

Tweed Shire Council

CLARRIE HALL DAM RAISING

State Significant Infrastructure
Application – Scoping Report



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Limitations Statement

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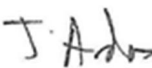
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Revision History

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Tweed Shire Council

CLARRIE HALL DAM RAISING

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PART ONE



1 Introduction

Tweed Shire Council (Council) is proposing to raise Clarrie Hall Dam by 8.5 metres. Kellogg Brown and Root Pty Ltd (KBR) has prepared this scoping report on behalf of Council for an application for the Secretary's Environmental Assessment Requirements (SEARs). The SEARs will then guide the preparation of Environmental Impact Statement (EIS), which is required for a State Significant Infrastructure (SSI) application for the raising of Clarrie Hall Dam.

Clarrie Hall Dam is located on Doon Doon Creek, 15 kilometres (km) south-west of Murwillumbah in the Tweed Shire local government area (LGA) in New South Wales (NSW), as shown in Figure 1-1.

Details of the proponent are provided in Table 1-1.

Table 1-1 Proponent details

Proponent information	Details
Proponent name	Tweed Shire Council
ABN	90 178 732 496
Address	Tweed Heads Administration Office, Civic and Cultural Centre, Corner Brett Street and Wharf Street, Tweed Heads NSW 2485 PO Box 816 Murwillumbah NSW 2484

This Scoping Report provides an overview of the proposed raising of Clarrie Hall Dam, sets out the statutory context, and identifies the key environmental and planning issues likely to be associated with the proposal. It has been prepared in accordance with the NSW Department of Planning and Environment (DPE) *State significant infrastructure guidelines – preparing a scoping report* (2022).

Upon receipt of the SEARs, the information contained in this Scoping Report will form the basis of an EIS prepared in accordance with the requirements of Division 5.2 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and the *State significant infrastructure guidelines – preparing an environmental impact statement* (DPE, 2022).

Chapter 6 provides an overview of matters that require further assessment, supplemented by a scoping summary table in Appendix A that includes relevant guidelines.

1.1 PROJECT DESCRIPTION

Tweed Shire Council propose to raise the wall of Clarrie Hall Dam by 8.5 m to a height of 70 m Australian Height Datum (AHD) (RL 70 m), thereby increasing the capacity of the dam from 16,000 megalitres (ML) to approximately 42,300 ML (the Proposal). The Proposal location is provided in Figure 1-1.

The Proposal would include:

- raising the dam wall by 8.5 m
- a new spillway channel constructed higher in the left abutment with a flip bucket at the downstream end

- re-establishment of the quarry used to construct the existing dam for the purpose of sourcing rock material to raise the dam wall
- construction of associated haul roads to transport quarry material for the proposed raising of the dam wall
- establishment of a construction area for plant, equipment, storage, material handling and offices
- establishment of stockpile sites associated with construction
- construction of work compounds and site offices
- establishment of materials storage and handling facilities
- construction of workers accommodation
- construction of a concrete batching plant
- realignment of Clarrie Hall Dam Road higher in the right abutment
- raising of the existing intake tower and bridge
- decommissioning of existing recreational facilities at the dam wall area
- construction of new dam operational facilities including signage, car parking, security fences, lighting, monitoring equipment and a boat ramp
- removing or reconstructing impacted recreational infrastructure and facilities at Crams Farm
- upgrading the Kyogle Road and Clarrie Hall Dam Road intersection
- replacing McCabes Bridge and realignment of Commissioners Creek Road
- relocating existing power and telecommunications utilities
- construction of new recreation facilities including an amenities block, public shelters, viewing areas, interpretation signage, paths, car parks, and landscaping.

The upgraded dam operational footprint would increase the area of inundation to below the RL 70 m contour, which is the waterline boundary at full supply level (FSL).

An overview of the elements of the Proposal is provided in Figure1-2. Further details of the Proposal are provided in section 3.1.



Figure 1-1 Location of Clarrie Hall Dam

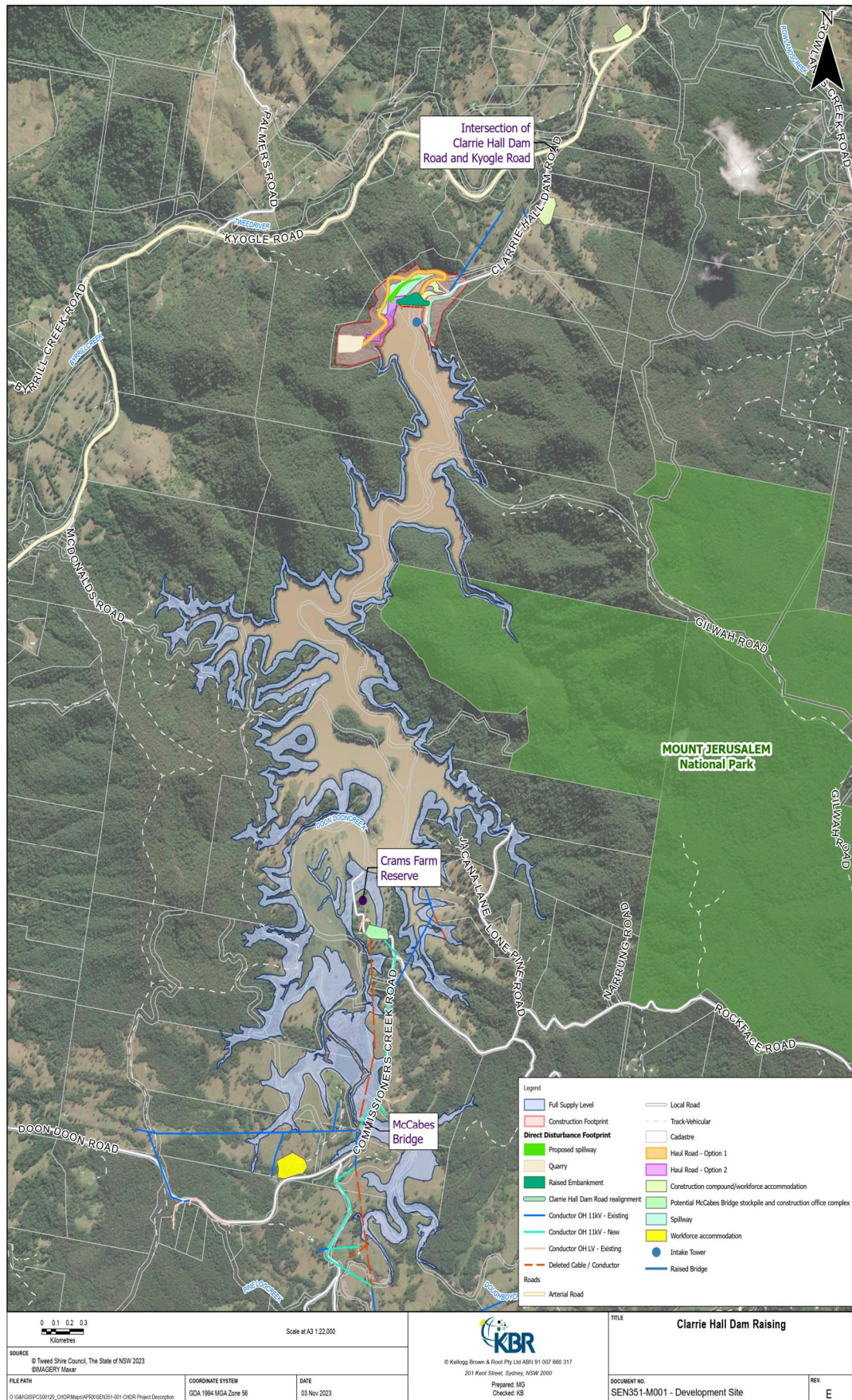


Figure 1-2 Overview of the Clarrie Hall Dam raising Proposal

1.1.1 Related development infrastructure

Related infrastructure that is subject to a separate approval process is the Bray Park Weir Tidal Protection Project. Bray Park Weir was built in 1960 and is a critical component of the Tweed Shire Council infrastructure, as it provides in-stream storage for the Bray Park Water Treatment Plant. Most of the Tweed Shire's potable water is sourced from the Tweed River at the Bray Park Weir.

Climate change is causing more frequent extreme weather events. It is also causing sea levels to rise and is reducing the flow of water in the Tweed River. The rise in sea level is increasing the risk of tidal salt water and sea-level anomalies overtopping the Bray Park Weir, which could affect the quality of the water supply. Council is developing and assessing options to mitigate this risk separately to the Proposal.

1.2 PROJECT OBJECTIVES

Council aims to ensure that the Tweed Shire community continues to be provided with a safe and adequate water supply beyond 2028 by raising Clarrie Hall Dam. It is proposed this would be achieved by increasing the storage capacity of Clarrie Hall Dam from 16,000 ML to 42,300 ML to provide a FSL of RL 70 m.

The Proposal considers the future growth projections and the predicted impacts of climate change. In conjunction with other water conservation actions, the Proposal aims to provide increased water storage to permit the continued growth of the region and ensure the resilience of the community, even in drought conditions, which are predicted to increase in frequency due to climate change. This increased storage would provide adequate water supply to the Tweed Shire until at least 2065.

Clarrie Hall Dam is operated according to the relevant Water Sharing Plan (WSP) – that is, the Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2023. The raised dam would be required to meet the WSP objectives.

The water supply objective of Council, stated in section 1.3.4 of the Tweed Shire Council Delivery Program 2017–2021 and Operational Plan 2020–2021 (amended December 2020 for proposed 2021/22 Special Rate variation) is:

- To provide secure, high quality and reliable drinking water which meets health and environmental requirements.

To fulfil Council's requirement of ensuring that all customers are provided with a safe and adequate water supply, the Proposal would satisfy the principal objectives identified by Council for water supply services, including:

- providing water supply services within a strategic business planning framework
- providing best practice management of the urban water supply in accordance with Council's Integrated Water Cycle Management Strategy
- meeting legislative requirements, including licence requirements regarding surface and groundwater supply extraction conditions
- providing additional system capacity that meets sustainable growth projections to operate the water supply systems efficiently and sustainably
- providing an equitable, responsive and cost-effective water supply service
- providing a high quality, reliable and sufficient water supply service
- promoting water cycle education, including conservation and reuse

- managing assets on a whole-of-lifecycle cost basis to ensure the ongoing adequate provision of water supply services
- implementing a management regime for all matters relating to the provision of the water supply service.

The proposed raising of Clarrie Hall Dam would also meet relevant objectives of the Far North Coast Regional Water Strategy as discussed in section 2.1.2.

1.3 PROJECT BACKGROUND

Clarrie Hall Dam was constructed in 1983 by the NSW Department of Public Works and is owned and operated by Tweed Shire Council for the primary purpose of providing a drinking water supply to the Tweed Shire area.

Clarrie Hall Dam is located on Doon Doon Creek, a third-order stream forming a tributary of the south arm of the Tweed River. The dam is located in Doon Doon, approximately 15 km south-west of Murwillumbah and 4 km south-west of Uki in the Tweed Shire.

The dam has a catchment area of approximately 60 square kilometres (km²) and a storage capacity of 16,000 ML. Water is released down Doon Doon Creek via release valves in an intake tower within the dam to the Tweed River, where it is subsequently harvested at the Bray Park Weir.

There is a requirement to augment the Tweed Shire district water supply by 2028. This is because of an increasing demand for water as a result of projected population growth, and the increasing uncertainty of water supply yield due to climate change.

2 Strategic context

The key strategic issues that are relevant to the assessment and evaluation of the Proposal are outlined below.

2.1 JUSTIFICATION

Due to increasing demand for water as a result of projected population growth and the increasing uncertainty of water supply yield associated with climate change, there is a requirement to augment the Tweed Shire district water supply by 2028. Factoring in ongoing implementation of demand management and revisions of the secure yield of the Tweed district water supply based on an increase of one degree Celsius by the year 2030, peak demand is expected to exceed secure yield by 2026 (NSW Urban Water Services, 2016).

Consideration of 6 water supply augmentation options was conducted after a wide range of options was first considered in 2009–2010. Environmental, social and economic analysis of the 6 water supply options consistently indicated that raising Clarrie Hall Dam was the most advantageous to Council and the community (see section 3.3 for a discussion on alternatives).

2.1.1 Water demand

In August 2021, Council engaged an external consultant to update the forecast demand for the Tweed District Water Supply (Hydrosphere Consulting, 2021) (Appendix B) and a second external consultancy to update the secure yield modelling including using the latest climate predictions to assess strategic need and climate change risk to the present and proposed water supply system (NSW Urban Water Services, 2021) (Appendix C). The updated secure yield modelling shows that a raised Clarrie Hall Dam would be able to provide a secure water supply to the Tweed until at least 2065, and probably beyond.

Council has the following responsibilities:

- Under section 60 of the *Water Management Act 2000*, critical human needs are the first priority during extreme events, such as drought, so it is Council's responsibility to ensure adequate supply during these times.
- A new regulatory and assurance framework that applies to local water utilities in regional NSW, such as Tweed Shire Council, commenced from 1 July 2022. This means that Tweed Shire Council, who is exercising water supply functions under Division 2 of Part 3 (Chapter 6) of the *Local Government Act 1993*, and exercising water supply functions under the *Water Management Act 2000*, is required to ensure local water utilities risks are managed effectively and strategically.

2.1.2 Far North Coast Regional Water Strategy

[The Far North Coast Regional Water Strategy](#) (FNCRWS) (DPE, 2023) recently released by DPE, provides a 20-year Far North Coast region-specific strategy to improve the security and certainty of water resources.

The raising of Clarrie Hall Dam would assist Council to achieve objective 1 of the FNCRWS, with the exception of flood management, which states:

Deliver and manage water for local communities: improve water security, water quality and flood management for regional towns and communities.

The FNCRWS identifies the following opportunity in response to the challenge of water security for towns and communities in the Far North Coast:

Opportunity: Improve the resilience of town water supplies by planning for the uncertainties of population growth and projected climate change.

The FNCRWS identifies population growth as putting pressure on town water supply systems in the Far North Coast region. It also finds that the risks to these systems could increase with the increasing frequency and severity of dry periods likely to occur in the future.

Furthermore, DPE modelling suggests that the risks to town water supplies in the Far North Coast region occur mostly during extreme dry periods and notes this is of particular concern for the Tweed Shire Council and Rous County Council water supply systems because they service large populations, and the consequences of shortages could be severe.

Furthermore, the FNCRWS states:

Both Rous County Council and Tweed Shire Council have limited water storage available, with roughly 12–18 months of water storage available for the major urban supplies in the Far North Coast.

If a drought were to occur for longer than this period, Council would need to rely on emergency supplies such as temporary desalination plants. This is impractical as the lead times for this infrastructure can be one to two years, requiring a decision on implementation very early on in a drought.

