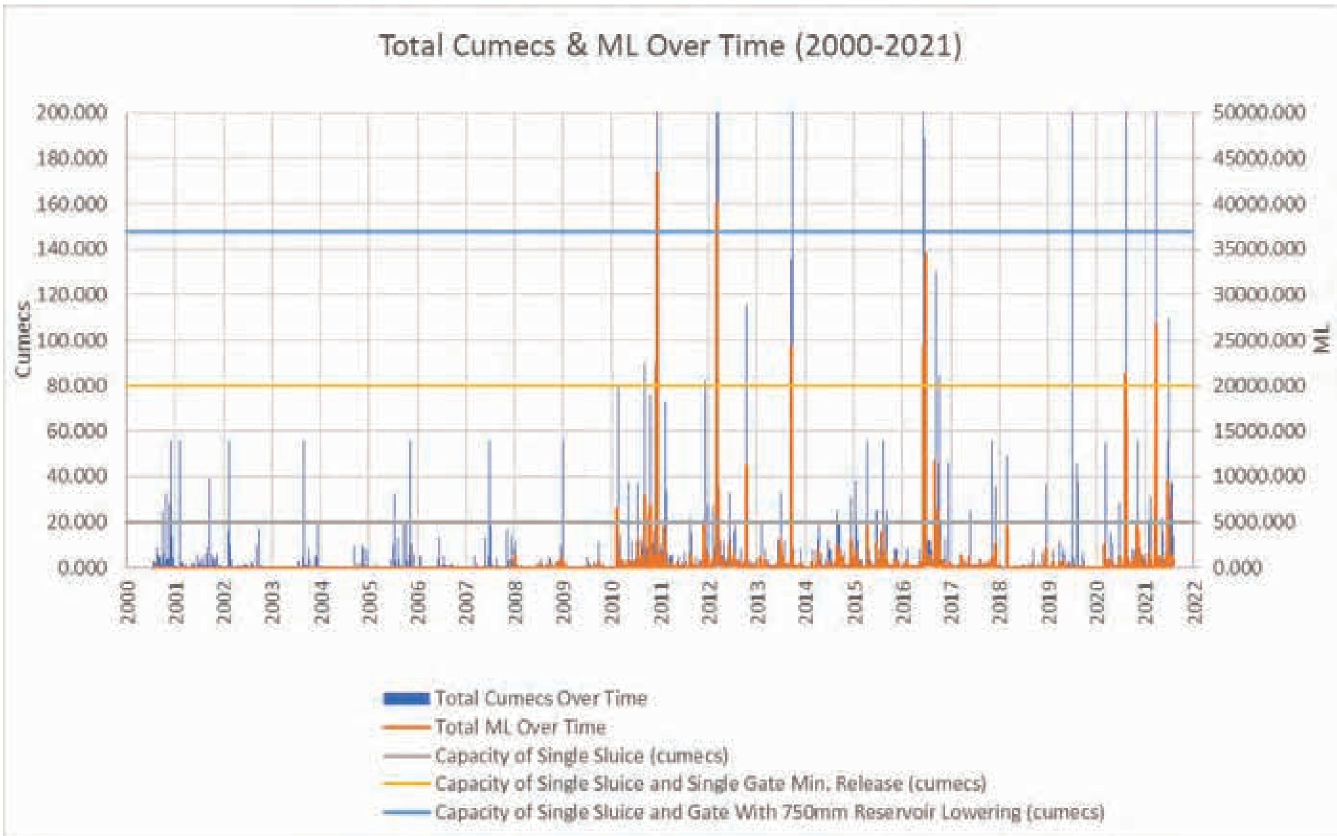

Reservoir Level (2000-2021)
Lake Level (m)
558
557.5
557
556.5
556
555.5
555
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Date
Full Supply Level (FSL)
FSL + 150mm
FSL - 150mm
Lake Level

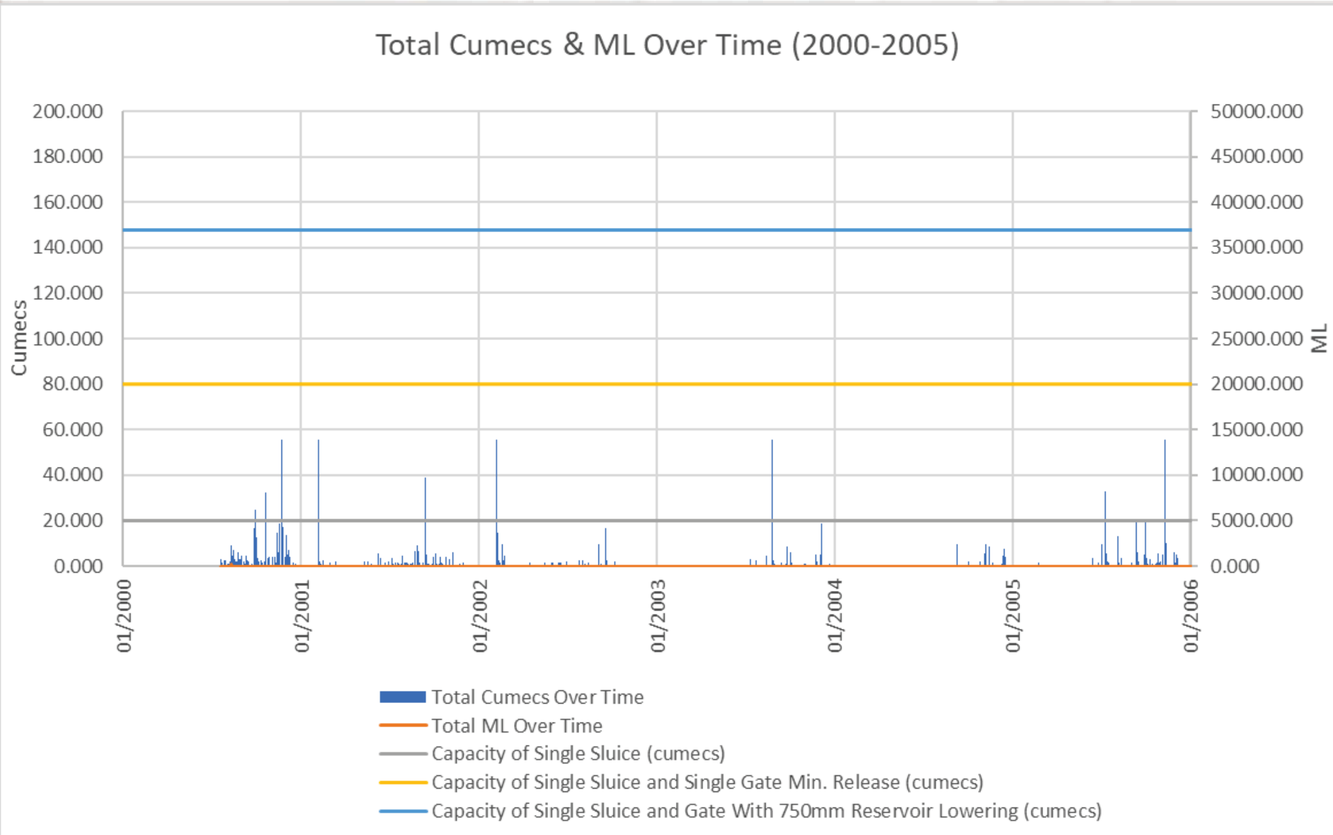

Reservoir Level (2000-2005)
Lake Level (m)
558.000
557.500
557.000
556.500
556.000
555.500
555.000
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
Date
Lake Level
Full Supply Level (FSL)
FSL + 150mm
FSL - 150mm

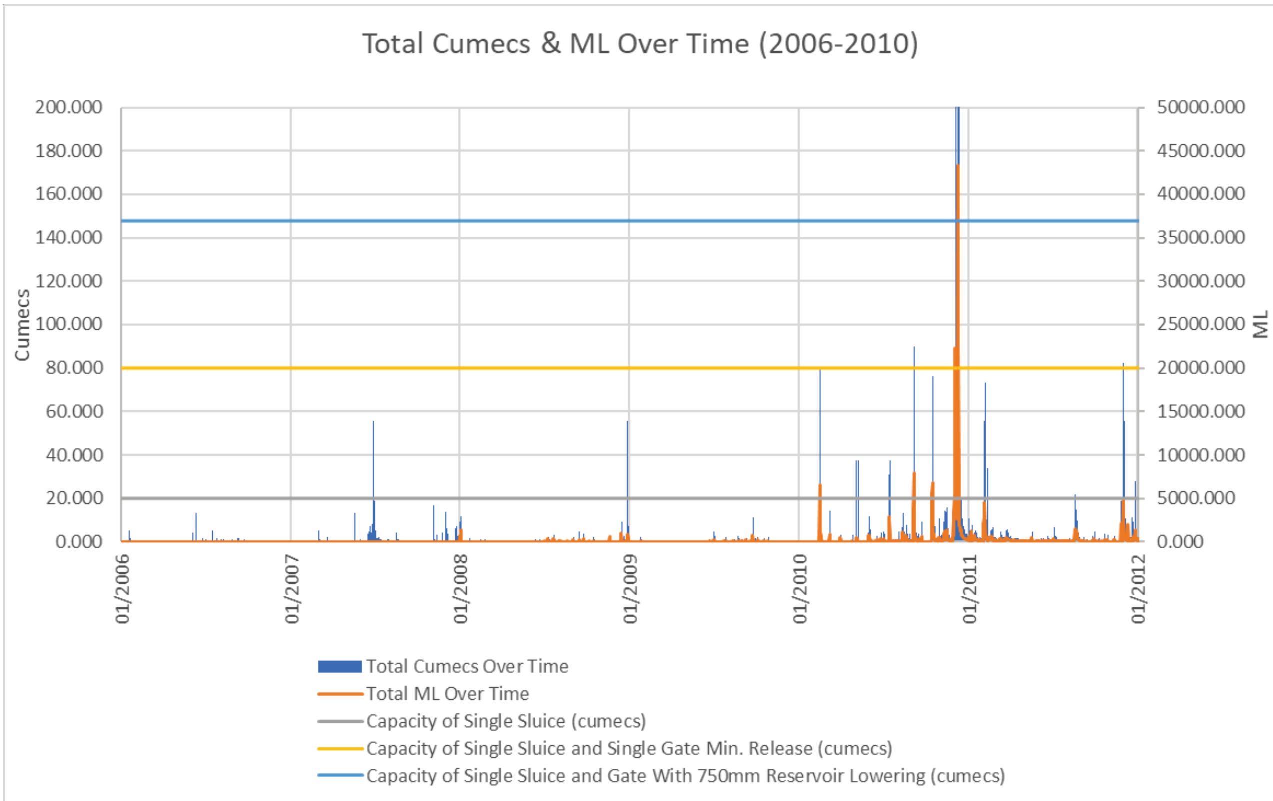

Reservoir Level (2006-2010)
Lake Level (m)
558.000
557.500
557.000
556.500
556.000
555.500
555.000
01/2006
01/2007
01/2008
01/2009
01/2010
01/2011
Date
Lake Level
Full Supply Level (FSL)
FSL + 150mm
FSL - 150mm