Tweed Shire Council currently needs to plan for emergency supplies once Clarrie Hall Dam drops to about 97% capacity. Projections suggest that in the future demand will increase and climate change will reduce inflows. This will lead to dam levels dropping faster. As a result, planning for emergency augmentations will need to happen much earlier. Some models suggest that by 2030 Tweed Shire Council will need to start planning emergency augmentations when Clarrie Hall Dam is completely full.

In addition, there can be significant costs to maintaining reliable water supplies during drought. The FNCRWS states that councils in the Far North Coast region need to consider the levels of risk that Far North Coast communities are willing to endure and need to balance these with the associated costs of their emergency supplies.

The FNCRWS identifies Tweed Shire Council as already focusing on reducing the risks to supplies through actively trying to reduce general water use, while also augmenting Clarrie Hall Dam to increase supply. The FNCRWS states that these kinds of actions can reduce system risk by delaying the need for emergency supplies.

The 2017–2020 drought highlighted that the region's town water supply systems can be put under pressure during drought. The FNCRWS therefore identifies the raising of Clarrie Hall Dam as a key initiative for the region:

Tweed Shire Council is planning augmentation of Clarrie Hall Dam (from 16 GL to 42.3 GL capacity).

This is further discussed as action 4.3 in the Far North Coast Implementation Plan, as shown in Figure 2-1.

Department of Planning and Environment dpie.nsw.gov.au Regional Water Strategy Far North Coast June 2023  				
Department of Planning and Environment dpie.nsw.gov.au Regional Water Strategy Far North Coast – Implementation Plan June 2023  				
Action	Our starting point	What we will do next	What we will do later	Lead
Action 4.3: Support regional-scale, adaptive decision-making for town water supplies in the Far North Coast	Rous County Council is undertaking planning, design and approvals for the short- and medium-term actions identified in its Future Water Project 2060: - Stage 1: Upgrade of Marom Creek water treatment plant, accessing Alstonville and Woodburn groundwater - Stage 2: New groundwater source at Tyagarah. Tweed Shire Council is continuing to plan the Clarrie Hall Dam augmentation and is completing, and seeking approval for, an environmental impacts statement. Byron Shire Council is working on emergency connections for Mullumbimby to the Rous County Council bulk water supply with NSW Government funding for flood resilience.	Rous County Council will construct/improve Alstonville and Woodburn groundwater source infrastructure.	Rous County Council to operate Marom Creek Water Treatment Plant upgrade and Alstonville/Woodburn groundwater schemes. Tweed Shire Council to construct Clarrie Hall Dam augmentation (pending approval). Investigate the feasibility, including whole-of-life costs, yield assessments, lead times, community acceptance, environmental impacts, technical complexity and regulatory barriers for: - linking the Tweed Shire Council and Rous County Council water systems - connecting smaller systems in the Richmond/Brunswick catchments (Casino, Nimbin, Mullumbimby) to the Rous County Council bulk water supply on a permanent basis - constructing a regional desalination facility.	Local councils

Figure 2-1 Actions to plan and conduct the EIS for the proposed raising of Clarrie Hall Dam are included in the Regional Water Strategy Far North Coast Implementation Plan

2.2 KEY FEATURES

Key features of the site and surrounds that could affect or be affected by the Proposal are discussed below.

2.2.1 Local and regional community

Clarrie Hall Dam is situated on Clarrie Hall Dam Road, Uki, in the small rural locality of Doon Doon, approximately 15 km south-west of Murwillumbah and 4 km south-west of Uki in the Tweed Shire LGA (see Figure 1-1).

Access to the dam wall and spillway area is from Clarrie Hall Dam Road, which runs south from Kyogle Road. The southern extent of Clarrie Hall Dam is accessed from Crams Farm, located off Commissioners Creek Road.

The majority of the Doon Doon sub-catchment of the Tweed River Catchment consists of rural and agricultural land uses (more than 70% of land is zoned 1a Rural).

Land tenure

The Proposal is situated within several different existing land tenures. These are further detailed in the Schedule of Lands shown in Figure 2-2.

Seventeen properties have been identified as impacted by the implementation of the Proposal. To date, Council has either acquired, and/or has under contract, all, or a sub-divided portion, of 15 of the 17 identified affected properties. One property owner is not negotiating further until the EIS has been determined and Council has resolved to implement the Proposal. An area of about 1.91 hectares (ha) has been revoked from Mount Jerusalem National Park.

2.2.2 Landscape features

Important landscape features are discussed below.

Clarrie Hall Dam

Clarrie Hall Dam (see Figure 1-2 and Figure 2-3) consists of a concrete faced rockfill embankment, a concrete lined spillway, intake and outlet works constructed on a foundation of very hard/strong Rhyolite rock (of volcanic origin). The rockfill embankment has a height of 43 m, crest length of 175 m and a volume of about 160,000 cubic metres (m³). The crest width is 6 m, and the upstream and downstream slopes are 1V (vertical) to 1.3H (horizontal). The upstream slope is covered by a 300 millimetre (mm) thick concrete face slab which connects at the top to a wave wall along the embankment crest.

The present FSL of the dam is RL 61.5 m, which is 7 m below the embankment wave wall crest level (RL 68.5 m). The spillway is an ungated concrete chute with ogee weir and flip bucket located on the left abutment. The spillway chute and approach area between the dam toe slab and spillway crest are fully lined and have 6 to 8 m high walls. The spillway chute is 110 m long. The spillway crest is 22 m wide, and the chute width narrows to 12 m for much of its length.

Clarrie Hall Dam is located in a relatively remote rural setting. Recreational access to Clarrie Hall Dam is either via Clarrie Hall Dam Road to the spillway end of the dam, or from Crams Farm via Doon Doon Road and Commissioners Creek Road at the southern end of the reservoir. Clarrie Hall Dam is open to the public from 7 am to 5 pm (6 pm during daylight savings) all year round. Access is via security gates at the two access points: at the entrance to Crams Farm and at the intersection of Kyogle Road and Clarrie Hall Dam Road.

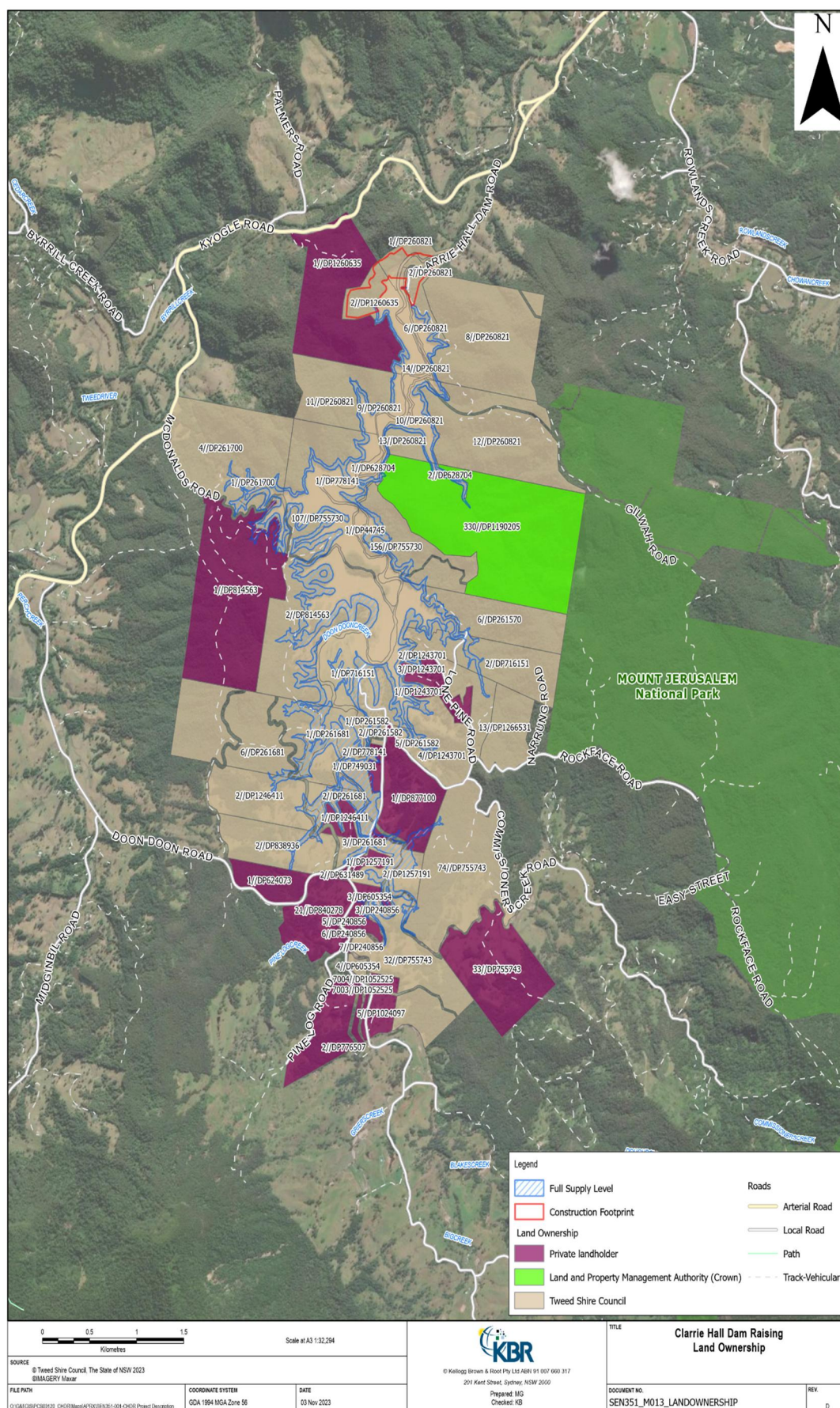


Figure 2-2 Land ownership



Figure 2-3 Panoramic view of spillway, dam wall and intake tower

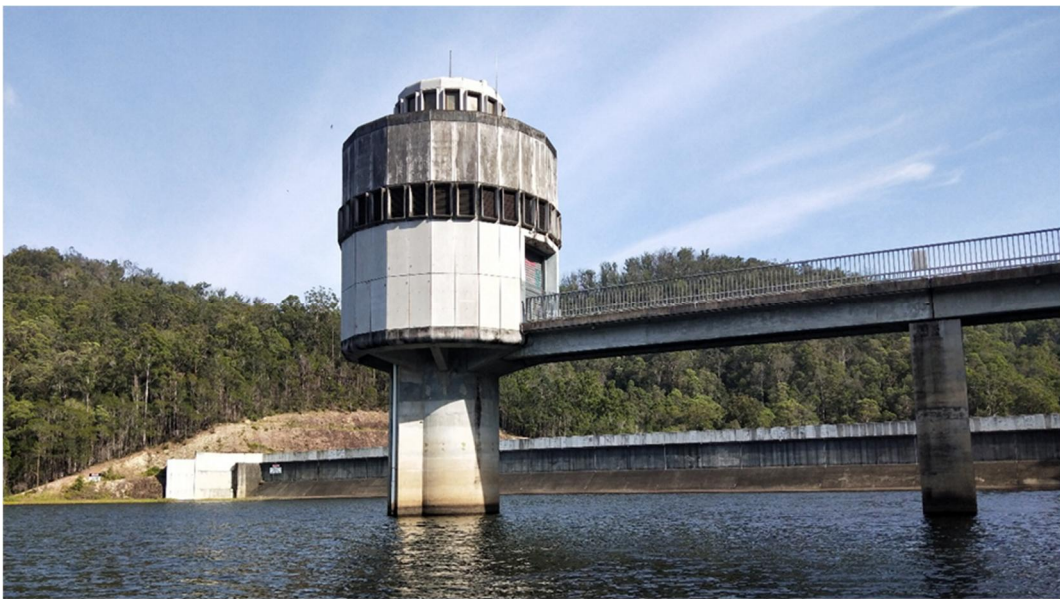


Figure 2-4 Intake tower

Permitted recreational uses at the dam include bushwalking, nature appreciation (bird-watching, nature photography), picnicking, recreational fishing, sailing, canoeing, kayaking and rowing, motorboating (electric motors only – fuel motors should be removed from boats), and special uses approved by Council (such as fuel motorboats for research and monitoring). Camping and overnight stays are prohibited.

Recreational facilities at the spillway area includes an amenities facility, shade shelters, a viewing area to the dam wall and spillway consisting of seating and interpretive signage, walking paths, visitor car parking, a boat ramp and security fencing. The public can walk across the top of the dam wall towards the spillway. Recreation infrastructure at Crams Farm includes an amenity building, shade structures and barbeques, a boat ramp and adjacent pontoon, a sealed access road and informal car parking. Two buildings that were identified as local heritage items, Doon Doon Hall and the Crams Farm complex, are also located at Crams Farm (see Figure 2-5). Doon Doon Hall is used for functions, with bookings managed by Tweed Shire Council.



Figure 2-5 a. Crams Farm internal road leading to pontoon and canoe/boat launch



Figure 2-5 b. Crams Farm internal road leading to canoe/boat launch area



Figure 2-5 c. Crams Farm internal road and picnic area



Figure 2-5 d. View of the dam from Crams Farm

Figure 2-5 Crams Farm recreation area

Surrounding catchment

The Doon Doon catchment incorporates parts of Nightcap National Park in the south-west and Mount Jerusalem National Park in the east and south (partially excised). The sub-catchment is predominantly vegetated with native bushland (~54%); however, a large portion is cleared (~30%) and is typically used for cattle grazing. The surrounding Council-owned land does not allow cattle, as it is managed for drinking water protection.

2.2.3 Risks and hazards

Hazards and risks identified during the risk workshops undertaken in 2017 for the Proposal relate to design and construction risk and hazards. Design risks that are being further investigated relate to site-specific seismic assessments, hydraulic performance of the new spillway to cater for predicted design floods, and flood security of the dam in relation to construction stages.

During construction, likely hazards and risks include restricted access due to floods, flooding of the worksite from valve releases, working under flood protection structures, bushfire, hazardous substances, and working in and around dangerous machinery.

An interim Dam Safety Emergency Plan (approved by the NSW Dams Safety Committee) for the construction period that takes into account the changed conditions and operation of the dam during the works would be required.

Risks and hazards associated with flooding, bushfire prone land, contaminated land, soils and potential landslips and climate change are further discussed in Chapter 6.

2.3 CUMULATIVE IMPACTS

Currently, the Proposal is unlikely to generate cumulative impacts with other potential future projects. A cumulative impact assessment would be conducted for the EIS in accordance with the *Cumulative Impact Assessment Guidelines for State Significant Projects* (DPE 2022).

2.4 EXISTING AGREEMENTS

The proposed raising of Clarrie Hall Dam would require the acquisition of inundated land and would include a 7 m maintenance zone above RL 77 m. All affected landholders have been approached to discuss property acquisitions or boundary adjustments, including fencing realignments and temporary leases.

3 Project

3.1 PROJECT DESCRIPTION

In 2018, a detailed concept design was prepared by NSW Public Works Advisory (PWA). The options assessment and concept design for the raised dam and its components were based on hydrological studies, geotechnical investigations, and seismic and structural assessments. The preferred option for the dam raising incorporates increasing the height of the existing concrete faced rockfill embankment and constructing a new concrete lined spillway higher up in the left abutment. The existing intake tower and access bridge would also be raised.

The optimum size of the proposed raised Clarrie Hall Dam is 42,300 ML, based on raising the dam wall height by 8.5 m to a height of RL 70 m (AHD). The raised dam would, as a result, provide adequate water supply to the Tweed Shire until at least 2065. Raising the wall height further was not considered feasible due to topographical constraints in the catchment.

The concept design includes:

- constructing access roads to construction areas and establishing the construction site
- re-establishing the quarry used to construct the existing dam
- removing and storing parapet walls for reuse
- increasing the base width of the valley-side abutment and raising the crest of the concrete-faced rockfill embankment to RL 70 m
- constructing a new concrete lined spillway higher on the west abutment
- extending the upstream concrete face to the new crest height
- raising the intake tower and access bridge
- constructing a new section of the Clarrie Hall Dam Road to provide access to the east abutment of the dam wall
- establishing new recreation and operational facilities including an amenities block, public shelters, viewing areas, interpretation signage, paths, car parks, landscaping, security fences, lighting, monitoring equipment and a boat ramp.

The Concept Design Report is provided in Appendix D.

In addition, construction activities would include:

- upgrading the Kyogle Road and Clarrie Hall Dam Road intersection
- replacing MCabes Bridge and realigning Commissioners Creek Road
- removing or reconstructing impacted infrastructure and facilities at Crams Farm
- relocating Telstra assets
- realigning power line easements along Doon Doon Road and Commissioners Creek Road.

Further work has recently been completed that identified several options for locating staff accommodation, the concrete batching plant and site offices during construction. These areas are discussed in section 3.2.1.1.

An overview of the Proposal is shown in Figure 1-2.

3.2 PROJECT AREA

The location of the Proposal is the existing Clarrie Hall Dam. The disturbance areas include the main construction area, ancillary works areas, FSL and areas where potential changes in upstream and downstream hydrology may occur, including the probable maximum flood (PMF). The types and extent of these disturbance areas are discussed below.

Approximately 150 ha of native forest, 13 ha of native plantation and 70 ha of predominately cleared land are estimated to be impacted due to construction and operation. The estimated extent of impact areas will be revised during preparation of the EIS.

3.2.1 Construction disturbance area

The construction disturbance area and associated activities include the dam wall area and ancillary areas.

Land title information for the proposed construction disturbance areas is shown in Table 3-1.

Table 3-1 Land tenure information for the proposed construction disturbance area

Lot and DP no.	Proposed use
Lot 1 / DP260821 Lot 2 / DP1260635	Spillway
Lot 14 / DP260821 Lot 2 / DP260821	Site offices and compounds
Lot 14 / DP260821 Lot 1 / DP260821 Lot 2 / DP260822	Embankment and site compound areas
Lot 1 / DP260821 Lot 14/DP260821	General haul road
Lot 6 / DP260821 Lot 2 / DP 260821	Realignment of Clarrie Hall Dam Road and associated works including the new boat ramp and raised tower and access bridge
Lot 2 / DP1260635	Quarry and quarry haul road(s)
Lot 76 / DP755730 Lot 8 / DP46078 Lot 10 / DP46078 Lot 10 / DP 46048 Lot 9 / DP 46048	Potential location for concrete batching plant and/or construction worker accommodation.
Lot 29 / DP755730	Potential location for concrete batching plant and/or construction worker accommodation.
Lot 5 / DP1130130	Potential location for concrete batching plant and/or construction worker accommodation.

Lot and DP no.	Proposed use
Lot 1 / DP877100 Lot 1 / DP749031 Lot 2 / DP778141 Lot 2 / DP261681 Lot 3 / DP261681 Lot 2 / DP838936 Lot 2 / DP 631489 Lot 2 / DP229800 Lot 1 / DP1257191	Realignment of Commissioners Creek Road and new McCabes Bridge
Lot 1 / DP716151	Potential use as workforce accommodation and McCabes Bridge construction compound Potential location for Borrow Pit

3.2.1.1 Dam wall area

The dam wall construction disturbance areas comprise the following activities:

- increasing the height of the existing concrete faced rockfill dam embankment
- constructing a new intake tower and bridge
- constructing a new concrete lined spillway higher up in the west abutment
- excavating the quarry and haul roads
- establishing construction compounds and stockpile sites
- realigning Clarrie Hall Dam Road
- new recreational areas, boat ramp, operational facilities and amenities.

Downstream of the current dam embankment wall and stockpile areas a temporary crossing at Doon Doon Creek is proposed to support the construction activities. The temporary crossing would be developed using rockfill material to enable construction equipment to travel between the dam wall construction site and the quarry.

The construction disturbance area also includes the following, potentially located a short distance from the dam wall area:

- workers accommodation
- concrete batching plant.

Further details on the construction works are below.

Raised embankment

Raising of the concrete face rock filled embankment is proposed, as shown in Figure 3-1. The concept design indicates the re-use of the existing precast concrete parapet walls. These would be removed and stored onsite for later re-use. Additional wall units may be required and are anticipated to be fabricated offsite. They can be delivered to site as needed, therefore requiring no additional storage.

The new top of the parapet walls on the embankment wave wall crest would be at RL 77.0 m AHD to match the maximum flood level. The crest pavement level behind the parapet wall would be at RL 75.5 m (AHD) and the crest pavement width would be 5 m.

The embankment upstream and downstream slopes would be 1.3H to 1V, matching the existing embankment slopes.

Intake tower, access bridge and hoist house

The intake tower is used to transport water out of the reservoir and control the flow of water through the outlet pipe, into Doon Doon Creek. The existing vertical reinforced concrete circular shaft intake tower is proposed to be raised by 8.5 m, resulting in the total height of the proposed intake tower to be 42.15 m. The raised tower would incorporate 3 additional water inlet ports, for a new total of 11 water inlet ports, to facilitate selective water withdrawal, supporting a series of trash racks and shutters with a crane over the tower deck.

The access bridge enables safe access to the intake tower. The current intake tower access bridge consists of two unequal spans 16 m and 28 m long, supported by a reinforced concrete pier and abutment block. The existing bridge is to be dismantled, disposed offsite and replaced with a new bridge to match the raised height of the intake tower.

A new hoist house similar to the existing hoist house is proposed to be constructed on top of the raised intake tower. The raised intake tower would have the radial beams built into its wall and a peripheral beam running on the outer edge of the radial beams (similar to the existing configuration) to support the floor and super structure. The existing compressed AC cladding would be replaced with other suitable material in the new hoist house.

The location of the intake tower, access bridge and hoist house and crane required during construction works is shown in Figure 3-1.

Spillway

The existing spillway would be covered over by the raised embankment. To ensure the spillway has suitable discharge capacity, a new spillway channel has been designed to pass the PMF. The new spillway is proposed to be located higher in the left (western) abutment, as shown in Figure 3-1. The new spillway crest is designed at RL 70.0 m (AHD), which corresponds to the FSL of the raised dam. The spillway crest design is 55 m wide, and the spillway channel would reduce to 15 m wide at the downstream end, with a flip bucket as the terminal structure.

The new spillway channel concept design is for a fully concrete lined structure. The proposed spillway and construction impact area is shown in Figure 3-1.

Clarrie Hall Dam Road realignment

A section of Clarrie Hall Dam Road would be upgraded to ensure alignment of the road with the new FSL, higher in the landscape (see Figure 3-1). A vertical cut 8–10 m high, adjacent to the existing road, would be required. The boat ramp for operations and maintenance personnel would be relocated as part of the access road upgrade.

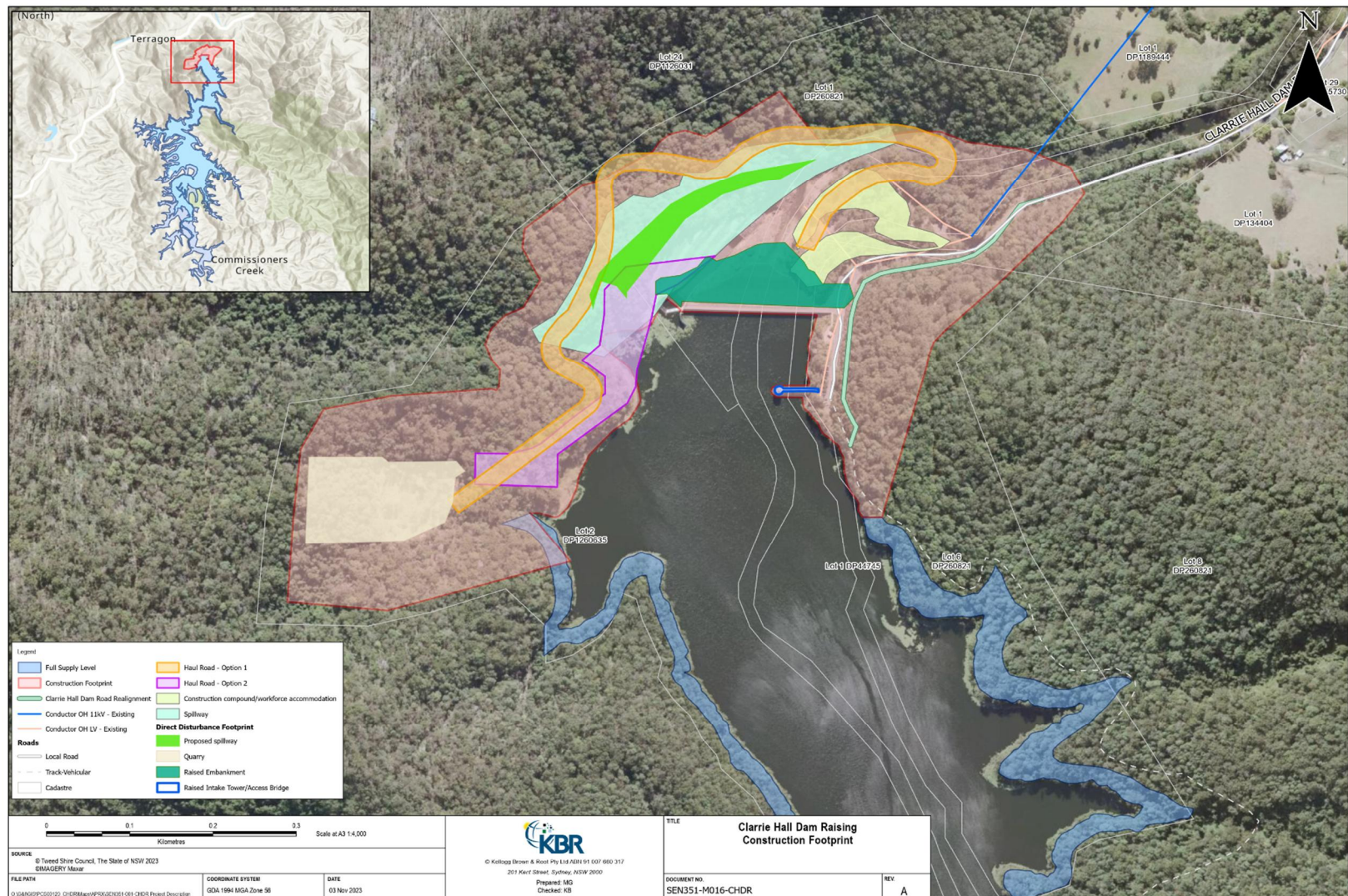


Figure 3-1 Embankment construction area

Quarry and haul road

A quarry was established during construction of the existing Clarrie Hall Dam to supply the required volumes of suitable rockfill material. The quarry is located approximately 600 m upstream of the existing dam wall. The quarry would be re-established and expanded to supply material required for the Proposal.

Material sourced through the quarry expansion would be used in construction of the raised dam wall, new spillway, new access road and McCabes Bridge works. The expanded quarry footprint would include an area required for the topsoil, overburden and rockfill stockpiles needed during the construction phase. Waste rock material from the new spillway construction area would be used to backfill the quarry void and develop the final landform. Haul roads suitable for heavy vehicles would be required to transport rockfill material between the quarry site and the dam wall embankment. Two haul route options are proposed, as shown in Figure 3-1.

Construction compounds and stockpile sites

Construction site offices, construction compounds, laydown areas and other facilities are proposed to be located as shown in Figure 3-2.

The construction compound area downstream of the embankment, is a key access point to all the construction work sites. However, it is also the location of critical dam operational assets including the outlet tunnel, outlet control valves and discharge valves.

This location requires most of the area to be cleared and graded to support siting of office accommodation and welfare facilities (toilets, canteens, storerooms).

Concrete batch plant

Several options are proposed for the location of a concrete batch plant, as shown in Figure 3-2. The batch plant requires a minimum area of 5,000 square metres. This includes areas for the batch plant, silos, conveyors, material bins, offices, material stockpiles and yard, delivery and concrete truck movement and circulation. Additional buffer areas for environmental controls would also be required.

Because the concrete materials, sands and other cement components are coming from external sources, there will be truck movements related to external deliveries. Having a location just outside of the main site allows these vehicles to deliver without needing to access the main works site.

Of the concrete produced, 70% would be used for the spillway, 25% for the raised embankment, 2% for the intake tower and 3% for McCabes Bridge.

Concrete supply will also require over 3 ML of water for concrete mix alone. Proximity to a suitable water source and approval for extraction are key considerations.