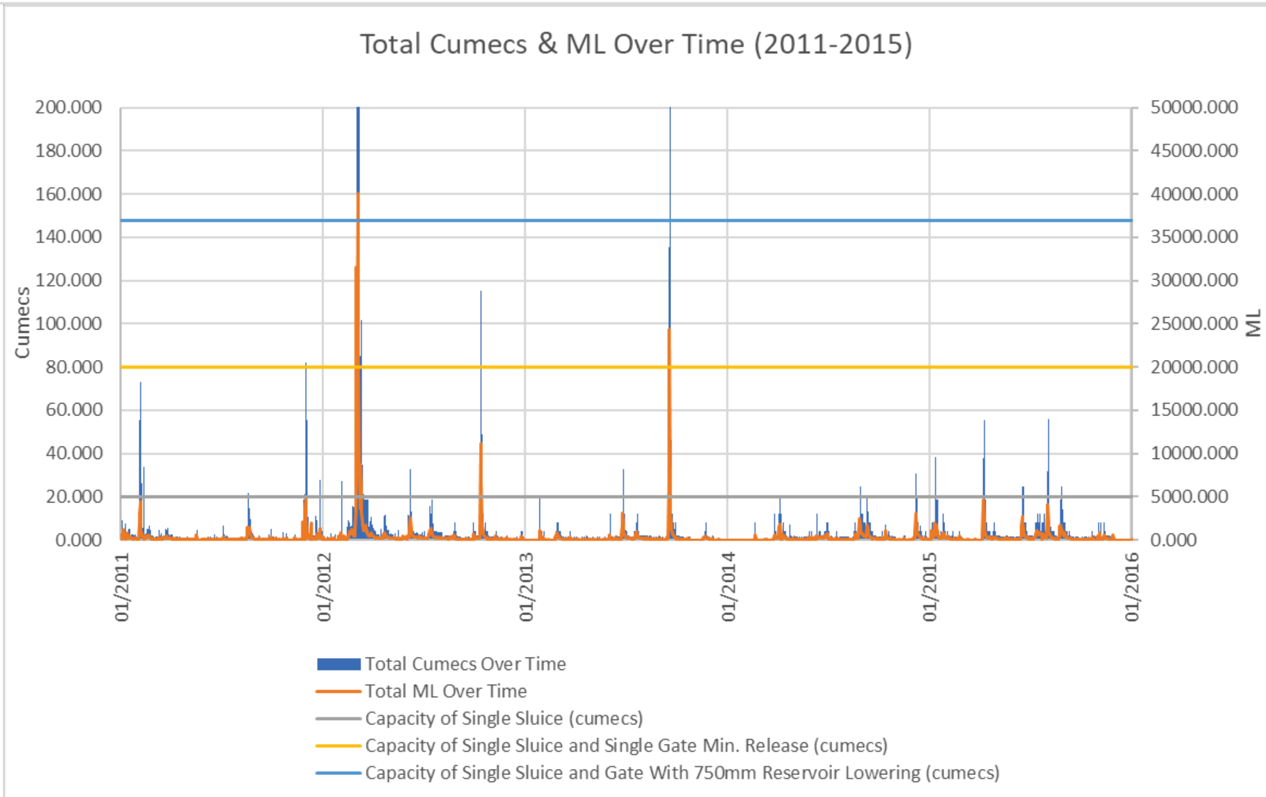

Reservoir Level (2011-2015)
Lake Level (m)
558
557.5
557
556.5
556
555.5
555
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
Date
Full Supply Level (FSL)
FSL + 150mm
FSL - 150mm
Lake Level

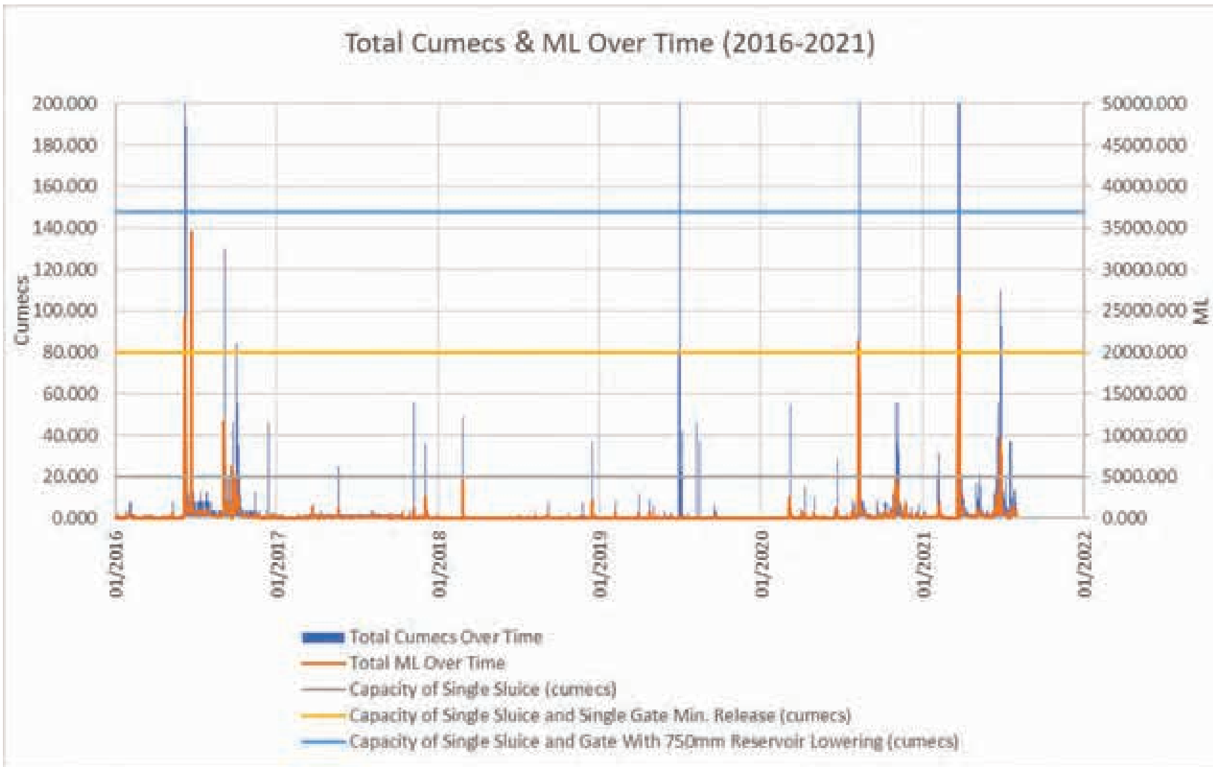

Reservoir Level (2016-2021)
Lake Level (m)
558
557.5
557
556.5
556
555.5
555
01/2016
01/2017
01/2018
01/2019
01/2020
01/2021
01/2022
Date
Full Supply Level (FSL)
FSL + 150mm
FSL - 150mm
Lake Level

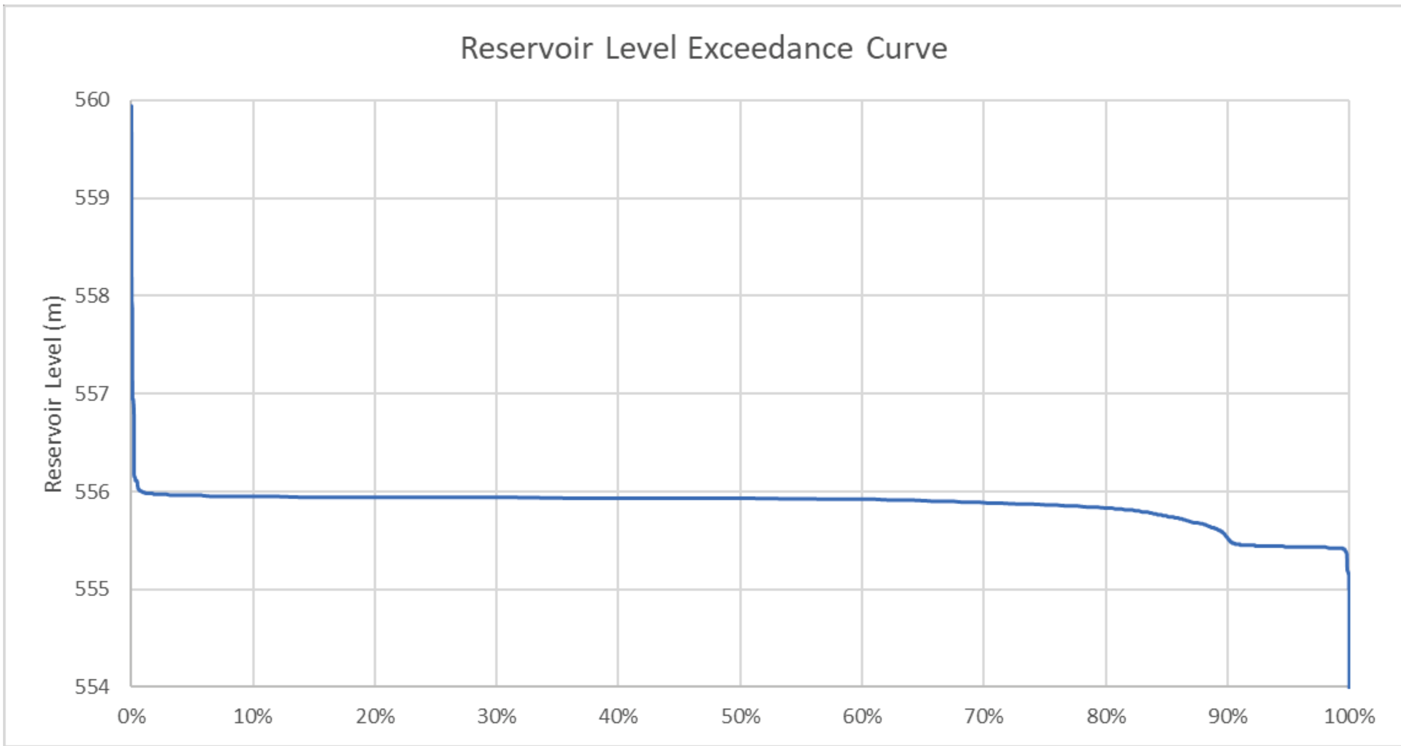

Total Cumecs & ML Over Time (2000-2021)
Cumecs
ML
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Total Cumecs Over Time
Total ML Over Time
Capacity of Single Sluice (cumecs)
Capacity of Single Sluice and Single Gate Min. Release (cumecs)
Capacity of Single Sluice and Gate With 750mm Reservoir Lowering (cumecs)

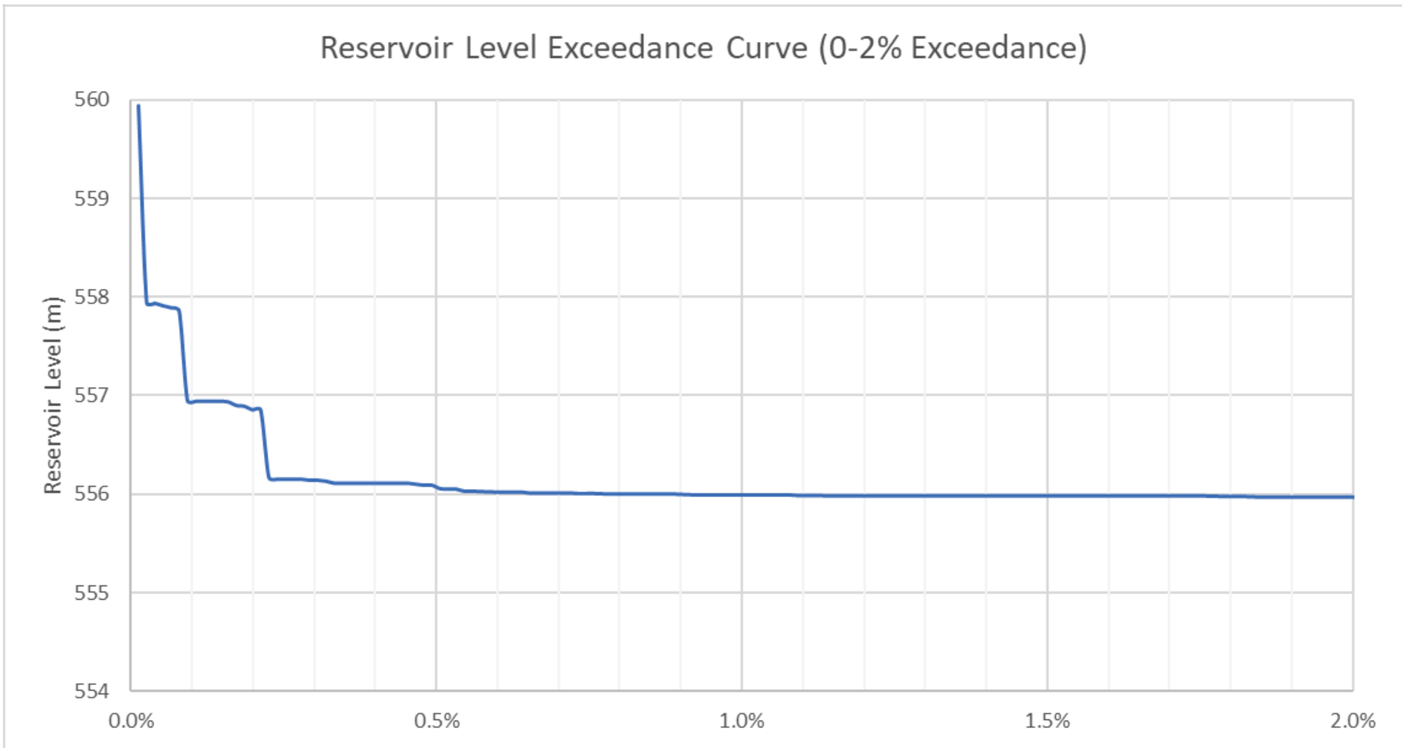

Total Cumecs & ML Over Time (2000-2005)
Cumecs
ML
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
01/2000
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006
Total Cumecs Over Time
Total ML Over Time
Capacity of Single Sluice (cumecs)
Capacity of Single Sluice and Single Gate Min. Release (cumecs)
Capacity of Single Sluice and Gate With 750mm Reservoir Lowering (cumecs)

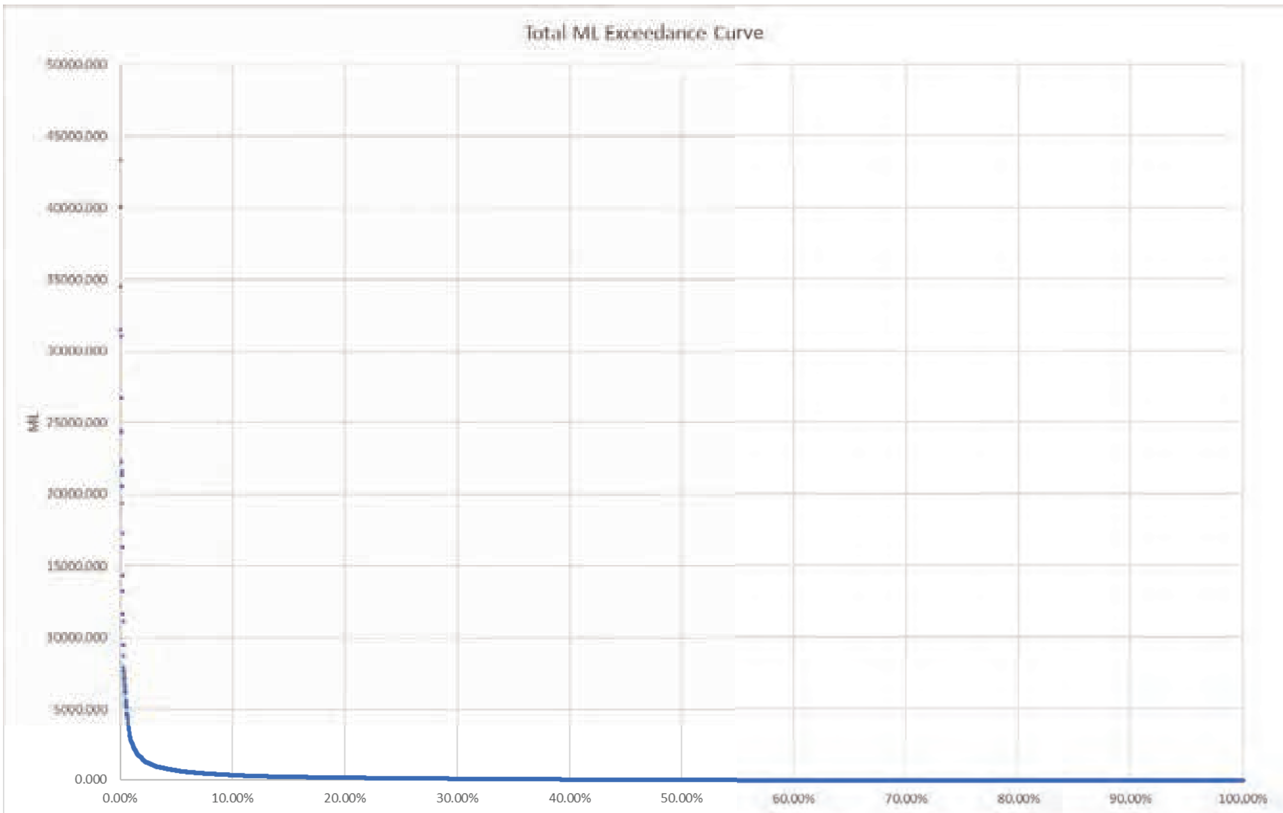

Total Cumecs & ML Over Time (2006-2010)
Cumecs
ML
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
01/2006
01/2007
01/2008
01/2009
01/2010
01/2011
01/2012
Total Cumecs Over Time
Total ML Over Time
Capacity of Single Sluice (cumecs)
Capacity of Single Sluice and Single Gate Min. Release (cumecs)
Capacity of Single Sluice and Gate With 750mm Reservoir Lowering (cumecs)

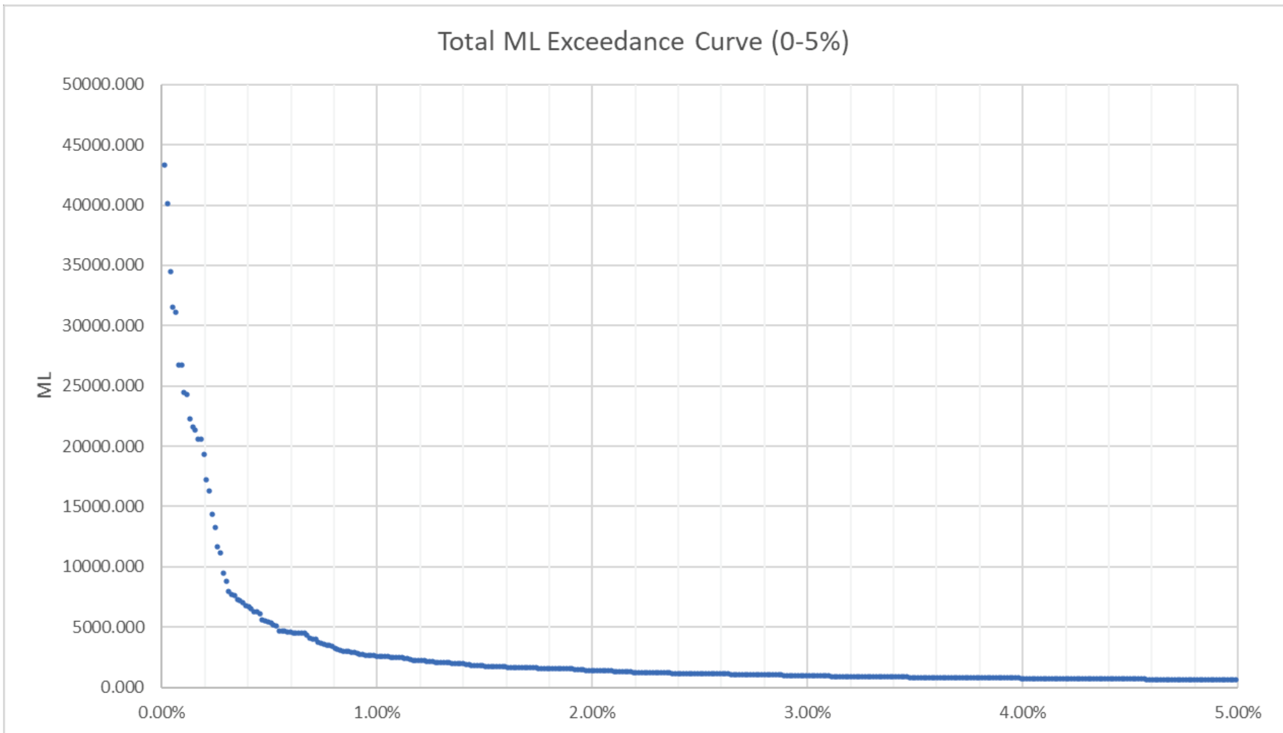

Total Cumecs & ML Over Time (2011-2015)
Cumecs
ML
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
Total Cumecs Over Time
Total ML Over Time
Capacity of Single Sluice (cumecs)
Capacity of Single Sluice and Single Gate Min. Release (cumecs)
Capacity of Single Sluice and Gate With 750mm Reservoir Lowering (cumecs)

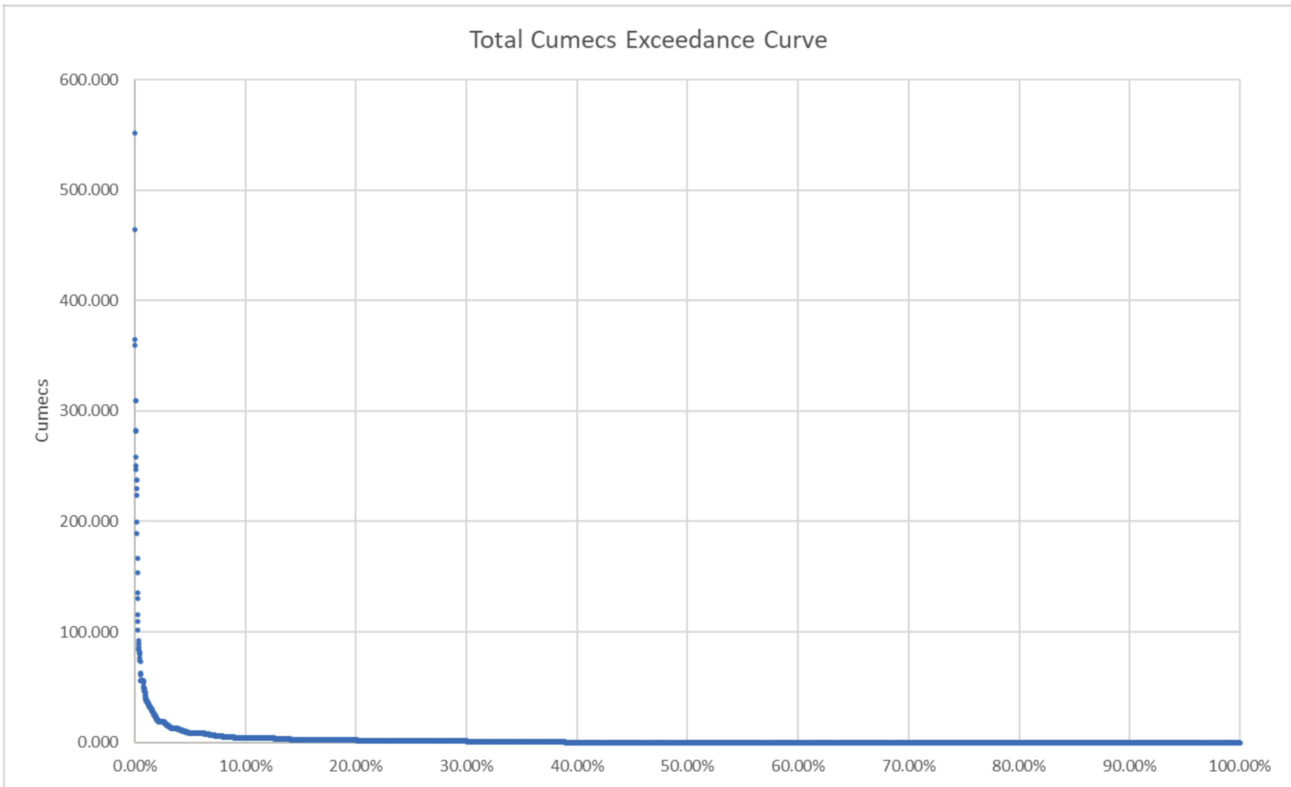

Total Cumecs & ML Over Time (2016-2021)
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
Cumecs
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
ML
01/2016
01/2017
01/2018
01/2019
01/2020
01/2021
01/2022
Total Cumecs Over Time
Total ML Over Time
Capacity of Single Sluice (cumecs)
Capacity of Single Sluice and Single Gate Min. Release (cumecs)
Capacity of Single Sluice and Gate With 750mm Reservoir Lowering (cumecs)