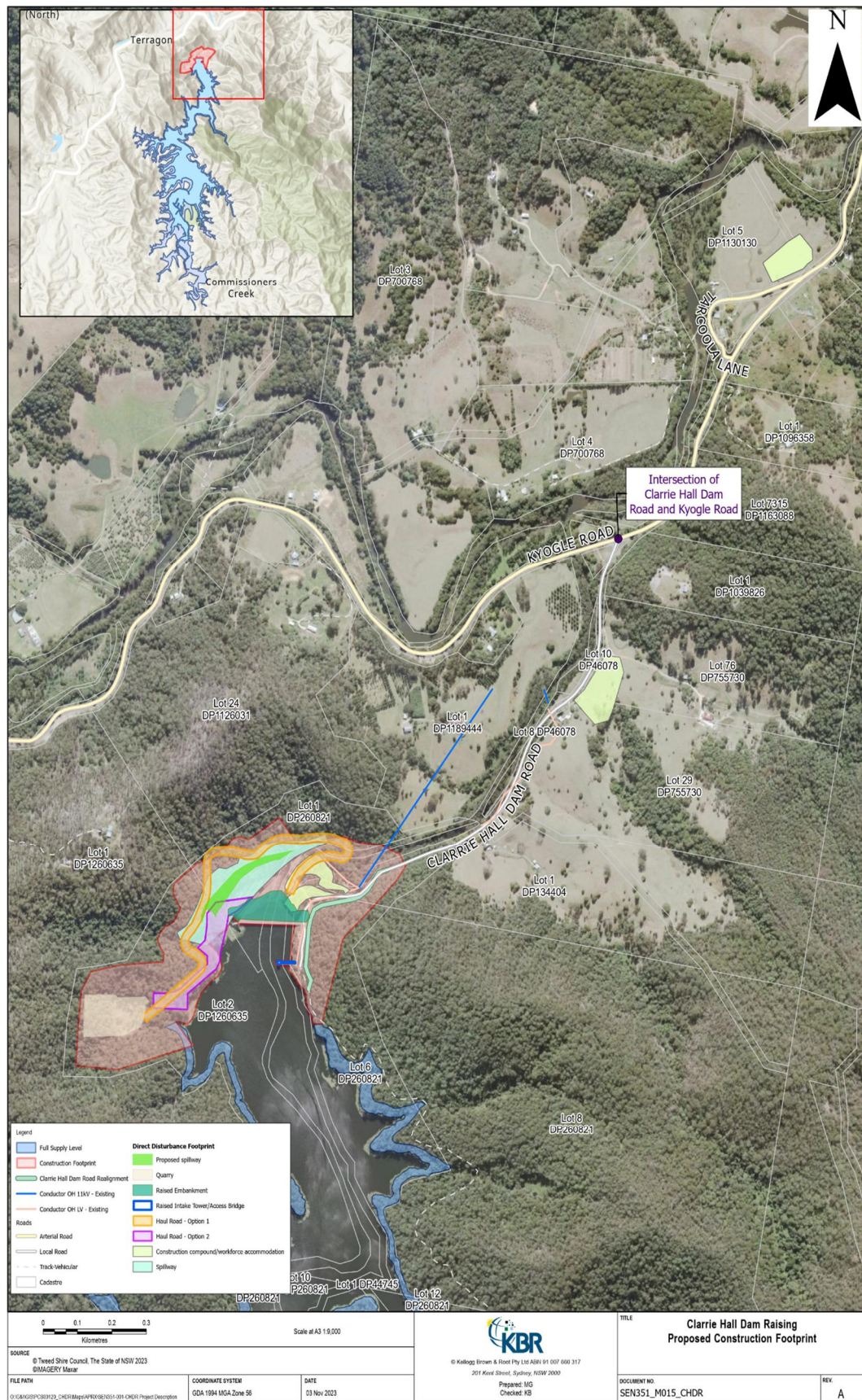


Figure 3-2 Proposed location of construction compounds, site offices, welfare buildings and access

Recreational facilities

The existing recreational infrastructure located in downstream construction areas would be relocated or removed. Upon completion of the dam raising, the rockfill stockpile would no longer be required. Therefore, the area would be developed into a new recreational and operational facilities area including amenities facility, public shelters, viewing areas, interpretation signage, pathways, car parking, landscaping, security fencing and lighting. Dam operations monitoring equipment would be installed, and the boat ramp would be relocated to align with the new access road.

Site-office accommodation

The main site-office complex can be located as one complex or as multiple discrete elements.

Each work zone will likely have its own satellite offices and facilities in addition to the main office complex.

Several options are proposed for the locations of the main site office, as shown in Figure 3-2.

The construction disturbance area is shown in Figure 3-3 and Figure 3-4.

Workforce accommodation

Assessment of worker numbers per activity based on the concept design construction schedule was used to estimate a peak workforce of around 180 persons at the main dam site.

The local town of Murwillumbah, 20 minutes from Clarrie Hall Dam, does not have enough hotels or other accommodation that could allow for temporary worker accommodation.

Tweed Heads and other coastal areas would offer suitable accommodation options; however, a minimum of 50 minutes travel time to and from site may be considered excessive and potentially lead to fatigue and safety issues both onsite and whilst travelling. A shuttle bus service is a potential option. However, the logistics of these services are complex and often not fully utilised by workers.

Therefore, the option for onsite temporary workforce accommodation has been included. It is estimated that an accommodation facility for 100 to 120 personnel would be required during construction.

An area of approximately 12,000 square metres would be required for cabins, facilities and car parking area.

Several options are proposed for the location of workforce accommodation, as shown in Figure 3-2 and Figure 3-4.

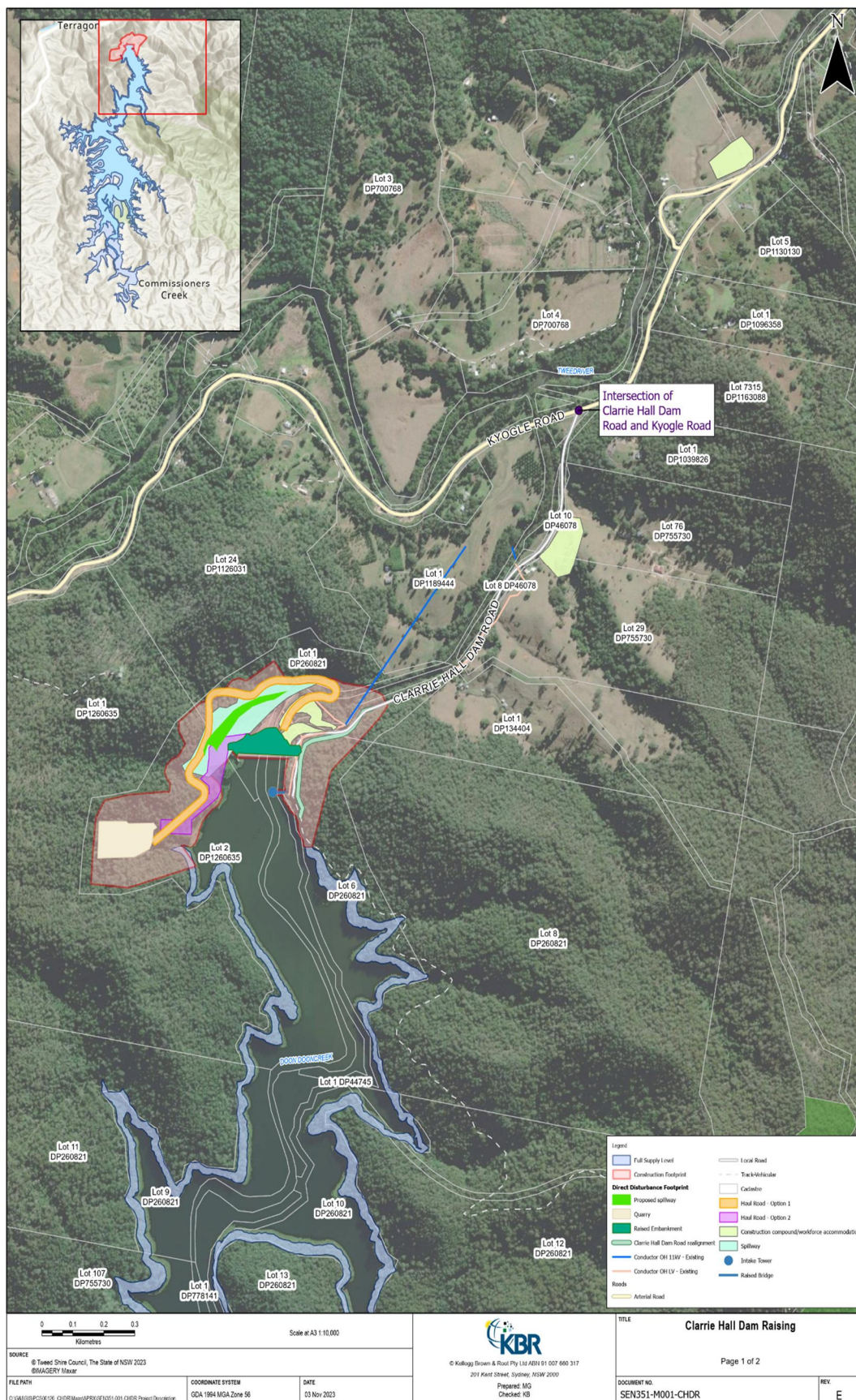


Figure 3-3 Dam construction disturbance area (north)

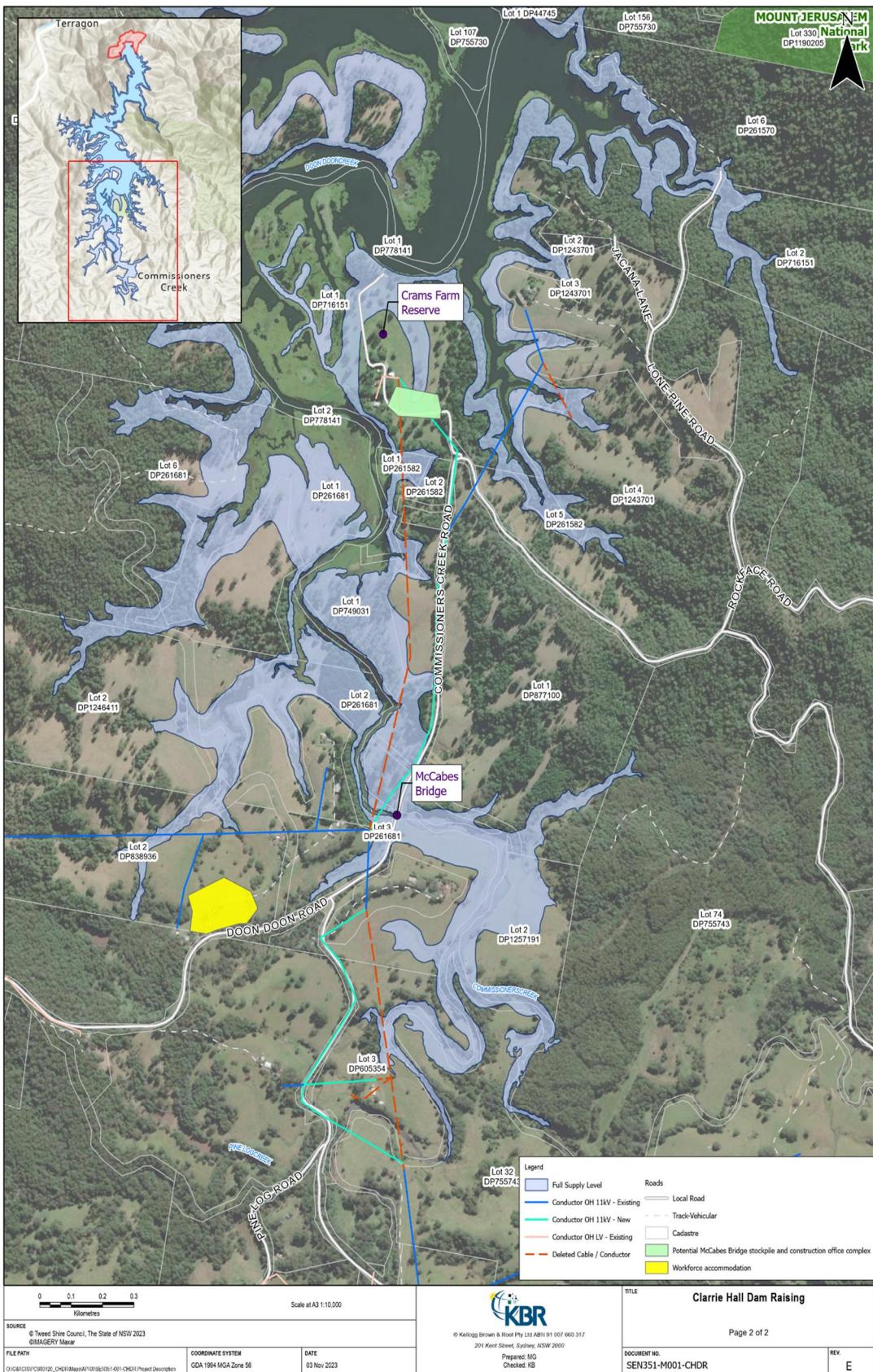


Figure 3-4 Construction disturbance area (south)

3.2.1.2 Ancillary infrastructure

Upgrade to Kyogle Road and Clarrie Hall Dam Road intersection

The Kyogle Road and Clarrie Hall Dam Road intersection is the primary access road to the Proposal's construction site. An assessment of the intersection to accommodate construction workforce access and transport of rockfill material required for the McCabes Bridge upgrade from the quarry would be conducted as part of the transport and traffic assessment. The assessment will determine if works are required to upgrade the intersection. The potential area of upgrade is shown in Figure 3-5.

Recreational facilities – Crams Farm

The proposed FSL would inundate areas of Crams Farm such as the boat ramp (refer to Figure 3-3). It is proposed to either remove or relocate various infrastructure, such as the boat ramp, pontoon, signage and access roads.

No changes to the amenity facilities or Doon Doon Hall would occur.

The access road at Crams Farm would be inundated at PMF (refer to Figure 6-1).

Existing property fences

Existing property fences located within the proposed FSL would be removed and replaced above FSL, where required.

McCabes Bridge and Commissioners Creek Road realignment

The existing McCabes Bridge is approximately 20 m long and 4 m wide. It is of a concrete girder/deck type and consists of 3 spans. The existing bridge would be inundated by the proposed FSL.

The proposed replacement bridge and realignment of Commissioners Creek Road would include:

- a two-lane reinforced concrete bridge raised approximately 5.5 m above the existing bridge level
- three 18 m spans
- a width of 8.4 m
- a length of 50 m.

The entire realignment is approximately 1,000 m to account for gullies and to reach the design level of RL 72.5 m, as shown in Figure 3-5.

There are 2 land parcels that could be used for construction compounds, laydown areas and stockpile locations close to the proposed new McCabes Bridge and road realignment. These are:

- Lot 2 DP838936 – this site is located at the southern end of the McCabes Bridge alignment works, with access off Doon Doon Road
- Crams Farm Reserve – Lot 1 DP716151, which is located approximately 700 m north of the northern end of the McCabes Bridge alignment works, with sealed access from Commissioners Creek Road.

Both of these sites, as shown in Figure 3-6, are relatively flat and have open areas of grassland.