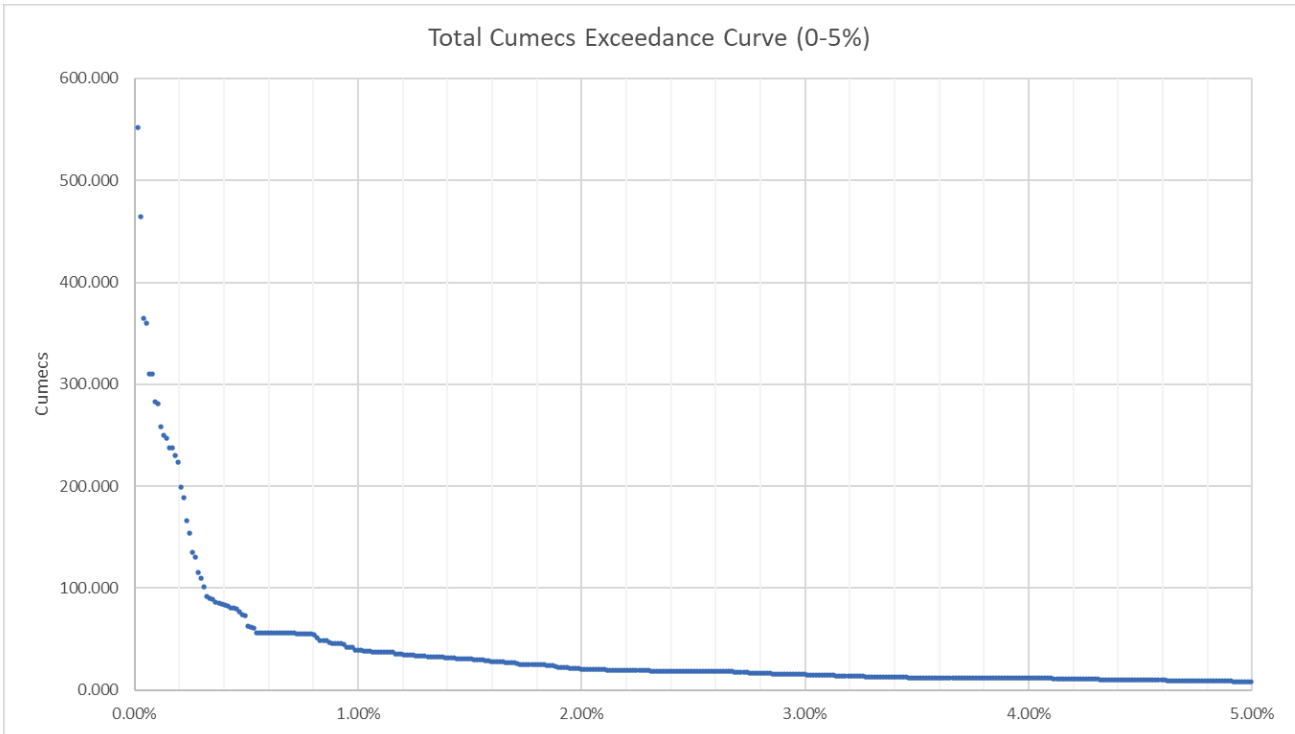

Reservoir Level Exceedance Curve
Reservoir Level (m)
560
559
558
557
556
555
554
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Reservoir Level Exceedance Curve (0-2% Exceedance)
Reservoir Level (m)
560
559
558
557
556
555
554
0.0%
0.5%
1.0%
1.5%
2.0%


Total ML Exceedance Curve
ML
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
80.00%
90.00%
100.00%


Total ML Exceedance Curve (0-5%)
ML
50000.000
45000.000
40000.000
35000.000
30000.000
25000.000
20000.000
15000.000
10000.000
5000.000
0.000
0.00%
1.00%
2.00%
3.00%
4.00%
5.00%


Total Cumecs Exceedance Curve
Cumecs
600.000
500.000
400.000
300.000
200.000
100.000
0.000
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
80.00%
90.00%
100.00%

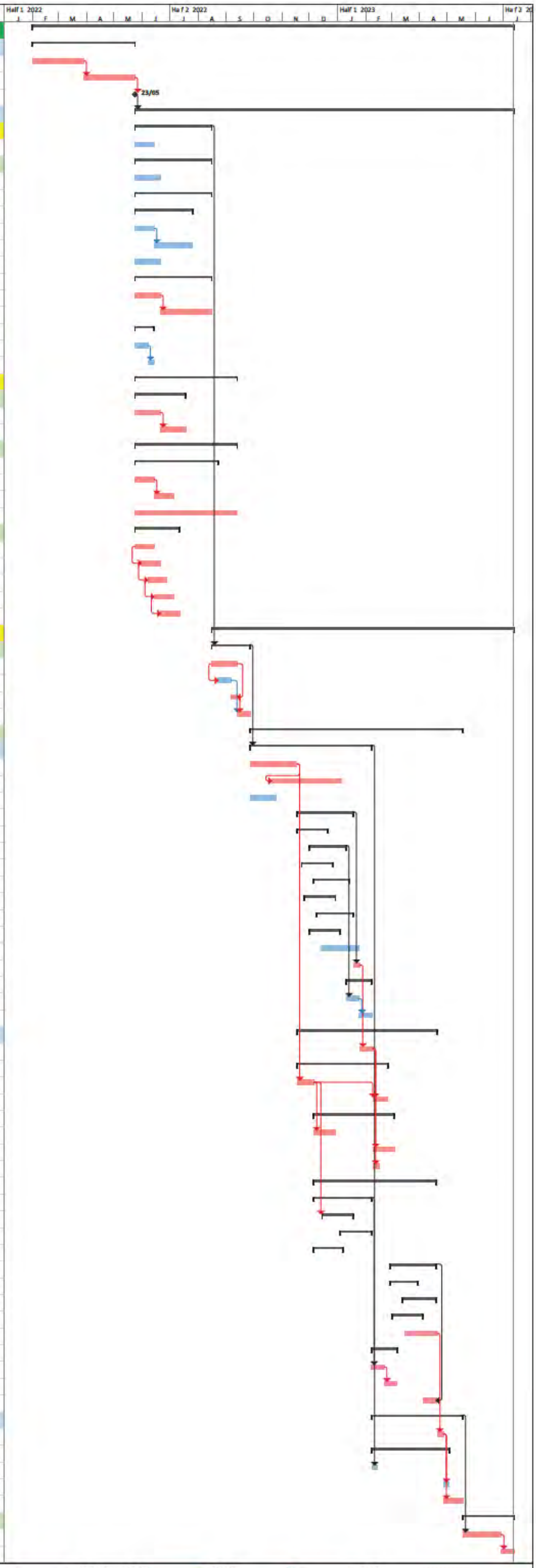

Total Cumecs Exceedance Curve (0-5%)
Cumecs
600.000
500.000
400.000
300.000
200.000
100.000
0.000
0.00%
1.00%
2.00%
3.00%
4.00%
5.00%

Appendix C

Construction Program

Summary Program

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Scrivener Dam Options Assessment**	**75.4 wks**	**Tue 1/02/22**	**Wed 12/07/23**	
2	**Tender**	**16 wks**	**Tue 1/02/22**	**Mon 23/05/22**	
3	Tender Period	40 days	Tue 1/02/22	Mon 28/03/22	
4	Assessment Period	40 days	Tue 29/03/22	Mon 23/05/22	3
5	Award	0 wks	Mon 23/05/22	Mon 23/05/22	4
6	**Project Delivery**	**59.4 wks**	**Tue 24/05/22**	**Wed 12/07/23**	5
7	**Prelims including management plans approvals etc**	**12 wks**	**Tue 24/05/22**	**Mon 15/08/22**	
8	Insurances and Securities - Including contract works (assume taken out by PC)	3 wks	Tue 24/05/22	Mon 13/06/22	
9	**Management Plans**	**12 wks**	**Tue 24/05/22**	**Mon 15/08/22**	
10	Project Management Plan	4 wks	Tue 24/05/22	Mon 20/06/22	
11	**Sub Plans**	**12 wks**	**Tue 24/05/22**	**Mon 15/08/22**	
12	**CEMP**	**9 wks**	**Tue 24/05/22**	**Mon 25/07/22**	
13	Development	3 wks	Tue 24/05/22	Mon 13/06/22	
14	Approval - Assume regulator approval	6 wks	Tue 14/06/22	Mon 25/07/22	13
15	Flood Management Plan	4 wks	Tue 24/05/22	Mon 20/06/22	
16	**Noise Management Plan**	**12 wks**	**Tue 24/05/22**	**Mon 15/08/22**	
17	Assessment and Mitigation Measures Development	4 wks	Tue 24/05/22	Mon 20/06/22	
18	Procurement of Noise Controls	8 wks	Tue 21/06/22	Mon 15/08/22	17
19	**Traffic Management**	**3 wks**	**Tue 24/05/22**	**Mon 13/06/22**	
20	Development	2 wks	Tue 24/05/22	Mon 6/06/22	
21	Approval	1 wk	Tue 7/06/22	Mon 13/06/22	20
22	**Procurement - Critical Items**	**16 wks**	**Tue 24/05/22**	**Mon 12/09/22**	
23	**Coffer Dam**	**8 wks**	**Tue 24/05/22**	**Mon 18/07/22**	
24	Design and approvals (Including Third Party Assessments)	4 wks	Tue 24/05/22	Mon 20/06/22	
25	Manufacture ready for Installation	4 wks	Tue 21/06/22	Mon 18/07/22	24
26	**Materials**	**16 wks**	**Tue 24/05/22**	**Mon 12/09/22**	
27	**Concrete**	**13 wks**	**Tue 24/05/22**	**Mon 22/08/22**	
30	Anchors Bars & Accessories	3 wks	Tue 24/05/22	Mon 13/06/22	
31	Reinforcement Bar	3 wks	Tue 14/06/22	Mon 4/07/22	30
32	Waterstop	16 wks	Tue 24/05/22	Mon 12/09/22	
33	**Key Subcontractors**	**7 wks**	**Tue 24/05/22**	**Mon 11/07/22**	
34	Site Craneage	3 wks	Tue 24/05/22	Mon 13/06/22	
35	Anchor Installations	3 wks	Tue 31/05/22	Mon 20/06/22	34SS 1 wk
36	Concrete Works - Form Reo Pour	3 wks	Tue 7/06/22	Mon 27/06/22	35SS 1 wk
37	Temporary Works Engineer	3 wks	Tue 14/06/22	Mon 4/07/22	36SS 1 wk
38	Demolition Works	3 wks	Tue 21/06/22	Mon 11/07/22	37SS 1 wk
39	**Onsite Works**	**47.4 wks**	**Tue 16/08/22**	**Wed 12/07/23**	
40	Site Estab ishment	6 wks	Tue 16/08/22	Mon 26/09/22	7
41	Site Compound Access Road Environmental Controls	4 wks	Tue 16/08/22	Mon 12/09/22	
42	Dewatering of Downstream Stil ing and River	2 wks	Tue 23/08/22	Mon 5/09/22	41SS 1 wk
43	Craneage Setup including tower cranes and material storage areas	1 wk	Tue 6/09/22	Mon 12/09/22	41FF
44	Coffer Dam Setup - Left Abutment Protection	2 wks	Tue 13/09/22	Mon 26/09/22	42 43
45	**Spillway Construction**	**33.4 wks**	**Tue 27/09/22**	**Wed 17/05/23**	
46	**Stage 1: LH Abutment**	**19.1 wks**	**Tue 27/09/22**	**Tue 7/02/23**	40
47	Anchors: 4000l.m @ 100l.m/day/rig x 2 rigs - including allowance for grout & redr ils	7.5 wks	Tue 27/09/22	Thu 17/11/22	
48	Baffle Extension: 32 Items. Scabble Reo including Dowels Pour - Allow 5 days for 3 items	11 wks	Thu 20/10/22	Thu 5/01/23	47FS-4 wks
49	Under slab Drainage Adjustment - Allowance	4 wks	Tue 27/09/22	Mon 24/10/22	
50	**Slab Construction**	**8.8 wks**	**Thu 17/11/22**	**Wed 18/01/23**	
51	**Slab 1**	**4.8 wks**	**Thu 17/11/22**	**Wed 21/12/22**	
57	**Slab 2**	**5.8 wks**	**Wed 30/11/22**	**Tue 10/01/23**	
63	**Slab 3**	**4.8 wks**	**Tue 22/11/22**	**Mon 26/12/22**	
69	**Slab 4**	**5.8 wks**	**Mon 5/12/22**	**Fri 13/01/23**	
75	**Slab 5 & 6**	**4.8 wks**	**Fri 25/11/22**	**Thu 29/12/22**	
81	**Slab 7**	**5.8 wks**	**Thu 8/12/22**	**Wed 18/01/23**	
87	**Slab 8**	**4.8 wks**	**Wed 30/11/22**	**Tue 3/01/23**	
93	Chute Block Adjustments - 24 Items - Allow 4 per week	6 wks	Tue 13/12/22	Tue 24/01/23	55SS 1 wk
94	Misc. Works and Defect Management	1 wk	Wed 18/01/23	Wed 25/01/23	50
95	**Rip Rap Rock Protection to Abutment Wall**	**4 wks**	**Tue 10/01/23**	**Tue 7/02/23**	
96	Concrete works to existing accessway	10 days	Tue 10/01/23	Tue 24/01/23	57
97	Rip Rap Placement	2 wks	Tue 24/01/23	Tue 7/02/23	96
98	**Stage 2: RH Abutment**	**21.9 wks**	**Thu 17/11/22**	**Wed 19/04/23**	
99	Coffer Dam Switch - Protection of Right Abutment Including pump down	2 wks	Wed 25/01/23	Wed 8/02/23	94
100	**Anchors: 4000l.m @ 80l.m/day/rig x 2 rigs**	**14.3 wks**	**Thu 17/11/22**	**Fri 24/02/23**	
101	Early Start on Upper Level: 2000 l.m	2.5 wks	Thu 17/11/22	Mon 5/12/22	47
102	Lower Level: 2000 l m	2.5 wks	Wed 8/02/23	Fri 24/02/23	99 101
103	**Baffle Extension: 21 Items. Scabble, Reo including Dowels, Pour - Allow 5 days for 3 items**	**12.8 wks**	**Tue 6/12/22**	**Fri 3/03/23**	
104	Early Start on Upper Level: 10 Items	3.5 wks	Tue 6/12/22	Thu 29/12/22	101
105	Lower Level: 11 Items	3.5 wks	Wed 8/02/23	Fri 3/03/23	99
106	Under slab Drainage Adjustment - Allowance	1 wk	Wed 8/02/23	Wed 15/02/23	99
107	**Slab Construction**	**19.2 wks**	**Tue 6/12/22**	**Tue 18/04/23**	
108	**Early Start on Upper Level**	**9 wks**	**Tue 6/12/22**	**Mon 6/02/23**	
109	**Slab 12**	**4.8 wks**	**Thu 15/12/22**	**Tue 17/01/23**	101
115	**Slab 13**	**4.8 wks**	**Wed 4/01/23**	**Mon 6/02/23**	
121	**Slab 14**	**4.8 wks**	**Tue 6/12/22**	**Fri 6/01/23**	
127	**Lower Level**	**7.4 wks**	**Mon 27/02/23**	**Tue 18/04/23**	
128	**Slab 9**	**4.6 wks**	**Mon 27/02/23**	**Wed 29/03/23**	
134	**Slab 10**	**5.4 wks**	**Mon 13/03/23**	**Tue 18/04/23**	
140	**Slab 11**	**4.6 wks**	**Thu 2/03/23**	**Mon 3/04/23**	
146	Chute Block Adjustments - 20 Items - Allow 4 per week	5 wks	Thu 16/03/23	Wed 19/04/23	132
147	**Rip Rap Rock Protection to Abutment Wall**	**4 wks**	**Tue 7/02/23**	**Mon 6/03/23**	
148	Concrete works to existing accessway	10 days	Tue 7/02/23	Mon 20/02/23	108
149	Rip Rap Placement	2 wks	Tue 21/02/23	Mon 6/03/23	148
150	Misc. Works and Defect Management	2 wks	Wed 5/04/23	Tue 18/04/23	127FF
151	**Site Demob**	**14.3 wks**	**Tue 7/02/23**	**Wed 17/05/23**	
152	Coffer Dam Removal	1 wk	Thu 20/04/23	Wed 26/04/23	146
153	**Tower Crane Removal**	**12.1 wks**	**Tue 7/02/23**	**Tue 2/05/23**	
154	TC1	4 days	Tue 7/02/23	Mon 13/02/23	46
155	TC2	4 days	Thu 27/04/23	Tue 2/05/23	152
156	Access Roads Compound Etc	3 wks	Thu 27/04/23	Wed 17/05/23	152
157	**Contingency and Risk Allowance**	**8 wks**	**Thu 18/05/23**	**Wed 12/07/23**	
158	Inclement Weather Impacts - Rain Wind (Unable to operator cranes etc): 40 weeks x 15%	6 wks	Thu 18/05/23	Wed 28/06/23	151
159	Scheduling Conf ict Contingency: 40 Weeks x 5%	2 wks	Thu 29/06/23	Wed 12/07/23	158



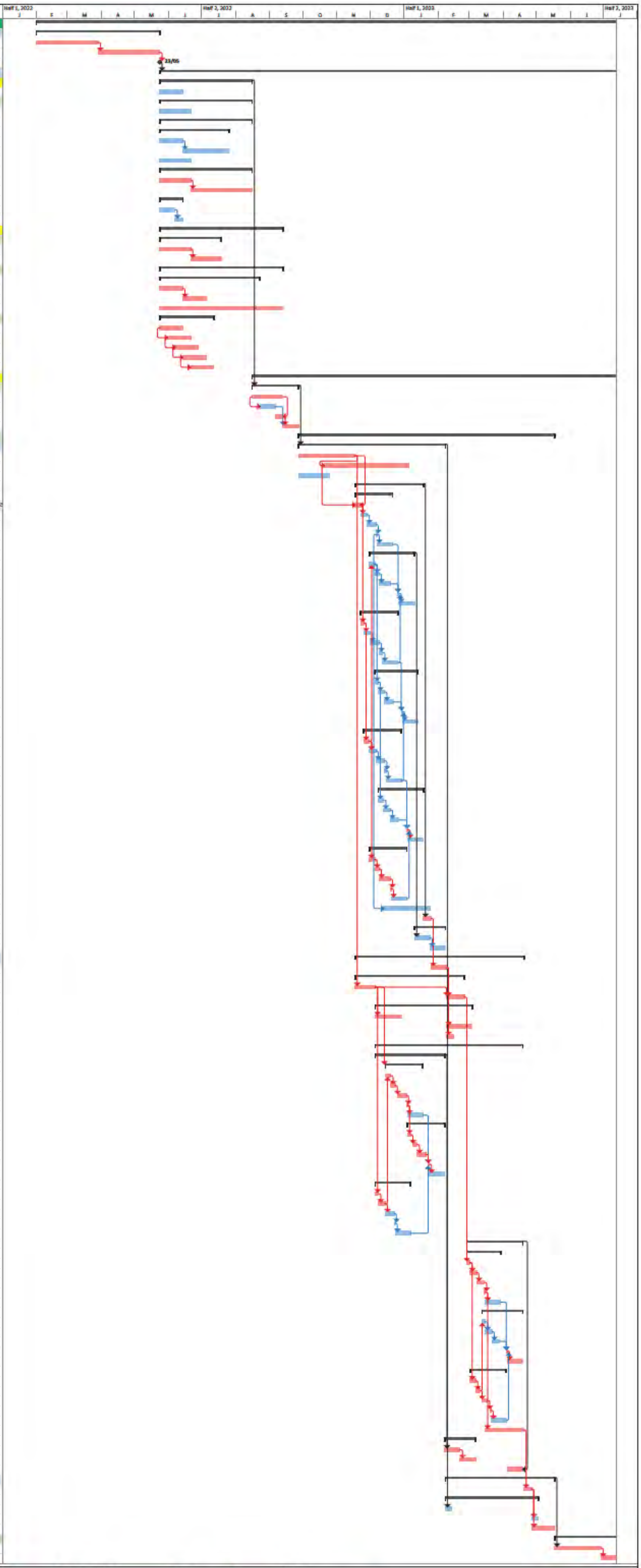
Project: msproj11
Date: Wed 20/10/21

Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Critical, Critical Split, Progress, Manual Progress

Detailed Program

National Capital Authority—Scrivener Dam Dissipator Strengthening project
Submission 1 - Attachment 5