Figure 3-5 Kyogle Road and Clarrie Hall Dam Road intersection area

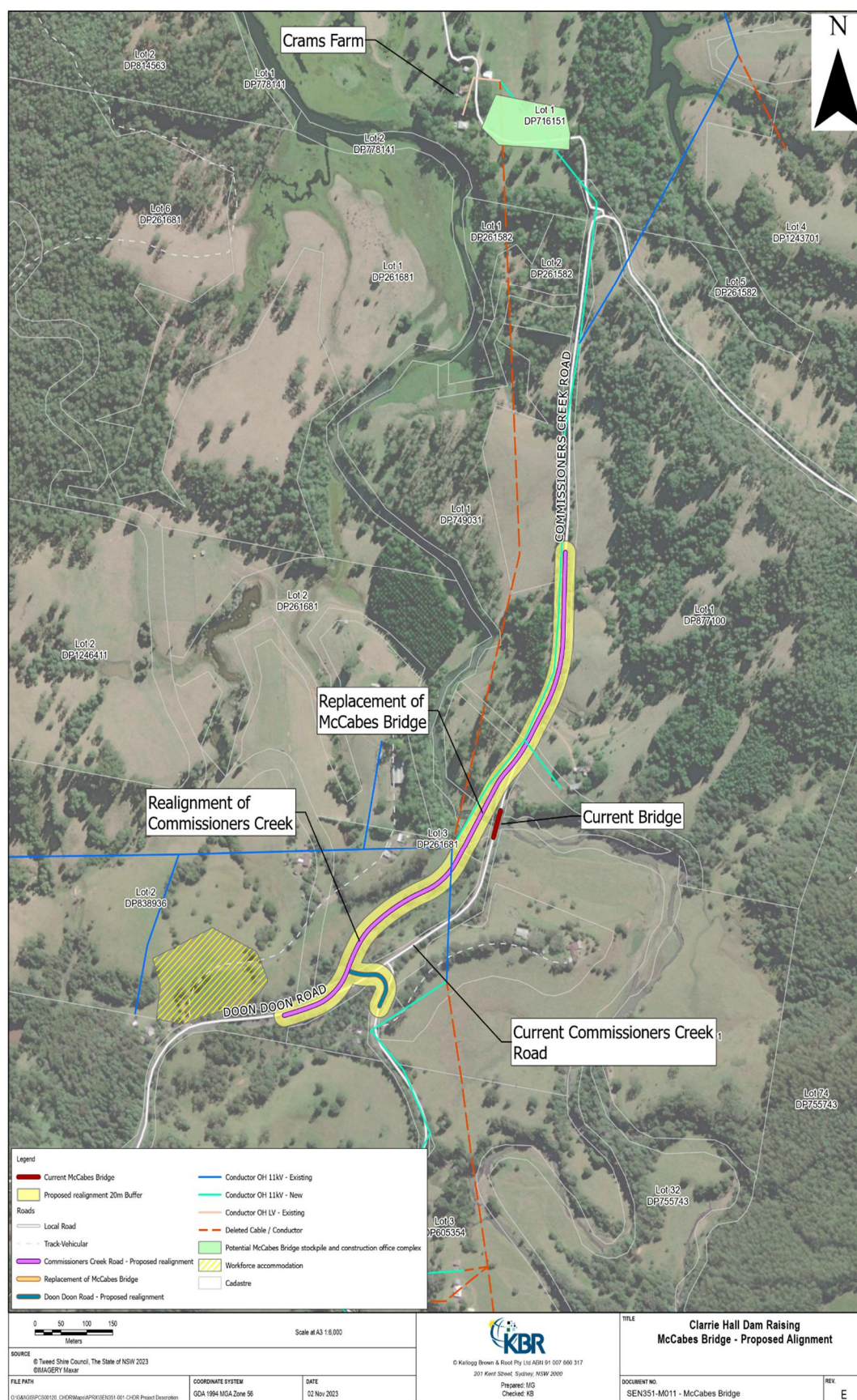


Figure 3-6 McCabes Bridge and Commissioners Creek Road realignment disturbance footprint

Utilities

Utilities to the dam construction area may require upgrading.

Relocation of the water supply to public toilets and other facilities may also be required.

At the southern end of the dam, some existing service provision assets are located within the FSL area. These structures must be realigned to ensure continued power supply to local residents, as shown in Figure 3-3. New poles and connections would be required along the roadside for sections of Doon Doon Road and Commissioners Creek Road for sections of the network located within or near the FSL area. Telstra assets would require relocation.

Timber harvesting and areas of deeper water around FSL

Timber harvesting of some existing plantation areas and possibly some select trees for fencing or other uses may occur in areas that would be inundated. Creating areas of deeper water around the new FSL to assist in algae growth mitigation is also proposed.

Decommissioning and rehabilitation

Decommissioning of existing assets would be required.

3.2.2 Operational footprint

The operational disturbance areas include the following:

- area of inundation increased to the area below the RL 70 m contour, which is the waterline boundary at FSL
- area between FSL and PMF (recent flood modelling has found minimal impacts above the FSL – see section 6.1)
- downstream areas due to changes in flow (recent modelling has found limited downstream changes in hydrology – see section 6.1).

The land title information for the proposed operational FSL and PMF level are shown in Table 3-2 and Figure 2-2.

Table 3-2 Property information for the proposed operational disturbance area

Lot and DP no.	Potential impact type
FSL	Lot 1 / DP260821; Lot 6 / DP260821; Lot 1 / DP44745; Lot 74 / DP755743; Lot 6 / DP261570; Lot 2 / DP716151; Lot 2 / DP261582; Lot 3 / DP605354; Lot 4 / DP605354; Lot 32 / DP755743; Lot 6 / DP261681; Lot 1 / DP624073; Lot 2 / DP631489; Lot 1 / DP261582; Lot 5 / DP261582; Lot 1 / DP261681; Lot 2 / DP261681; Lot 3 / DP261681; Lot 1 / DP261700; Lot 4 / DP261700; Lot 1 / DP716151; Lot 1 / DP749031; Lot 107 / DP755730; Lot 156 / DP755730; Lot 2 / DP814563; Lot 1 / DP814563; Lot 2 / DP838936; Lot 1 / DP877100; Lot 1 / DP628704; Lot 2 / DP628704; Lot 3 / DP240856; Lot 5 / DP240856; Lot 6 / DP240856; Lot 330 / DP1190205; Lot 7 / DP240856; Lot 2 / DP1243701; Lot 3 / DP1243701; Lot 4 / DP1243701; Lot 2 / DP1246411; Lot 2 / DP1257191; Lot 1 / DP1260635; Lot 8 / DP260821; Lot 9 / DP260821; Lot 10 / DP260821; Lot 11 / DP260821; Lot 12 / DP260821; Lot 13 / DP260821; Lot 1 / DP778141; Lot 2 / DP778141; Lot 10 / DP1139798; Lot 13 / DP1266531
PMF (RL 77 m)	Lot 7003 / DP1052525; Lot 2 / DP776507; Lot 7004 / DP1052525; Lot 5 / DP1024097; Lot 21 / DP840278; Lot 1 / DP1243701; Lot 1 / DP1246411; Lot 1 / DP1257191; Lot 33 / DP755743

The operational footprint includes upstream and downstream changes in inundation and hydrology. Figure 3-7 and Figure 3-8 show the proposed inundation level at FSL.

The PMF extent has been modelled and is shown in Figure 6-1 in section 6.1.2.

Water Sharing Plan for Tweed River

The Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources Order 2023 (2023 No 335) under the *Water Management Act 2000* provides operational rules for managing water.

3.3 CONSTRUCTION ACTIVITIES

The construction activities for the completion of the Proposal, including construction infrastructure, methodology, sequencing, activities and materials, are discussed in the following sections.

3.3.1 Construction infrastructure

The dam wall raising concept design showing the spillway, embankment and intake tower is shown in Figure 3-9 to Figure 3-12.

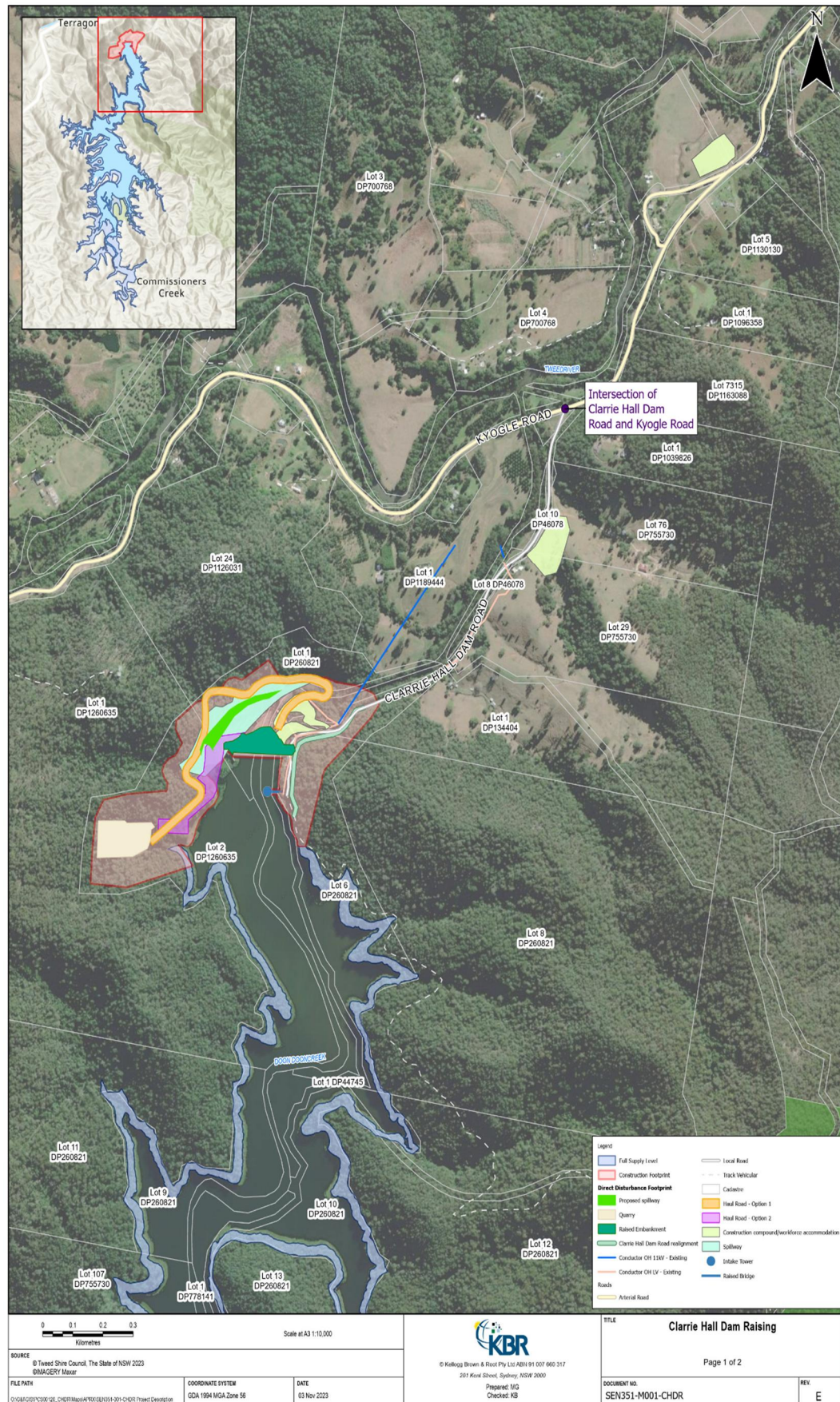


Figure 3-7 Full supply level (north)

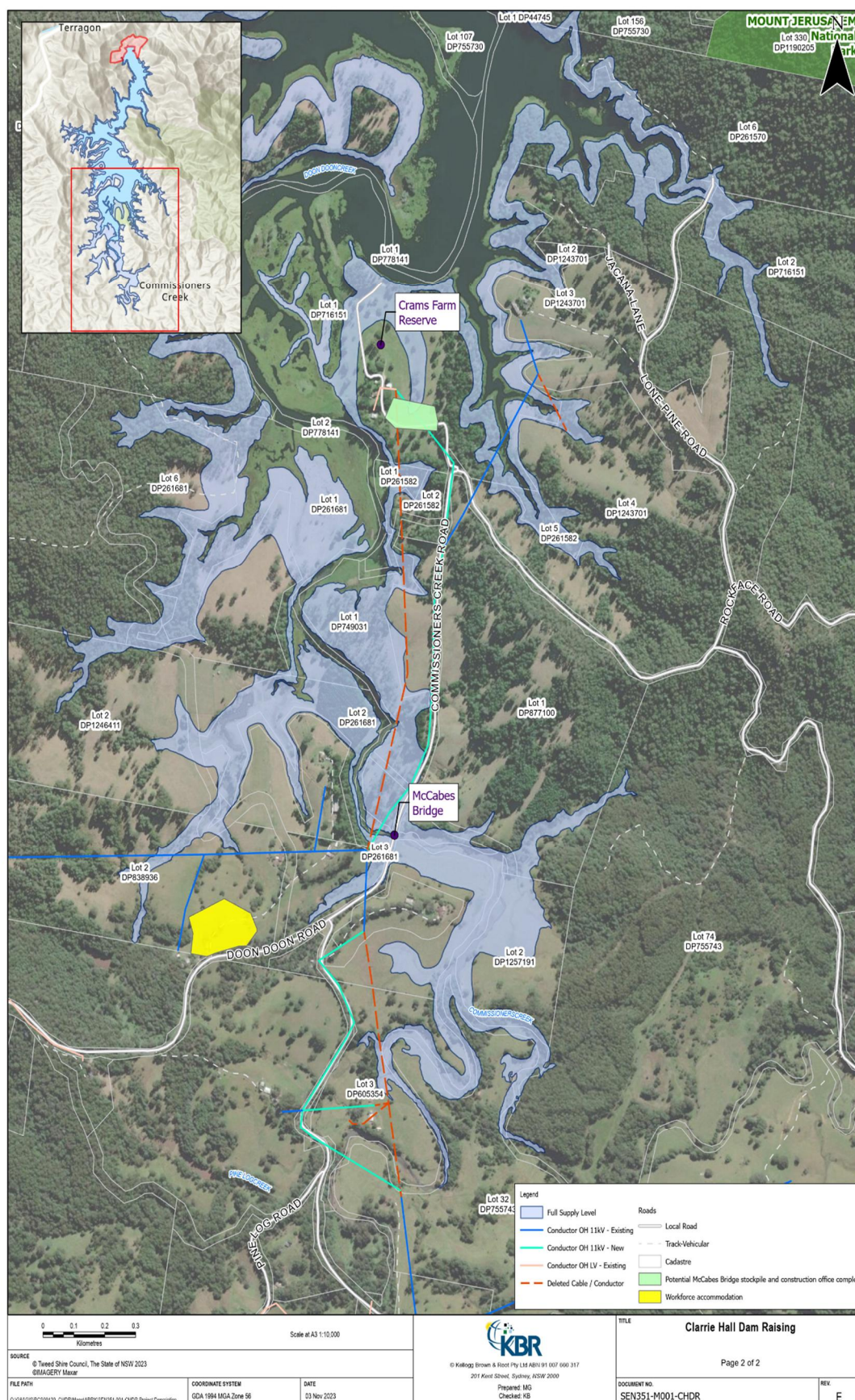


Figure 3-8 Full supply level (south)

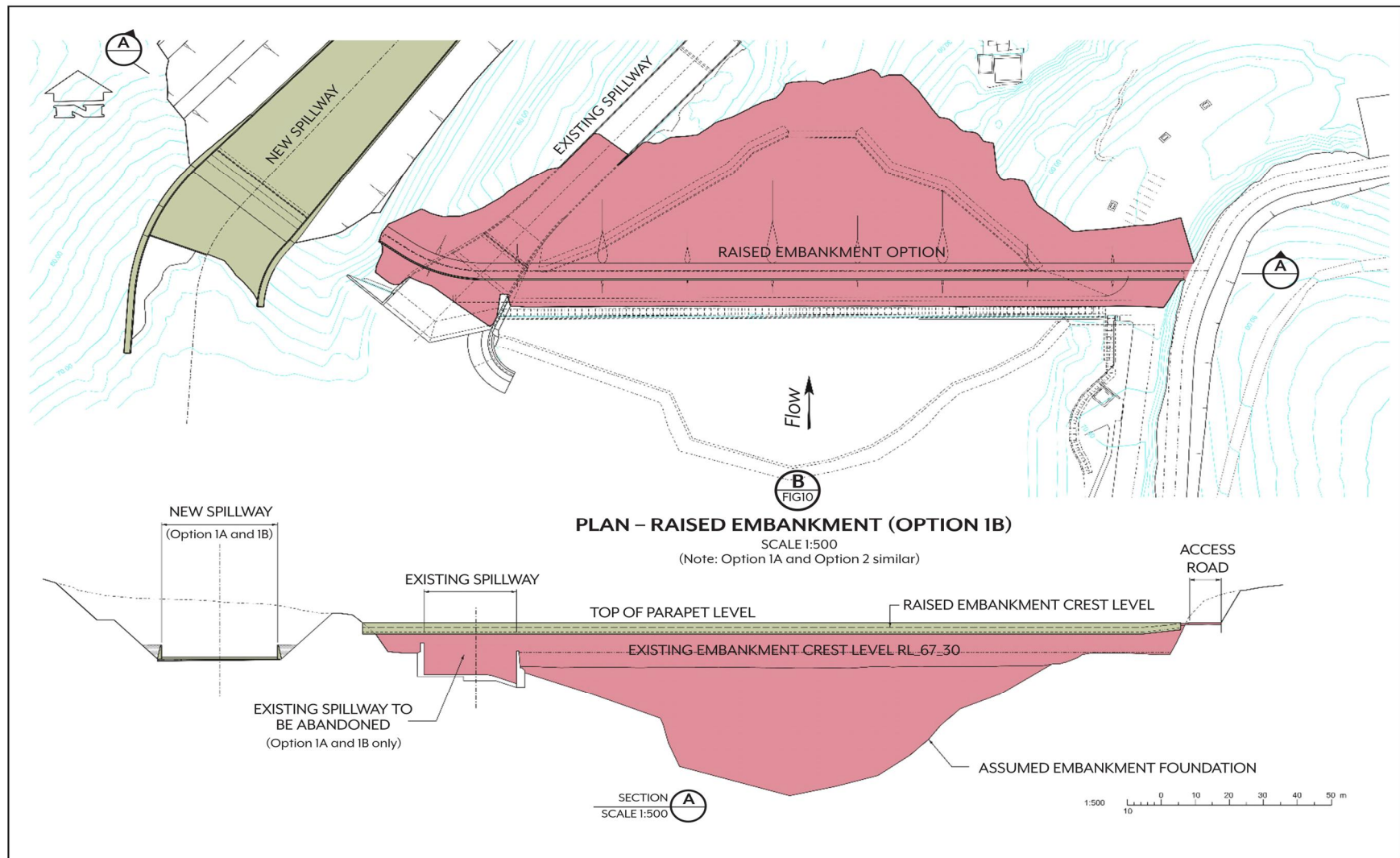


Figure 3-9 Raised dam wall and new spillway concept design
(Source: PWA, 2018)

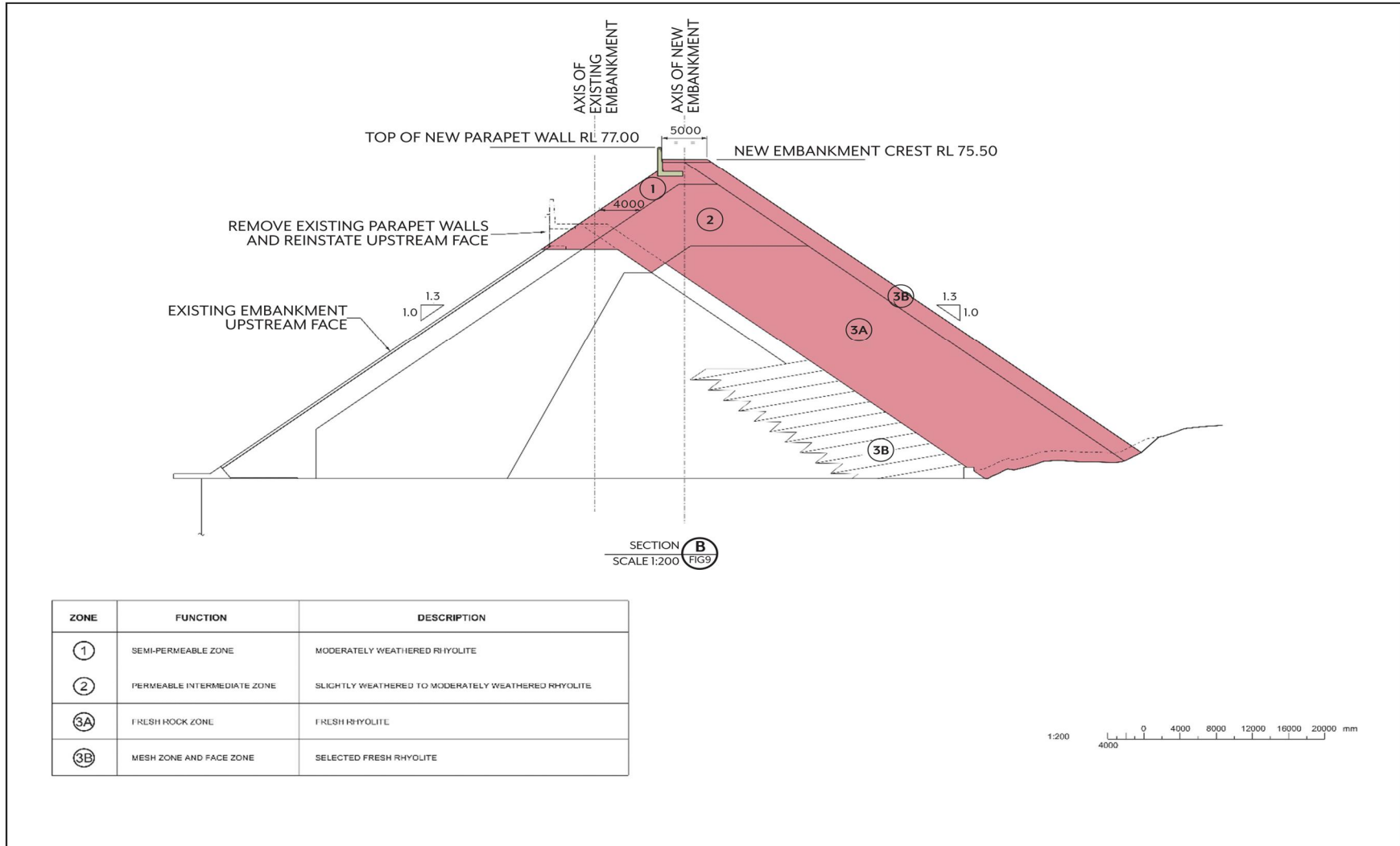


Figure 3-10 Raised dam wall concept design
(Source: PWA, 2018)

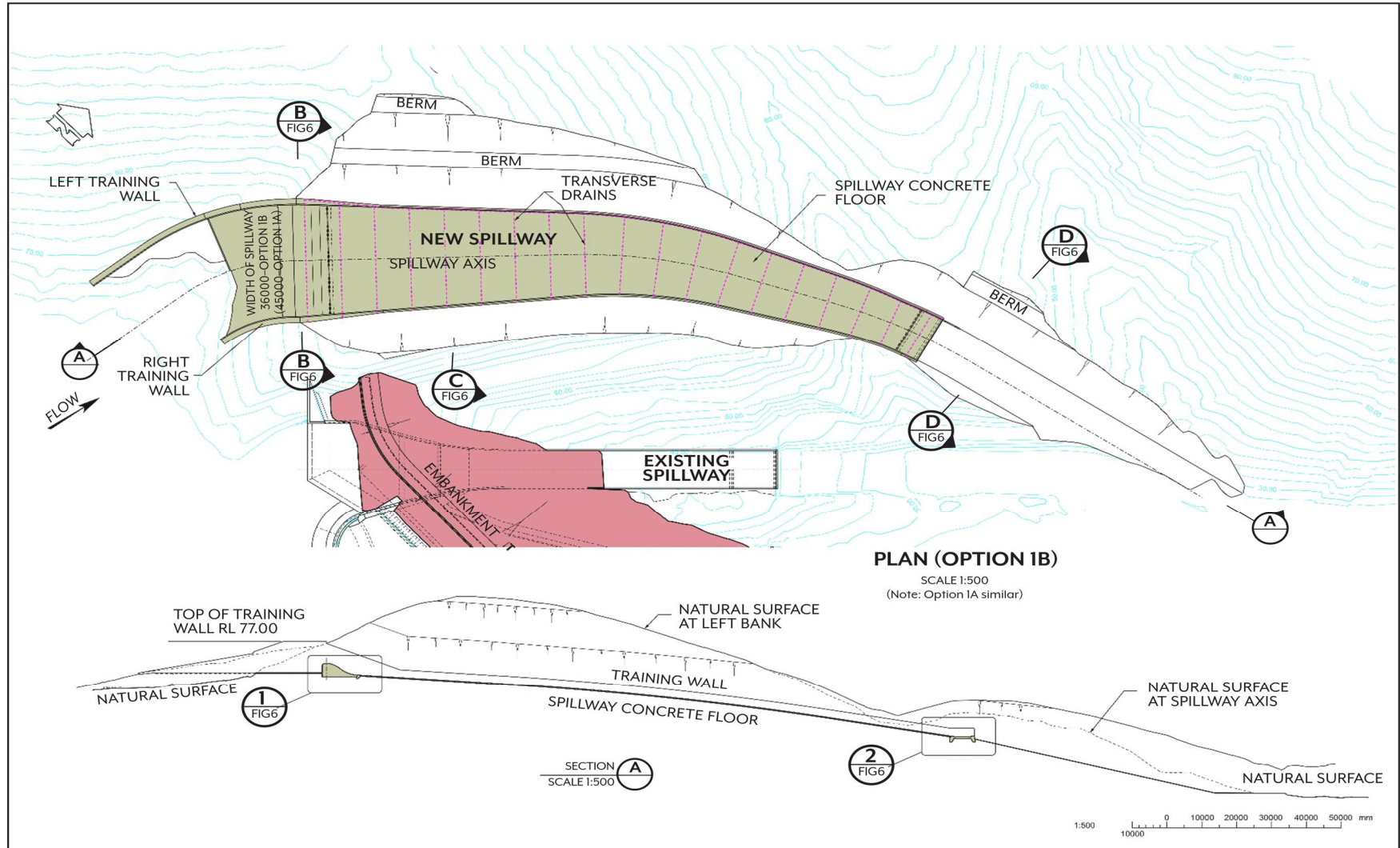


Figure 3-11 New spillway concept design
(Source: PWA, 2018)

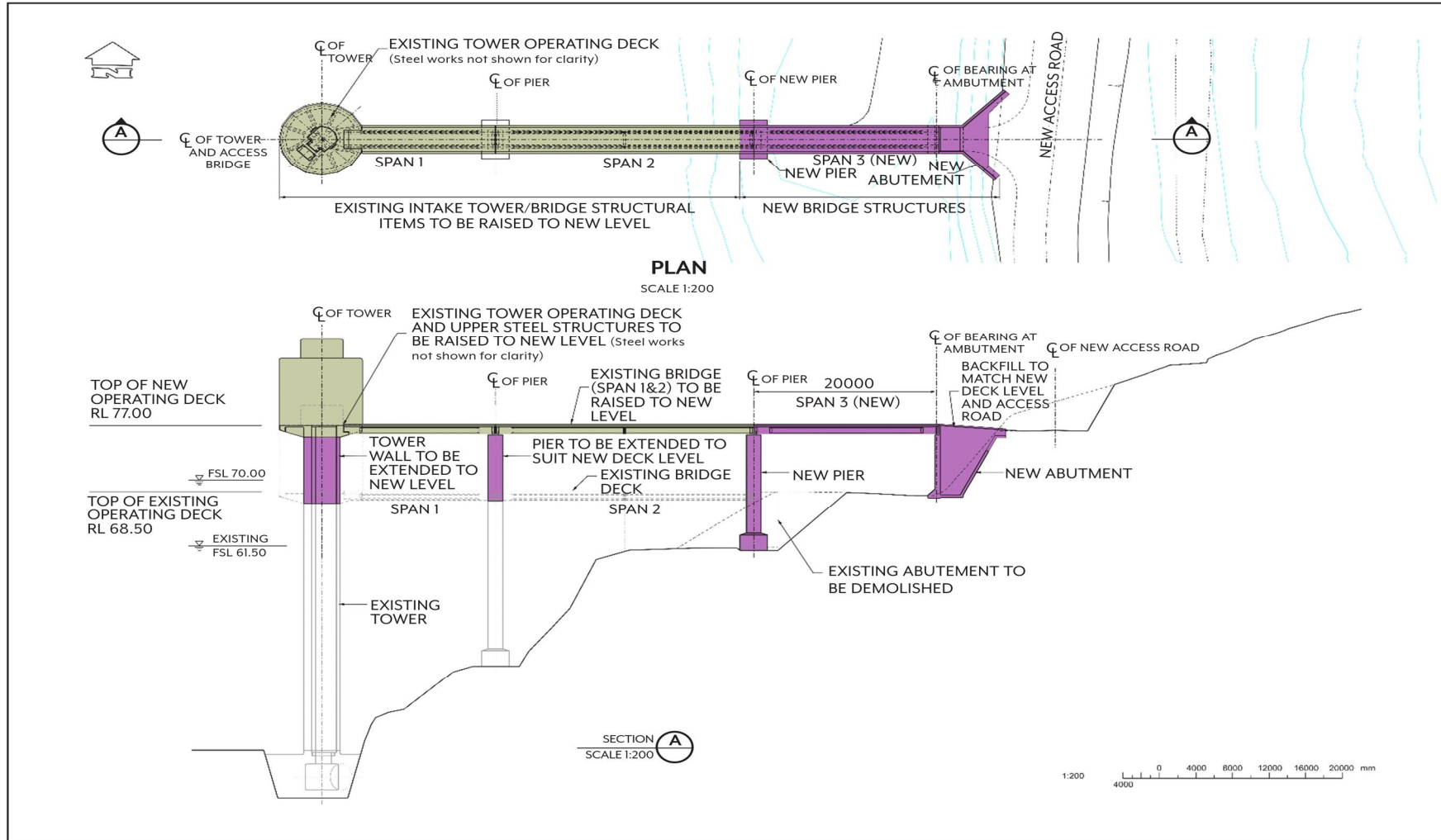


Figure 3-12 New intake tower concept design
(Source: PWA, 2018)

The following construction infrastructure, plant and equipment are required:

- temporary contractor's and principal's office, amenities and associated work areas
- plant and heavy equipment
- truck and vehicle access and parking
- materials storage areas
- an onsite concrete batching facility (which is proposed). A typical onsite concrete batching facility would likely consist of a trailer-mounted concrete mixer, cement bins, sand and aggregate stockpiles and a storage container for various equipment and tools
- a rock crusher, which would consist of a tracked mobile crushing unit, conveyor belts, feeder and engine
- crane
- road access to the construction area
- road access to and from the quarry
- realignment of Clarrie Hall Dam Road.