ID	Task Name	Du at on	ta t	F n sh	P edecesso s
1	**Scr vener Dam Opt onal Assessment**	**5 4 wks**	**ue 1/02/22**	**Wed 12/07/23**	
2	**Tender**	**6 wks**	**ue 1/02/22**	**Mon 23/05/22**	
3	Tende Pe od	0 days	ue 1/02/22	Mon 28/03/22	
4	Assessment Pe od	0 days	ue 29/03/22	Mon 23/05/22	3
5	Awa d	wks	Mon 23/05/22	Mon 23/05/22	4
6	**Pro ect Delivery**	**9 4 wks**	**ue 24/05/22**	**Wed 12/07/23**	5
7	**Prelims Includ ng management plans approvals etc**	**2 wks**	**ue 24/05/22**	**Mon 15/08/22**	
8	Insu ances and Secu t es - nclud ng cont act wo ks (assume taken out by PC)	wks	ue 24/05/22	Mon 13/06/22	
9	**Management Plans**	**2 wks**	**ue 24/05/22**	**Mon 15/08/22**	
10	P oject Management Plan	wks	ue 24/05/22	Mon 20/06/22	
11	**Sub Plans**	**2 wks**	**ue 24/05/22**	**Mon 15/08/22**	
12	**CEMP**	**wks**	**ue 24/05/22**	**Mon 25/07/22**	
13	Development	wks	ue 24/05/22	Mon 13/06/22	
14	App oval - Assume egulato app oval	wks	ue 14/06/22	Mon 25/07/22	13
15	Flood Management Plan	wks	ue 24/05/22	Mon 20/06/22	
16	**Noise Management Plan**	**2 wks**	**ue 24/05/22**	**Mon 15/08/22**	
17	Assessment and M t gat on Measu es Development	wks	ue 24/05/22	Mon 20/06/22	
18	P ocu ement of No se Cont ols	wks	ue 21/06/22	Mon 15/08/22	17
19	**Traffic Management**	**wks**	**ue 24/05/22**	**Mon 13/06/22**	
20	Development	wks	ue 24/05/22	Mon 6/06/22	
21	App oval	wk	ue 7/06/22	Mon 13/06/22	20
22	**Procurement - Cr t cal tems**	**6 wks**	**ue 24/05/22**	**Mon 12/09/22**	
23	**Coffer Dam**	**wks**	**ue 24/05/22**	**Mon 18/07/22**	
24	Des gn and app ovals (Includ ng Th d Pa ty Assessments)	wks	ue 24/05/22	Mon 20/06/22	
25	Manufactu e eady fo nsta lat on	wks	ue 21/06/22	Mon 18/07/22	24
26	**Mater als**	**6 wks**	**ue 24/05/22**	**Mon 12/09/22**	
27	**Concrete**	**3 wks**	**ue 24/05/22**	**Mon 22/08/22**	
30	Ancho s Ba s & Accesso es	wks	ue 24/05/22	Mon 13/06/22	
31	Re nfo cement Ba	wks	ue 14/06/22	Mon 4/07/22	30
32	Wate stop	6 wks	ue 24/05/22	Mon 12/09/22	
33	**Key Subcontractors**	**wks**	**ue 24/05/22**	**Mon 11/07/22**	
34	S te C aneage	wks	ue 24/05/22	Mon 13/06/22	
35	Ancho installat ons	wks	ue 31/05/22	Mon 20/06/22	34SS 1 wk
36	Conc ete Wo ks - Fo m, Reo, Pou	wks	ue 7/06/22	Mon 27/06/22	35SS 1 wk
37	Tempo a y Wo ks Eng nee	wks	ue 14/06/22	Mon 4/07/22	36SS 1 wk
38	Demol t on Wo ks	wks	ue 21/06/22	Mon 11/07/22	37SS 1 wk
39	**Onsite Works**	**7 4 wks**	**ue 16/08/22**	**Wed 12/07/23**	
40	S te Establ shment	wks	ue 16/08/22	Mon 26/09/22	7
41	S te Compound, Access Road, Env onmental Cont ols	wks	ue 16/08/22	Mon 12/09/22	
42	Dewate ng of Downst eam St ll ng and R ve	wks	ue 23/08/22	Mon 5/09/22	41SS 1 wk
43	C aneage Setup nclud ng towe c anes and mate al sto age a eas	wk	ue 6/09/22	Mon 12/09/22	41FF
44	Coffe Dam Setup - Left Abutment P otect on	wks	ue 13/09/22	Mon 26/09/22	42,43
45	**Sp llway Construct on**	**3 4 wks**	**ue 27/09/22**	**Wed 17/05/23**	
46	**Stage 1 LH Abutment**	**9 1 wks**	**ue 27/09/22**	**Tue 7/02/23**	40
47	Ancho s 4000Lm @ 100Lm/day/ g x 2 gs - nclud ng a lowance fo g out & ed lls	.5 wks	ue 27/09/22	Thu 17/11/22	
48	Baffle Extens on 32 tems. Scabble, Reo nclud ng Dowels, Pou - Allow 5 days fo 3 tems	1 wks	hu 20/10/22	Thu 5/01/23	47FS-4 wks
49	Unde slab D a nage Adjustment - Allowance	wks	ue 27/09/22	Mon 24/10/22	
50	**Slab Construction**	**.8 wks**	**hu 17/11/22**	**Wed 18/01/23**	
51	**Slab 1**	**.8 wks**	**hu 17/11/22**	**Wed 21/12/22**	
52	P ep U/S Jo nt nclud ng wate stop	days	hu 17/11/22	Tue 22/11/22	47FF-2 wks,48
53	Scabble Ex t ng Su face & Fo m	days	ue 22/11/22	Mon 28/11/22	52
54	Re nfo cement, Includ ng T e ng nto ancho s	days	Mon 28/11/22	Tue 6/12/22	53
55	Place Conc ete	day	ue 6/12/22	Wed 7/12/22	54
56	Cu e	4 edays	Wed 7/12/22	Wed 21/12/22	55
57	**Slab 2**	**.8 wks**	**Wed 30/11/22**	**Tue 10/01/23**	
58	P ep U/S Jo nt nclud ng wate stop	days	Wed 30/11/22	Mon 5/12/22	76
59	Scabble Ex t ng Su face & Fo m	days	Mon 5/12/22	F 9/12/22	58
60	Re nfo cement, Includ ng T e ng nto ancho s	days	9/12/22	Mon 19/12/22	59
61	Place Conc ete	day	Mon 26/12/22	Tue 27/12/22	60,56,68
62	Cu e	4 edays	ue 27/12/22	Tue 10/01/23	61
63	**Slab 3**	**.8 wks**	**ue 22/11/22**	**Mon 26/12/22**	
64	P ep U/S Jo nt nclud ng wate stop	days	ue 22/11/22	F 25/11/22	52
65	Scabble Ex t ng Su face & Fo m	days	25/11/22	Thu 1/12/22	64
66	Re nfo cement, Includ ng T e ng nto ancho s	days	hu 1/12/22	F 9/12/22	65
67	Place Conc ete	day	9/12/22	Mon 12/12/22	66
68	Cu e	4 edays	Mon 12/12/22	Mon 26/12/22	67
69	**Slab 4**	**.8 wks**	**Mon 5/12/22**	**Fri 13/01/23**	
70	P ep U/S Jo nt nclud ng wate stop	days	Mon 5/12/22	Thu 8/12/22	58
71	Scabble Ex t ng Su face & Fo m	days	hu 8/12/22	Wed 14/12/22	70
72	Re nfo cement, Includ ng T e ng nto ancho s	days	Wed 14/12/22	Thu 22/12/22	71
73	Place Conc ete	day	hu 29/12/22	F 30/12/22	72,68,80
74	Cu e	4 edays	30/12/22	F 13/01/23	73
75	**Slab 5 & 6**	**.8 wks**	**ri 25/11/22**	**Thu 29/12/22**	
76	P ep U/S Jo nt nclud ng wate stop	days	25/11/22	Wed 30/11/22	64
77	Scabble Ex t ng Su face & Fo m	days	Wed 30/11/22	Tue 6/12/22	76
78	Re nfo cement, Includ ng T e ng nto ancho s	days	ue 6/12/22	Wed 14/12/22	77
79	Place Conc ete	day	Wed 14/12/22	Thu 15/12/22	78
80	Cu e	4 edays	hu 15/12/22	Thu 29/12/22	79
81	**Slab 7**	**.8 wks**	**hu 8/12/22**	**Wed 18/01/23**	
82	P ep U/S Jo nt nclud ng wate stop	days	hu 8/12/22	Tue 13/12/22	70
83	Scabble Ex t ng Su face & Fo m	days	ue 13/12/22	Mon 19/12/22	82
84	Re nfo cement, Includ ng T e ng nto ancho s	days	Mon 19/12/22	Tue 27/12/22	83
85	Place Conc ete	day	ue 3/01/23	Wed 4/01/23	84,80,92
86	Cu e	4 edays	Wed 4/01/23	Wed 18/01/23	85
87	**Slab 8**	**.8 wks**	**Wed 30/11/22**	**Tue 3/01/23**	
88	P ep U/S Jo nt nclud ng wate stop	days	Wed 30/11/22	Mon 5/12/22	76
89	Scabble Ex t ng Su face & Fo m	days	Mon 5/12/22	F 9/12/22	88
90	Re nfo cement, Includ ng T e ng nto ancho s	days	9/12/22	Mon 19/12/22	89
91	Place Conc ete	day	Mon 19/12/22	Tue 20/12/22	90
92	Cu e	4 edays	ue 20/12/22	Tue 3/01/23	91
93	Chute Block Adjustments - 24 tems - A low 4 pe week	wks	ue 13/12/22	Tue 24/01/23	55SS 1 wk
94	M sc. Wo ks and Defect Management	wk	Wed 18/01/23	Wed 25/01/23	50
95	**Rip Rap Rock Protection to Abutment Wall**	**wks**	**ue 10/01/23**	**Tue 7/02/23**	
96	Conc ete wo ks to ex st ng accessway	0 days	ue 10/01/23	Tue 24/01/23	57
97	R p Rap Placement	wks	ue 24/01/23	Tue 7/02/23	96
98	**Stage 2 RH Abutment**	**1 9 wks**	**hu 17/11/22**	**Wed 19/04/23**	
99	Coffe Dam Sw tch - P otect on of R ght Abutment, nclud ng pump down	wks	Wed 25/01/23	Wed 8/02/23	94
100	**Anchors 4000Lm @ 80Lm/day/rig x 2 r gs**	**4 3 wks**	**hu 17/11/22**	**Fri 24/02/23**	
101	Ea ly Sta t on Uppe Level 2000 Lm	.5 wks	hu 17/11/22	Mon 5/12/22	47
102	Lowe Level 2000 Lm	.5 wks	Wed 8/02/23	F 24/02/23	99,101
103	**Baffle Extension 21 tems. Scabble, Reo Includ ng Dowels, Pour - Allow 5 days for 3 items**	**2 8 wks**	**ue 6/12/22**	**Fri 3/03/23**	
104	Ea ly Sta t on Uppe Level 10 tems	.5 wks	ue 6/12/22	Thu 29/12/22	101
105	Lowe Level 11 tems	.5 wks	Wed 8/02/23	F 3/03/23	99
106	Unde slab D a nage Adjustment - Allowance	wk	Wed 8/02/23	Wed 15/02/23	99
107	**Slab Construction**	**9 2 wks**	**ue 6/12/22**	**Tue 18/04/23**	
108	**Early Start on Upper Level**	**wks**	**ue 6/12/22**	**Mon 6/02/23**	
109	**Slab 12**	**.8 wks**	**hu 15/12/22**	**Tue 17/01/23**	101
110	P ep U/S Jo nt nclud ng wate stop	days	hu 15/12/22	Mon 19/12/22	123
111	Scabble Ex t ng Su face & Fo m	days	ue 20/12/22	F 23/12/22	110
112	Re nfo cement, Includ ng T e ng nto ancho s	days	Mon 26/12/22	Mon 2/01/23	111
113	Place Conc ete	day	ue 3/01/23	Tue 3/01/23	112
114	Cu e	4 edays	ue 3/01/23	Tue 17/01/23	113
115	**Slab 13**	**.8 wks**	**Wed 4/01/23**	**Mon 6/02/23**	
116	P ep U/S Jo nt nclud ng wate stop	days	Wed 4/01/23	F 6/01/23	113
117	Scabble Ex t ng Su face & Fo m	days	Mon 9/01/23	Thu 12/01/23	116
118	Re nfo cement, Includ ng T e ng nto ancho s	days	13/01/23	F 20/01/23	117
119	Place Conc ete	day	Mon 23/01/23	Mon 23/01/23	118,114,126
120	Cu e	4 edays	Mon 23/01/23	Mon 6/02/23	119
121	**Slab 14**	**.8 wks**	**ue 6/12/22**	**Fri 6/01/23**	
122	P ep U/S Jo nt nclud ng wate stop	days	ue 6/12/22	Thu 8/12/22	101
123	Scabble Ex t ng Su face & Fo m	days	9/12/22	Wed 14/12/22	122
124	Re nfo cement, Includ ng T e ng nto ancho s	days	hu 15/12/22	Thu 22/12/22	123
125	Place Conc ete	day	23/12/22	F 23/12/22	124
126	Cu e	4 edays	23/12/22	F 6/01/23	125
127	**Lower Level**	**.4 wks**	**Mon 27/02/23**	**Tue 18/04/23**	
128	**Slab 9**	**.6 wks**	**Mon 27/02/23**	**Wed 29/03/23**	
129	P ep U/S Jo nt nclud ng wate stop	days	Mon 27/02/23	Wed 1/03/23	102
130	Scabble Ex t ng Su face & Fo m	days	hu 2/03/23	Tue 7/03/23	129
131	Re nfo cement, Includ ng T e ng nto ancho s	days	Wed 8/03/23	Tue 14/03/23	130
132	Place Conc ete	day	Wed 15/03/23	Wed 15/03/23	131
133	Cu e	4 edays	Wed 15/03/23	Wed 29/03/23	132
134	**Slab 10**	**.4 wks**	**Mon 13/03/23**	**Tue 18/04/23**	
135	P ep U/S Jo nt nclud ng wate stop	days	Mon 13/03/23	Wed 15/03/23	142
136	Scabble Ex t ng Su face & Fo m	days	hu 16/03/23	Tue 21/03/23	135
137	Re nfo cement, Includ ng T e ng nto ancho s	days	Wed 22/03/23	Tue 28/03/23	136
138	Place Conc ete	day	ue 4/04/23	Tue 4/04/23	137,133,145
139	Cu e	4 edays	ue 4/04/23	Tue 18/04/23	138
140	**Slab 11**	**.6 wks**	**hu 2/03/23**	**Mon 3/04/23**	
141	P ep U/S Jo nt nclud ng wate stop	days	hu 2/03/23	Mon 6/03/23	129
142	Scabble Ex t ng Su face & Fo m	days	ue 7/03/23	F 10/03/23	141
143	Re nfo cement, Includ ng T e ng nto ancho s	days	Mon 13/03/23	F 17/03/23	142
144	Place Conc ete	day	Mon 20/03/23	Mon 20/03/23	143
145	Cu e	4 edays	Mon 20/03/23	Mon 3/04/23	144
146	Chute Block Adjustments - 20 tems - A low 4 pe week	wks	hu 16/03/23	Wed 19/04/23	132
147	**Rip Rap Rock Protection to Abutment Wall**	**wks**	**ue 7/02/23**	**Mon 6/03/23**	
148	Conc ete wo ks to ex st ng accessway	0 days	ue 7/02/23	Mon 20/02/23	108
149	R p Rap Placement	wks	ue 21/02/23	Mon 6/03/23	148
150	M sc. Wo ks and Defect Management	wks	Wed 5/04/23	Tue 18/04/23	127FF
151	**Site Demob**	**4 5 wks**	**ue 7/02/23**	**Wed 17/05/23**	
152	Coffe Dam Removal	wk	hu 20/04/23	Wed 26/04/23	146
153	**Tower Crane Removal**	**2 1 wks**	**ue 7/02/23**	**Tue 2/05/23**	
154	TC1	days	ue 7/02/23	Mon 13/02/23	46
155	TC2	days	hu 27/04/23	Tue 2/05/23	152
156	Access Roads, Compound Etc	wks	hu 27/04/23	Wed 17/05/23	152
157	**Cont ngency and Risk Allowance**	**wks**	**hu 18/05/23**	**Wed 12/07/23**	
158	Inclement Weathe Impacts - Ra n, W nd (Unable to ope ate c anes etc) 40 weeks x 15%	wks	hu 18/05/23	Wed 28/06/23	151
159	Schedul ng Confl ct Cont ngency 40 Weeks x 5%	wks	hu 29/06/23	Wed 12/07/23	158