All potential dam construction sites are downstream of the dam, except the road access to and from the quarry.

3.3.2 Construction methodology

Contractor site facilities, workshops and material storage areas would be established before construction.

Some lowering of dam storage (approximately 300 mm below FSL is anticipated) would be required to allow for construction of the raised embankment including toe slab extension, grout curtain extension and upstream concrete face slab extension. Some diversion/dewatering works would be required to ensure flood-free construction, particularly for raised dam abutments.

Rock would be transported from the new spillway excavation to the stockpile (likely downstream) and to disposal (on- or offsite).

Rock would be delivered progressively to the dam site from the quarry along the haul roads through the left bank of the storage. Existing access routes to the site would have to be altered to allow for a new main access road higher in the right abutment and for construction access generally.

Sequencing of construction

The proposed stages and sequencing of construction include:

1. establishing site compounds, parking, offices and materials stockpile areas
2. site establishing, including clearing and grubbing
3. clearing and construction access roads
4. decommissioning the amenities block, viewing areas, recreation areas and other infrastructure, and electrical supply where required

5. removing the existing concrete parapet wall from the current dam embankment including removal and storage of the recyclable precast concrete panels
6. removing the crest pavement from the existing embankment to expose underlying rockfill
7. excavating the left and right abutments for the upstream concrete toe slab extension
8. stripping the foundation downstream of the existing embankment for the raised embankment footprint including removal of concrete gutter and seepage weir
9. demolishing the concrete walls at the existing spillway entrance and disposal of waste
10. excavating the new spillway channel higher in the left abutment (some blasting may be required in the lower downstream areas)
11. excavating the new permanent access road higher in the right abutment
12. stockpiling suitable rock from the spillway excavation, and disposing of the remainder
13. establishing haul routes between the old quarry and the dam site
14. constructing the upstream concrete toe slab extension in both the left and right abutments
15. installing the grout curtain extension through the upstream toe slab extension on the left and right abutments (no blasting is envisaged, but slope correction may be required)
16. stripping of the old quarry site and excavation of suitable rockfill (excavation of the quarry would probably require some blasting)
17. establishing a large crane or other means to transfer rock delivered from the quarry across the length of the raised embankment as required
18. placing and compacting rockfill on the raised embankment (within configured zones as per the design)
19. extending the upstream concrete face slabs (possibly by slip forming)
20. constructing the concrete sill, floor and walls for the raised spillway (including anchors and drainage)
21. installing large rock protection below the flip bucket downstream of the new spillway channel and entry to the creek
22. installing precast concrete parapet wall units obtained from the existing embankment on to the raised embankment, and connecting the parapet wall units to the raised upstream concrete face slabs
23. supplying and installing new precast concrete parapet walls on the ends of the raised embankment
24. removing the existing intake tower house and tower access bridge deck
25. demolishing the existing intake tower deck
26. raising the concrete intake tower
27. raising the existing concrete pier, construction of a new concrete pier and construction of new concrete abutment support

28. constructing the raised concrete tower deck
29. constructing the raised bridge deck
30. constructing a new tower house
31. installing all mechanical equipment including additional shutters, trash racks and the crane in the raised tower
32. reinstating electrical supply
33. constructing a new permanent access road and seal on the right abutment to join the raised tower bridge and down to the new boat ramp location
34. removing temporary access and haul roads
35. rehabilitating construction areas (including landscaping)
36. disestablishing.

It is expected that construction would take approximately 70 weeks after the contract has been awarded.

3.3.3 Activities

The activities involved in construction of the Proposal are listed above. These activities include stockpiling material, aligning the haul road, upgrading to the existing Clarrie Hall Dam Road, constructing the embankment dam and raising the hoist house/intake structure and associated access bridge.

Potential sources of noise associated with construction activities include:

- excavation works
- blasting operations
- loading activities and rock placement
- heavy vehicle movements and increased traffic on Clarrie Hall Dam Road and other roads.

3.3.4 Materials

The raised embankment is proposed to be constructed from the following materials:

- a semi-permeable Zone 1 immediately under the upstream concrete face slabs – moderately weathered rhyolite
- a permeable intermediate Zone 2 – slightly weathered to moderately weathered rhyolite
- a permeable fresh rock Zone 3A/3B in the downstream part – slightly weathered rhyolite.

The volumes required for construction of the embankment include:

- Zone 1 – 8,000 m³
- Zone 2 – 30,000 m³
- Zone 3A/3B – 95,000 m³.

Rockfill materials needed for construction would be sourced from the quarry and transported along the haul road to the proposed upgraded dam embankment wall, as well as along Clarrie Hall Dam Road, Kyogle Road and Doon Doon Road to the McCabes Bridge construction site.

Rockfill would be stockpiled on the site and any excess rockfill from the spillway excavation disposed of.

The main energy sources would be to power the concrete batching plants and chilled water units, and fuel (mainly diesel) to power plant and equipment. Energy would be sourced from the local power network or from generators.

3.4 FEASIBLE ALTERNATIVES

In 2009, Council commissioned an options study to augment the Tweed District water supply (MWH, 2009). The 9 considered options are summarised in Table 3-3.

Table 3-3 Option consideration (MHA, 2009)

Option no.	Option summary	Reason not pursued
1	Raising the existing Clarrie Hall Dam	N/A
2	New dam on Byrrell Creek	There was potential for considerable escalation of costs due to the long lead time envisaged before construction could commence.
3	New dam on Oxley River, near Tyalgum (Rocky Cutting site)	There was potential for considerable escalation of costs due to the long lead time envisaged before construction could commence. There is significant habitat for threatened flora and fauna species near the proposed site as well as the social impacts due to the proximity to Tyalgum. There was also the potential for flooding parts of the village and rural properties. These issues would contribute to planning approval difficulties.
4	Pipeline link to Rous Water, at Ocean Shores	This option did not meet the secure yield required (5,250 ML/annum) and established technologies and feasibility criteria. It would only be able to provide approximately 1,825 ML/annum.
5	Pipeline link to the South East Queensland Water Grid, near the Tugun desalination facility)	This option has a large number of political and legislative difficulties due to interstate transfer of resources. These impacts are not likely to be diminished during periods of prolonged drought, when alternative supplies are needed most.
6	Desalination	This option is too expensive and involved significant environmental impacts associated with disposal of brine waste.
7	Groundwater supply	This option did not meet the secure yield required (5,250 ML/annum) and established technologies and feasibility criteria. It would only be able to provide approximately 1,470 ML/annum.
8	Indirect potable reuse	This option is expensive and not socially acceptable. These issues would contribute to planning approval difficulties.

Option no.	Option summary	Reason not pursued
9	Direct potable reuse	This option did not meet the secure yield required (5,250 ML/annum) and established technologies and feasibility criteria. It is also expensive and not socially acceptable. These issues would contribute to planning approval difficulties.

Council, through further studies and consultation with the community, shortlisted 3 options for further consideration. Those options were:

- Raising Clarrie Hall Dam
- Byrrill Creek Dam Construction
- Pipeline to the Seqwater Grid.

The options were reconsidered by Council in 2014. The options considered were:

- Raising Clarrie Hall Dam
- Small Byrrill Creek Dam Construction
- Large Byrrill Creek Dam construction
- Staged Byrrill Creek Dam construction
- Pipeline to the SEQ Water Grid
- Pipeline link to City of Gold Coast.

The consideration noted that the Byrrill Creek Dam option had been prohibited by the Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2010. The consideration also included updated costings (PWA, 2015), advice from Seqwater on the costs of connection to the SEQ Water Grid and revised secure yield and demand projections. A cost risk assessment of the raised Clarrie Hall Dam option was updated by PWA in 2018 and again in 2023. Biodiversity offset costs were not included in the options assessments and for the preferred option, offsets costs will be estimated as part of the biodiversity assessment.

Consideration of these water supply augmentation options, including analysis of environmental, social and economic factors, indicated that raising Clarrie Hall Dam was the most advantageous option to Council and the community. In December 2015, Council resolved to adopt the raising of Clarrie Hall Dam as the preferred option for future water security and proceed with the planning approval and land acquisitions phase for the Proposal.

In October 2016, Council approved the commencement of a range of investigations at Clarrie Hall Dam to further inform the project team, Councillors and the community on the potential impacts of the Proposal, and to further guide decision-making in relation to a preferred option. As a result of these studies and ongoing augmentation assessments, Council is progressing the preferred option to raise Clarrie Hall Dam, consistent with the 2015 resolution.

In 2018, investigations into the biodiversity, heritage, hydrology and geology of the Proposal area were undertaken and informed the development of a concept design for the Proposal prepared by NSW PWA.

During the concept design stage completed by the PWA, 5 dam raising options were assessed:

- single-stage construction to FSL at RL 70.0 m (AHD)
- single-stage construction to FSL at RL 67.0 m (AHD)
- single-stage construction to FSL at RL 64.5 m (AHD)
- two-stage construction, to FSL at RL 67.5 m (AHD), and then from FSL at RL 67.5 m (AHD) to FSL at RL 70.0 m (AHD)
- two-stage construction, to FSL at L 64.5 m (AHD), and then from FSL at RL 64.5 m (AHD) to FSL at RL 70.0 m (AHD).

The study showed that the optimum dam size for Clarrie Hall Dam was considered to have a FSL of RL 70.0 m (AHD). Inundation mapping of the storage levels showed that above a storage level of RL 70.0 m (AHD), significant breakouts could occur in the upstream storage, which would result in the need for saddle dams, significantly increasing the cost of the Proposal.

Cost estimates were completed for each option, and they showed that the single construction option was far more economical than raising the dam in stages. It was also noted that single-stage dam raising had less impact on the surrounding environment and constructability of the works. Operation of the dam would also be disrupted further by staged dam raising. It was therefore a recommendation of the study that single-stage construction to FSL RL 70.0 m (AHD) be adopted for concept design.

The preferred dam raising option incorporates increasing the height of the existing concrete faced rockfill embankment and construction of a new concrete lined spillway higher up in the left abutment. The existing intake tower and access bridge would also be raised.

The Far North Coast Regional Water Strategy (DPE, 2023) showed that Clarrie Hall Dam inflows were likely to reduce by 5% due to climate change and by 34% under extreme dry conditions. Council has limited water storage available, with 12–18 months of water storage available for major urban supplies of the Far North Coast. In drought situations, local councils would have to rely on emergency supplies, which can have long lead times (12–24 months). This would mean that emergency supplies would have to be organised very early on in the drought. Specifically for Clarrie Hall Dam in its current state, Council would need to plan for emergency supplies once Clarrie Hall Dam drops to 97% capacity. Climate change modelling predicts reduced inflows leading to dam levels dropping faster. If the project is not carried out, models suggest that emergency augmentations would need to be planned by Council when Clarrie Hall Dam is completely full by 2030.

4 Statutory context

4.1 PLANNING APPROVAL AND PERMISSIBILITY

4.1.1 Environmental Planning and Assessment Act 1979

The assessment and approval framework for SSI is provided in Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The requirements of an EIS are provided in Division 5 of the *Environmental Planning and Assessment Regulation 2021*. This states, among other things, that an EIS must address the environmental assessment requirements (SEARs) of the Secretary of the NSW Department of Planning and Environment.

4.1.2 Relevant environmental planning instruments

Environmental planning instruments are statutory plans, made under Part 3 of the EP&A Act, that guide development and land use. These plans include State Environmental Planning Policies (SEPPs) and Local Environmental Plans (LEPs).

The Clarrie Hall Dam raising Proposal is considered to be SSI by virtue of State Environmental Planning Policy (Planning Systems) 2021 (Planning SEPP), which states:

Part 2.3 State significant infrastructure

2.13 Declaration of State significant infrastructure: section 5.12(2):

- (1) Development is declared, pursuant to section 5.12(2) of the Act, to be State significant infrastructure for the purposes of the Act if—*
 - (a) the development on the land concerned is, by the operation of a State environmental planning policy, permissible without development consent under Part 4 of the Act, and*
 - (b) the development is specified in Schedule 3.*

The Proposal to raise Clarrie Hall Dam is permissible without consent under Division 24 of State Environmental Planning Policy (Transport and Infrastructure) 2021 (Transport and Infrastructure SEPP) and is thereby consistent with the above:

2.159 Development permitted without consent:

- (1) Development for the purpose of water reticulation systems may be carried out by or on behalf of a public authority without consent on any land.*
- (2) Development for the purpose of water storage facilities may be carried out without consent if it is carried out by or on behalf of—*
 - (a) any public authority on land in Zone RU1 Primary Production, Zone RU2 Rural Landscape, Zone SP1 Special Activities, Zone SP2 Infrastructure or an equivalent land use zone, or*
- (3) A reference in subsection (2) to development for the purpose of water storage facilities, includes a reference to development for any of the following purposes—*
 - (a) catchment management works,*

- (b) recreation areas associated with a water storage facility.*
- (4) Development for the purpose of water treatment facilities may be carried out by or on behalf of a public authority without consent on land in a prescribed zone.*
- (5) Development for the purpose of a water supply system may be carried out on land reserved under the National Parks and Wildlife Act 1974 only if it is authorised by or under that Act.*

Schedule 3 of the Planning SEPP states:

- (4) Water storage or water treatment facilities*
- (1) Development for the purpose of water storage or water treatment facilities (not including desalination plants) carried out by or on behalf of a public authority that has a capital investment value of more than \$30 million.*

The Proposal is for the purpose of a water storage facility, located on the following land use zones (see Figure 4-1) under the Tweed Local Environmental Plan 2014 (Tweed LEP 2014):

- SP2 – Infrastructure
- RU2 – Rural Landscape
- C1 – National Parks and Nature Reserves
- DM – Deferred Matter.

DM refers to Deferred Matter – from the Tweed LEP 2000 7(I) – Environmental Protection (Habitat) Public utility undertakings – allowed only with consent and must satisfy the provisions of clause 8 (2) (Consent Considerations).

C1 refers to National Parks and Nature Reserves – Development not specified – Prohibited (Overridden as mentioned in Mount Jerusalem NP Plan of Management), noting that this land has been revoked and will be rezoned.

The Stotts Island Nature Reserve, located in the Tweed River near Tweed Heads, is zoned E1– National Parks and Nature Reserves according to the Tweed LEP 2014. It is located approximately 17 km downstream of Bray Park Weir and is not expected to be impacted as discussed in section 6.2.1.

NSW Public Works Advisory has estimated the capital investment value (CIV) at approximately \$90 million.

The assessment and approval process for an SSI project is consistent with the discussion above of the relevant planning instruments and requires assessment under Part 5, Division 5.2 of the EP&A Act. The determining authority for approval is the NSW Minister for Planning and Public Spaces, under section 5.19 of the EP&A Act.