P o ect map ol11
Date Wed 20/10/21

Task | Split | Milestone | Summa y | P oject Summa y | Exte nal Tasks | Exte nal Milestone | Inact ve Task | Inact ve Milestone | Inact ve Summa y | Manual Task | Du at on-only | Manual Summa y Ro lup | Manual Summa y | Sta t-only | F n sh-only | Deadl ne | C t cal | C t cal Spl t | P og ess | Manual P og ess

Appendix D

Risk Register

RISK VARIANCE REGISTER
Scrivener Dam Stilling Basin Upgrade

					Unmitigated			Risk Mitigation Measures	M tigated			Impact Summary		Potential Cost imapcts			Potential ime Impacts			
Risk No	Category	Hazard	Potential Cause	Consequence/ mpact	L	C	RR		L	C	RR	Probabi ity	Notes/ Reasoning	M n Cost	Most likely Cost	Max Cost	Min ime (weeks)	Most likely ime (weeks)	Max ime (Weeks)	Distribution
1	Techn cal	Resourcing Constrain s	Dif iculties engaging suitable designers for deta led design (resource shor ages) leading o delays in the program	Additional costs to hire add tional contractors and consul ant. Program delays.		2	M	Early engagement with consultants to ensure availabi ity	3	2	M	[redacted]	Lack of resouces may de ay design of project but unlikely to have a cost or time impact on construc ion.	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	0
2	Techn cal	Changing Design Loads	Design loads increase eading to increased volume of concrete required for project or increase in depth of anchors	Cost and time imp ications	3	2	M	Obtain design loads early enough to prevent re-work and project delays	3	2	M	[redacted]	Change in design loads may lead to increased number of anchors or thickness of slab. Assume concre e thickness of 500mm, 600mm and 700mm, and anchor quan ity of [redacted] xtra anchors.	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
3	Techn cal	Extent of Abutment Erosion Protec ion	Amount of work required to protect abutments sign ficantly inc eases	Cost impacts		2	M	Physical model study will be used to assess the e os on potential of abutments and pro ec ion works w ll be des gned as required		2	M	[redacted]	Increase area of protect on by [redacted] Assume works done concurrently with sti ling basin, therefore no time impact.	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
	Techn cal	Addit onal Wa l Raising	Divider wal s require ra sing	Increase in height of wal s - cost impact	3	1	L	Make dec sions based on hydrau ic model testing.	2	1	L	[redacted]	Raise divider walls by 0m, 0 5m and 1.0m (Assume 50m ength by 0. m thick at	[redacted] -	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
5	Techn cal	Model Studies	Phys cal hydraulic model study required to confirm loads	Risk of not properly understanding trans ent loads in s ab		3	H	Carry out phys cal testing along w th CFD to properly unders and transient oads		3	H	[redacted]	Cost of phys cal model	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
6	Techn cal	Instrumenta ion	Instrumentat on required in stil ing basin	Risk of lacking knowledge of loads if instrumentation not included in design		2	M	Include instrumentat on in the stil ing basin to understand oads		2	M	[redacted]	Instrumentat on requirements for project - estimate of cost - may involve piezos or CCTV installation or combination.	[redacted] [redacted]	[redacted]	[redacted] [redacted]		[redacted]	[redacted]	Triangular
7	Techn cal	Drainage Wo ks	Additional drainage works required	Cost implicat ons	3	3	H	Rev ew survey and contour da a pr or to construct on o indicate need for additional drainage works	2	3	M	[redacted]	Need for additional drainage works associated w th dam oundat on upift pressures - potential for ver ical drains and outlet system	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
8	Techn cal	Downstream Erosion Protec ion	Downstream eros on protection required	Deg eda ion of downstream. Additional costs and time re ated to design and construc ion of protection		2	M	Physical model study will be used to assess the e os on potential downstream of the dam and protect on works w ll be designed as required	3	2	M	[redacted]	Assume basic trimming and shaping, versus mass concrete pro ect on works extending 5m and 10m from oe. Works done concurrently - no time imapct	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
9	Techn cal	Lengthening Sti ling Basin	Hydraulic model ind ca es that st lling basin needs to be engthened	Additional costs and time re ated to design and construc ion	3	3	H	Obtain resul s from model early enough to prevent delays in the design phase for st lling basin lengthening	2	3	M	[redacted]	Assume lengthening by 0m, 5m and 10m	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
10	Techn cal	Errors in Drawings	Drawing er ors eading to delays in as-constructed drawings or rework	Program dealys.	3	2	M	External review of construction drawings prior to the start of construction	3	2	M	[redacted]	Impacts by [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
11	Techn cal	Adverse Foundat ons dentified During Design	Foundation conditions found to be worse than expected leading o addi ional anchor depths	Increase in anchor costs. Program delays.	5	2	H	Further geotechincal testing undertaken during the des gn phase o reduce founda ion uncertainty. Open foundation early. 3rd party reviews.	5	2	H	[redacted]	Assume anchors double in ength comp ising [redacted] of anchors	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
12	Techn cal	Access	Risk that erosion protect on on abutmen s closes o f access o spillway gates and add tional wo ks required to reinstate access.	Cost of alternative access/ modif ca ions to access	5	2	H	Assess during future design phases	5	2	H	[redacted]	Costs of concrete protect on wo ks/ re aining wall to contain eros on protect on.	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
13	Techn cal	Chute block stabil ty	Risk that concrete over ay slab on chute blocks requires add tional stabil ty in the form of anchors through the structure.	Cost of instal ing anchor (or s gn icant dowels) through chute over ay slab	5	2	H	Assess during future design phases	5	2	H	[redacted]	Costs assoc ated with instal ing anchors/dowels in di ficult access area.	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
1	Procurement	Lead Time	Extensive ead time on key tems (i e. anchors, waterstops etc)	Program delays. Additional costs.	5	2	H	Early procurement p anning, negot on, ordering. Go further afield if necessary		2	M	[redacted]	Impacts o [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
15	Procurement	Inability to Source Materia s	Inab lity to source key tems loca ly, requiring expensive import of mater als (i.e. waterstops)	Program delays. Additional costs.	5	2	H	Early procurement p anning, negot on, ordering		2	M	[redacted]	Impacts o [redacted] on de ivery. Increased haul delivery costs	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
16	Procurement	Concrete Materials	Dif iculties sourcing concrete products of adequate speci ication for the pro ect	Additional cost of concrete production		2	M	Mix re-design if possible, o accommodate the out-of-spec. product	3	2	M	[redacted]	Loading on ex sting concrete rate by [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
17	Procurement	Inflation/Escla ion	Market trends resulting in rapid increases in cost	Increase in otal overall cost	5	3	H	Hedge for key products	5	3	H	[redacted]	Overall increase in project direct costs by [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
18	Construc ion	Access	Access into sti ling basin is problemat c/ requires extensive work	Program delay.		3	H	Early review of stil ing basin to determine any access work requirements	3	2	M	[redacted]	Increase in ime by [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
19	Construc ion	Survey Errors	Survey data/contour data is innacurate due to er ors in datum points or inaccurate survey methods	Design re-work/po ent al construc ion issues if not found early		2	M	Compare and cross-check survey/topographic informat on		2	M	[redacted]	Error in survey leads to rework and time delays [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
20	Construc ion	Tight Program	Very t ght program requiring extensions of time	Cost implicat ons		2	M	Ensure pogram is realistic		2	M	[redacted]	Contrac or overruns time by [redacted]	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
21	Construc ion	Lack of Qual fied Resources	Dif iculties engaging contractors with adequate experience leading to increase in costs	Time imp ications along with a smal er amount of cost impl cat ons.		2	M	At the start of construct on, train local employees.		2	M	[redacted]	Contractor overruns time b [redacted] and and costs imp ications on abour	[redacted] [redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular

					Unmitigated			Risk Mit gation Measures	M tigated			Impact Summary	Potential Cost imapcts			Potential ime Impacts			
22	Construc ion	Unfavourable Foundat on Condi ions Iden ified During Construction	Unfavourable foundat on condit ons ident fied during construc ion leading to delays, rework, and addi ional anchoring/concrete works	Increase in anchor quantit es. Program delays	5	2	H	Further geotechincal testing would be undertaken during the design phase to reduce founda ion uncertainty. Open founda ion early. 3rd party reviews.		2	M	Assume anchors double in ength [redacted] comp ising [redacted] of anchors	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
23	Construc ion	Cofferdam Capacity	Cof erdam over ops due to flooding	Cost of clean-up, addi ional dewatering and program delay	5	2	H	Des gn cofferdams or over opping by major f ood. Dam regulator to review designs		2	M	Cost impacts, and de ays o [redacted] nd [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
2	Construc ion	Cofferdam Failure	Risk that cofferdam fa ls during lood	Cost of rebuilding cof erdam, damage to construct on equipment, c ean-up costs and program delay	3	3	H	Des gn cofferdams or major floods.	3	3	H	Cost of repairing cofferdam vesus re abr cating cof erdam and delay cos s of [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
25	Construc ion	Dewatering the Foundat on	Dif iculties dewatering the ex sting sti ling basin leading o time delays and requirements or addi ional sumps etc	Increased time and cost to dewater sti ling basin	5	2	H	Allow or addit onal time o dewater sti ling basin in planning. Al ow for this risk and ensure the dewatering is not part of crit cal pro ect path.		2	M	[redacted] Delays and pumping costs [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
26	Construc ion	Quality	Risk that qua ity of construction is inadequate (i.e. concrete slab cracks eading to repair works)	Program delays. Cost of car ying out repair wo ks.		2	M	Ensure strict adherance to construction plan to prevent poor qual ty works		2	M	Minor repairs versus replacement of sect ons, and time impacts of 1[redacted] nd [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	iangular
27	Construc ion	Laydown Areas	Inadequate aydown areas leading to addit onal haul times	Program delays. Additional costs.	3	2	M	Rev ew of layout of aydown areas as part of des gn. Adequate s te inductions, use of spotters when vehicles are reversing and separa e pedestrian and vehic e access.	3	2	M	Additional de ivery times, and program [redacted] delays o [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
28	Construc ion	Restricted Space	Work front becoming more restricted than anticipated leading to slow progress	Program delays. Additional costs.	5	2	H	Ensure adequate laydown areas prior to start of construct on and …		2	M	[redacted] Slower work - de ays of 1[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
29	Construc ion	Road Accident	Risk of road acc dents assoc ated with delivery of mater al	Injury, reputation, negative media coverage, compensation payouts, negative team mora e	3	1	L	OHS P an o be deve oped and implemented	2	1	L	Cost valuation equiva ent to program delay [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
30	Construc ion	Industr al Re ations	Risk that major industrial relations ssues impact the project	Cost and time imp lications.	3	1	L	Ensure proper induc ion and str ct adherence to IR protoco s.	3	1	L	Cost valuation equiva ent to program delay [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
31	Construc ion	Funding	Risk that project doesn't ob ain government funding	Pro ect is delayed or terminated	3	5	H	Early subm ssion for funding. Risk al ocation needs to be realistic. Unde stand government drivers to assist in providing basis for funding.	2	5	H	Not quantif ed - not applicab e in th s [redacted] context	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	N/A
32	Construc ion	Inc ement Weather	Risk that weather is too hot or cold for construction works	Program delays or possible cracking to be repai ed.	3	1	L	Allow or flexibi ity in program and adjust programme to place RCC during the coolest 5 months of the year to avoid extreme heat. Inves igate options for working through wet weather (ie. Surfacing access tracks, arps, etc.)	3	1	L	Cost valuation equiva ent to program delay [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
33	Construc ion	Construct on Safety	Risk of loss time injury during construction	Injury, reputation, negative media coverage, nega ive team mora e	3		H	Give OHS No. 1 prior ty on site - good training, tool box meetings, etc.	2		M	Cost valuation equiva ent to program delay [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
3	Construc ion	Financ al Distress	Risk that contrac or experiences financial d stress during project	Inab lity to fund the project. Cash flow issues, resourcing issues, poten ial program delays	2	3	M	Systems to ensure payment to OAPs, mu ti-ski l throughout, sys ems that can be rep icated - in erface backup, ac ion/response plan deve oped pr or to work, A liance culture - best for project, st ck w th project and contemplate employment agreemen s, OAP supplier arrangemen s with All ance	2	3	M	[redacted] Not quantif ed - Risk variance - Nil	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	N/A
35	Construc ion	Dr lling equipment/ product on rate	Trying to minim se noise may al er equipment used for dril ing impac ing time/cost.	May require different dril ing equipment therefore potential for increased costs.		2	M	The construct on of noise wal s around the zoo (around who e s te or isolated o noise generating equipment) and or the use of no se educing technologies		2	M	More expensive drill rigs, or need for no se wall, s ower drill rates, assume cost impact o [redacted] plus indirect costs with delays of [redacted] and [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	Triangular
36	Construc ion	Anchoring	Ancho ing work intercep ing pressurised ground water	Potent al inju y or danger to personnel. Program delays.	5	2	H	The use of modern day equipment that has technology to mi igate this risk	5	2	H	Need to install packers, prevent seepage, s ower drill rates, assume cost impact of [redacted] plus indirect costs [redacted] with de ays o [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	riangular
37	Approvals, Environmental, Soc al	Ob aining Approvals	Risk that obtaining approvals akes onger than expected	Program delays	3	1	L	Early engagement and consul ation with relevant authorities	3	1	L	Cost valuation equiva ent to program delay [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular
38	Approvals, Environmental, Soc al	St eam Turbid ty	Risk that construction works ead to excessive turbidity in downstream river	Negative pub lc ty, possible l tigation. Extra cost of bet er sedimen ation faci ity		1	M	Adhere to the condi ions and processes set out in the CEMP		1	M	Es imate of costs for si tation control [redacted] measures	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
39	Approvals, Environmental, Soc al	Truck Movements	Risk that there is signif cant community backlash at the increase in truck movemen s	Negative pol tical and med a at ent on.	3	1	L	Stakeho der management p an to be implemented and med a to be managed w th particular re erence o the extra trucks on the road	2	1	L	Additional cost of managing stakeholders, estimate [redacted] No time [redacted] impact.	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
0	Approvals, Environmental, Soc al	Zoo Impacts	Risk that there are unforeseen impac s on the zoo in terms of excessive vibrat on, dust, noise e c.	Negative pol tical and med a at ent on.		2	M	Early engagement and consul ation with the zoo		2	M	Es imate of noise wall [redacted] and [redacted] plus indirect costs with delays of [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
1	Approvals, Environmental, Soc al	Cultural Her tage	Risk that cultural her tage s te s found	Restrictions or cessation of construc ion operat ons. Program delays.	2	2	L	Adhere to the condi ions and processes set out in the CEMP	2	2	L	[redacted] Not quantif ed - assume captured in CEMP [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	Triangular
2	Approvals, Environmental, Soc al	Community	Need to close of portion of br dge above construction s te to prevent i ems being dropped on construc ion worke s	Potent al inju y or danger to personnel. Program delays.	3	2	M	Instal ation of temporary fencing or mesh along the bridge to prevent i ems being dropped on workers	2	2	L	Costs of road closure for period of time, [redacted] estimate [redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	riangular

Appendix E

Cost Estimate

Appendix F

Monte Carlo Assessment Outputs

Appendix G

Safety in Design Register

SAFETY IN DESIGN REGISTER
Scrivener Dam Stilling Basin Upgrade

Risk No	Category	Hazard	Details	Unmitigated			Risk Mitigation Measures	Responsibility	Mitigated		
				L	C	RR			L	C	RR
1	INTERFACES	Vehicle collision	Site personnel interaction with site vehicle or mobile plant leading to fatality	4	5	E	*Site speed limits *Vehicle maintenance (e.g. reversing alarms) *Make sure design of haul roads provide for adequate space for vehicles. *Procedures of work (e.g. reversing procedures, exclusion of non-essential personnel from area) *Use of spotters and of radio communication *PPE (e.g. High visability clothing) *Contractor to undertake site visit during tender phase	Designer/ Contractor	3	5	H
2	ENVIRONMENTAL	Flooding	Spillway gates are not adequately locked out/ tagged out for construction phase and accidentally open when people working downstream.	2	5	H	*Make sure lock out procedures are appropriate for works	NCA	1	5	M
3	ENVIRONMENTAL	Flooding	Storage floods leading to need to operate spillway gates in a hurry (while personnel are working on site or trying to retrieve equipment). Difficulty of escape leading to fatality	3	5	H	*Procedures of work (inc. Emergency response plan to overtopping) *Contractor to be made aware of early flood warning systems. * Specification to outline proposed procedure between NCA and Contractor for communicating impending floods.	Design, NCA, Contractor	2	5	H
4	ACCESS	Obstructions	Potentially restricted laydown areas leading to greater risk of accidents and severe personnel injury	3	4	H	*Review of layout of laydown areas as part of the design and make sure there is adequate room *Procedures of work *Site inductions *Using spotters when vehicles are reversing *Separate pedestrian access and vehicle access	Design/ Contractor	2	4	M
5	INTERFACES	Adjacent Property	Close proximity of National Zoo, within 50m of west end of stilling basin, and Government House, less than 500m away. Potential for unforseen impacts on the zoo staff and patrons in terms of excessive vibration, dust, noise, etc.	5	4	E	Early engagement and consultation with the Zoo and Government House Consider installing noise wall Dust supression at site (if appropriate) Comply with CEMP	Contractor	4	4	H
6	ENVIRONMENTAL	Dust	Minor concrete demoltion/ preparation works of slab, end sill and baffles and core drilling through existing slab increases risk of dust generation	5	2	H	* Procedures of work including dust control plans, application of water/dust suppressants	Contractor	3	2	M
7	TOXICITY	Handling	Work with concrete and various admixtures, leading to serious eye damage, respiratory or skin sensitisation	3	2	M	*Review of admixtures required in design. Potential to eliminate or substitute a less harmful product *Procedures of work *PPE	Contractor	2	2	L
8	CONDITIONS	Noise	Concrete demolition works and drilling - risk of hearing damage to site personnel	5	3	H	*PPE for all relavant personnel *Comply with CEMP *Consideration of noise reduction options	Contractor	2	3	M
9	CONDITIONS	Extreme Weather	Access to site (haul roads etc) made more difficult/ slippery due to rain, leading to injury	5	3	H	*Haul roads to be surfaced with appropriate material, where applicable.	Contractor	3	3	H
10	HEIGHTS	Falling/dropped objects	Potential for public on spillway bridge to drop items onto workers in the stilling basin, or for workers upgrading end walls on stilling basin to drop tools onto people working below.	3	4	H	*Consider establishment of safety exclusion zones on spillway bridge *Procedures of work	NCA	2	4	M
11	FORCE	High/Excess	Lifting of heavy anchor assembly into hole - potential for crush injuries.	3	4	H	*Procedures of work (request as part of tender information) *PPE *Highly trained contractors for high risk work *Radio communication	Contractor	3	3	H
12	FORCE	Rotating Equipment	Inherent risks associated with using/operating drill rigs (crush injuries/ loose clothing etc).	3	4	H	*Procedures of work *PPE *Use of highly trained contractors for high risk work	Contractor	3	3	H
13	ERGONOMICS	Slips/Trips/Falls	Inadequate long-term access into the stilling basin for surveillance and maintenance purposes leading to falls, slips and trips of O&M personnel.	4	3	H	*Provision for long term access to be considered in design *Removal of all tools, waste and materials post-construction to remove long-term impediments to access	Designer/ Contractor	2	3	M
14	INTERFACES	Members of the Public	Inadequate safety fencing around top of stilling basin leading to potential for public to access unsafe areas of the stilling basin (particularly during spill events).	3	4	H	*Provision for adequate fencing and security measures *Regular inspectiopn of fencing, signage and exlusion measures	Contractor/NCA	2	4	M

				Unmitigated			Risk Mitigation Measures	Responsibility	Mitigated		
15	ENERGY	High	Anchor fails during stress testing of anchors leading to injury/ fatality of contractor personnel	3	5	H	*Procedures of work *PPE *Highly trained contractor for high risk work	Contractor	2	4	M
16	HEIGHTS	Working at heights	Inadequate fall protection used during construction of triangular wa l extension on side walls of stilling basin - construction personnel falls.	3	5	H	*Equipment Selection (fall prevention system to be installed) *Procedures of work *Contractor safety requirements & legislative requirements *Provision for pre-qual fication of contractors	Contractor	2	4	M
17	FORCE	Fal ing Objects	Dropping large object onto stilling basin during heavy l ft (i.e. lifting drill rig over baffles, lifting formwork into place, lifting in reinforcing cages) - with personnel working beneath lift - poten tal for injury or fata ity	3	5	H	*Procedures of work (exclusion of non-essential personnel from area) *Radio communication	Contractor	3	5	H
18	ERGONOMICS	Too Heavy	Manual labour - back injuries, associated with l fting heavy equipment.	5	2	H	*Use of appropriate equipment such as trolleys, small mobile cranes, etc. *Procedures of work	Contractor	5	2	H
19	FORCE	High/Excess	High pressure sprays used to remove laitence/ surface prep of concrete for placement of new concrete slab - works lead to injury of construction personnel (jet blast eye injuries etc)	4	3	H	*PPE *Exclusion of non-essential personnel from area	Contractor	4	3	H
20	HEIGHTS	Working at hiehgts	Working from heights - placement of reinforcement, concrete and formwork for baffle construction requires placement higher than 1.5 metres - potential working from heights risks.	5	4	E	*Equipment Selection *Procedures of work *Contractor safety requirements & legislative requirements *Provision for pre-qual fication of contractors	Contractor/NCA	2	4	M
21	INTERFACES	Vehicle co lision	Truck - personnel interaction injuries associated with placement of erosion protection works on embankment.	3	4	H	*Exclusion of non-essential personnel from area *Use of spotters and of radio communication	Contractor	2	4	M
22	INTERFACES	Members of the Public	Public not adequately excluded from construction zone during works.	3	3	H	*Provision for adequate fencing and security measures *Regular inspectiopn of fencing, signage and exlusion measures	Contractor/NCA	2	3	M
23	INTERFACES	Adjacent Property	Interaction between tower cranes and spillway bridge - potential for crane to slew over bridge and damage tall vehicle/ equipment on bridge.	3	3	H	*Use of spotters *Pre-planning of crane routes and postions *Traffic management *Use of highly trained and experience crane operators	Contractor	2	3	M
24	ENERGY	Thermal	Burn injuries during welding of PVC waterstops.	3	2	M	* Number of waterstops minimised by reducing number of contraction joints *PPE *Highly trained contractors used for high risk work	Contractor	2	2	L
25	ENVIRONMENTAL	Contagious Diseases	COVID-19 potential risks working on site.	5	3	H	*Compliance with ACT COVID-19 guidelines & restrictions	Contractor	3	3	H
26	INTERFACES	Vehicle co lision	Construction - public vehicle accidents at entrance to worksite.	3	4	H	*Traffic management *Construction zone speed limits	Contractor	3	4	H

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