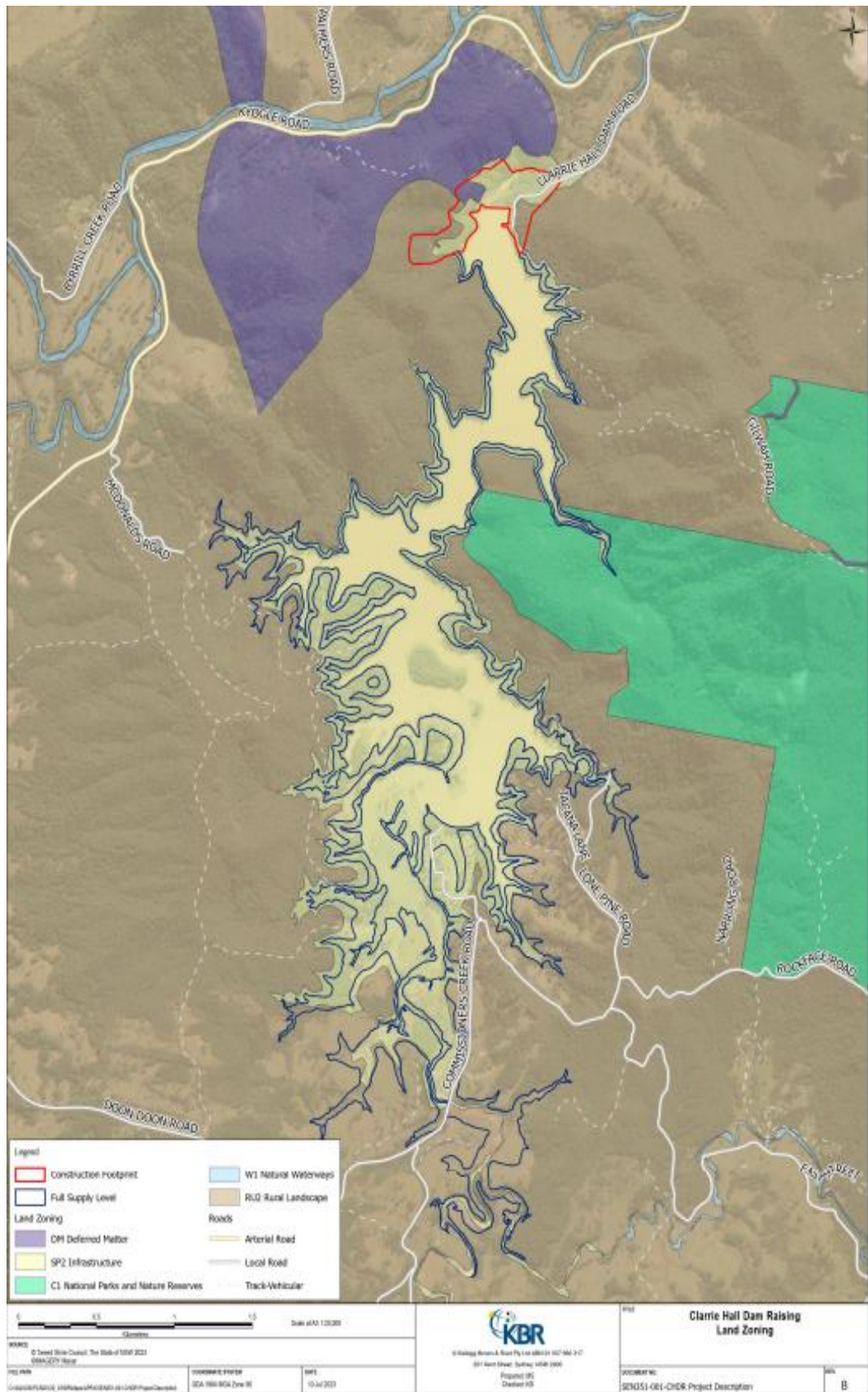


Figure 4-1 Land zoning

4.1.3 Other legislation

The following NSW legislation is applicable to preparing an EIS under Division 5.2 of the EP&A Act:

- *Biodiversity Conservation Act 2016*
- *Fisheries Management Act 1994*
- *Water Management Act 2000*
- *Roads Act 1993*
- *National Parks and Wildlife Act 1974*
- *Biosecurity Act 2015*
- *Protection of the Environment Operations Act 1997*
- *Waste Avoidance and Resource Recovery Act 2001*
- *Dangerous Goods (Road and Rail Transport) Act 2008*
- *Dams Safety Act 2015*
- *Contaminated Land Management Act 1997.*

In addition, the following Commonwealth legislation is relevant:

- *Environment Protection and Biodiversity Conservation Act 1999* (see section 4.2 of this report)
- *Native Title Act 1993.*

The Acts listed in this section include regulations, subordinate legislation and statutory instruments that have been made under the Acts.

The application of this legislation is discussed in Chapter 6.

4.2 ENVIRONMENTAL PLANNING AND PREPARATION OF AN EIS

An application under Part 5, Division 5.2 (SSI) of the EP&A Act for the Clarrie Hall Dam raising Proposal was submitted to the NSW DPE in 2018. The SEARs were issued on 15 August 2018 (SSI 9458).

On 27 February 2019, Council was advised that the Proposal is a Controlled Action (2018/8339) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Revised SEARs were therefore issued on 23 April 2019 to include controlled action environmental assessment requirements.

An EIS is required under Part 5, Division 5.2 of the EP&A Act and in accordance with the bilateral agreement between the NSW and Australian governments (see <https://www.planning.nsw.gov.au/policy-and-legislation/bilateral-agreement-environmental-assessment>). In November 2019, Council engaged consultants to prepare the EIS to support the Clarrie Hall Dam raising SSI application to DPE. A draft EIS was provided to Council in August 2021. The draft EIS was reviewed by an external consultant, and Council subsequently engaged KBR to update and complete the EIS.

Revised SEARs were issued by DPE in November 2021, as the original SEARs had expired. These SEARs are due to expire in November 2023.

This Scoping Report has been prepared to support a new SEARs application.

A request to vary the proposed action was submitted to the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) in May 2023. The request to vary the proposed action included:

- upgrading the Kyogle Road and Clarrie Hall Dam Road intersection
- replacing McCabes Bridge and realigning Commissioners Creek Road.

The variation has been accepted by DCCEEW as per the decision notice dated 30 June 2023 (Appendix E).

The Clarrie Hall Dam raising EIS is being prepared to assess the potential environmental impacts of the proposed dam wall raising based on the concept design (PWA, 2018). The EIS will be lodged with the DPE to support the SSI application.

4.3 AGENCY CONSULTATION

An overview of the consultation with various government agencies conducted to date is outlined in Table 4-1.

Table 4-1 Government agency consultation

Government agency	Details
Various agencies	A number of agencies were involved in preliminary workshops in 2016.
NSW Department of Planning and Environment (DPE)	Council and DPE representatives have had fortnightly meetings since March 2021.
DPE Water	A meeting was held with DPE Water on 17 February 2023 to discuss the project.
DPI Fisheries	Meetings with DPI Fisheries were held on 16 February 2023 and 9 March 2023 to discuss the hydrology modelling and the aquatic ecology assessment. DPI Fisheries provided comments on the proposed aquatic ecology assessment. Correspondence was received from DPI Fisheries dated 14 July 2023 regarding the section 218 determination for the proposed raising of Clarrie Hall Dam (Appendix F). The correspondence advised that DPI Fisheries has assessed the scope of the raising of the Clarrie Hall Dam project and has recommended the application of section 218, which requires the provision of suitable fish passage. As part of the determination, DPI Fisheries proposes that section 218 fish passage requirements for Clarrie Hall Dam be transferred to the construction of suitable fish passage at Bray Park Weir.
Biodiversity Conservation Directorate (BCD)	May 2020 – a survey strategy for the Biodiversity Assessment Method (BAM) was developed. September 2020 – advice was provided on the agreed approach for threatened flora surveys and amphibians, forest owls, brush-tailed phascogale and reptiles. Additional guidance, requirements and recommendations were provided for the assessment of koala habitat, bat surveys and glossy black-cockatoo. Updates on ecological findings were provided as surveys progressed and feedback was incorporated as work progressed (an advice record is available). June 2023 – biodiversity development assessment report (BDAR) gap analysis and a proposed methodology were submitted to BCD for comment and discussion. A meeting with BCD was held on 26 July 2023. August 2023 – a follow-up meeting with BCD was held on 9 August 2023 to clarify and discuss the survey methodology.

Government agency	Details
National Parks and Wildlife Service (NPWS)	November 2020 – 1.91 ha of land from the Mount Jerusalem National Park was identified and revoked for the Proposal. Compensation for NPWS from Council would be negotiated further along the Proposal timeline (Council internal document).
NSW Rural Fire Service	The NSW RFS, Far North Coast Fire Control Centre (Murwillumbah) provided input on fire weather conditions, fire history and ignition factors.
State Emergency Service	December 2020 – consultation took place with NSW SES Hazard Planning branch via letter. Issues addressed included aspects of dam safety and flood emergency planning.
Dam Safety NSW	Dam Safety NSW would be further involved during the development of the Dam Safety Emergency Plan for the Proposal.
Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW)	An EPBC referral was submitted in 2018. The proposed action was deemed a 'Controlled Action' under the EPBC Act (EPBC 2018/8339). A meeting was held with DCCEEW on 16 February 2023 to discuss varying the proposed action to increase the disturbance footprint by 3.5 ha, to facilitate: · upgrading of the intersection of Clarrie Hall Dam Road and Kyogle Road · realignment of Commissioners Creek Road, including replacement of McCabes Bridge. A letter requesting to vary the proposed action was subsequently submitted to DCCEEW, and a decision notice dated 30 June 2023 was received by Council, approving the variation to the proposed action (Appendix E).

4.4 OTHER APPROVALS

4.4.1 Approvals to be substantially consistent with approved SSI

The Proposal may require the following additional approvals under section 5.24 of the EP&A Act:

- Consent under section 138 of the Roads Act 1993 for road upgrades to the public road network.
- The NSW Environment Protection Authority (EPA) issues environment protection licences (EPLs) under the *Protection of the Environment Operations Act 1997* (POEO Act). An EPL may be required for the construction phase of the Proposal, as per Schedule 1 activities under the POEO Act. Schedule 1 activities that may apply include:
 - cement or lime works – construction works would require temporary establishment and operation of an onsite concrete batching plant. This is required if the total of pre-mixed concrete and/or concrete products is likely to exceed 30,000 tonnes per year
 - crushing, grinding or separating – the decommissioned quarry would be re-established as part of the Proposal. It is assumed that works at the quarry would involve crushing, grinding and/or separation
 - chemical storage – temporary storage of hydrocarbons, fuels and other materials for machinery maintenance during construction, depending on if the activity meets the criteria, is shown in Table 4-2. Types and volumes of chemicals are required to be known.

Table 4-2 Schedule 1 activities chemical storage criteria

Activity	Criteria
General chemicals storage	Capacity to store more than 20 tonnes pressurised gases, 200 tonnes liquefied gases or 2,000 tonnes chemicals in any other form
Onsite generated chemical waste storage	Involves storing onsite at any time more than 5 tonnes of any chemical substance produced onsite that is prescribed waste, not including excluded material (where 1,000 litres of liquid is taken to weigh 1 tonne)
Petroleum products storage	Capacity to store more than 200 tonnes liquefied gases or 2,000 tonnes chemicals in any other form

4.4.2 Approvals that are not required for approved SSI

Under section 5.23 of the EP&A Act, approvals and legislation that do not apply to SSI include:

- a permit under section 201, 205 or 219 of the *Fisheries Management Act 1994*
- an approval under Part 4, or an excavation permit under section 139, of the *Heritage Act 1977*
- an Aboriginal heritage impact permit under section 90 of the *National Parks and Wildlife Act 1974*
- a bushfire safety authority under section 100B of the *Rural Fires Act 1997*
- a water use approval under section 89, a water management work approval under section 90, or an activity approval (other than an aquifer interference approval) under section 91 of the *Water Management Act 2000*.

In addition, Division 8 of Part 6 of the Heritage Act does not apply to prevent or interfere with the carrying out of approved SSI.

4.4.3 Other approvals not considered within the SSI assessment

Other approvals that are not expressly considered within the SSI assessment include Water Access Licences under the Water Management Act, potential updates to the Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2010 and leasing under the National Parks and Wildlife Act.

5 Engagement

Tweed Shire Council has both informed and consulted its local community and key stakeholders, using various methods.

5.1 ENGAGEMENT CARRIED OUT

Tweed Shire Council has consulted with the local community and key stakeholders to obtain input on the development of water security options and on the development of the preferred option, the raising of Clarrie Hall Dam.

5.1.1 Water security consultation

Considerable investigation and community consultation has been undertaken to date with respect to augmenting the Tweed Water Supply. Council has been engaging with stakeholders regarding water augmentation options since 2009.

In determining a preferred water augmentation option, input from the community was considered in a year-long community engagement process. The engagement also included the formation of a Community Working Group (CWG), which held 5 meetings from December 2009 to March 2010. The CWG was tasked with reviewing and commenting on the various options. It proposed Clarrie Hall Dam raising as its recommendation.

In December 2015, Council resolved to adopt the raising of Clarrie Hall Dam as the preferred option for future water security and proceed with the planning approval and land acquisitions phase for the Proposal, subject to Council continuing to undertake comprehensive investigations of Council's water supply–demand options.

In October 2016, Council approved the commencement of a range of investigations at Clarrie Hall Dam to further inform the project team, Councillors and the community on the potential impacts of the Proposal, and to further guide decision-making in relation to a preferred option.

Investigations into the biodiversity, heritage, hydrology and geology of the Proposal area were undertaken and informed the development of a concept design for the Proposal prepared by NSW PWA. Council is now progressing the preferred option to raise Clarrie Hall Dam, consistent with the 2015 resolution.

More recently, Council has participated in engagement activities with the NSW DPE during preparation of the draft and final Far North Coast Regional Water Strategy, discussed in section 2.1.2.

5.1.2 Clarrie Hall Dam raising community consultation

A Communication and Engagement Plan (CEP) was developed in 2015 following a resolution of Council to adopt Clarrie Hall Dam as the preferred option for future water security and to proceed with the planning approval investigation and land acquisitions. The CEP was updated in 2017, 2019 and more recently in 2023.

Council categorised the community into primary and secondary groups to aid with aligning the most appropriate engagement approach to the needs of those groups. Primary stakeholders were considered to be the main groups directly affected by the Proposal. Secondary stakeholders were other groups indirectly affected. The primary and secondary groups are shown in Table 5-1.

Table 5-1 Community consultation groups and details

Group	Category	Details
Community and local interest groups	Primary	- Landowners whose properties would have water inundation at the full level of a raised dam or in Probable Maximum Flood. - Residents of Commissioners Creek whose road access would be cut at McCabes Bridge at the full water level after the dam is raised. - Aboriginal community (refer to section 6.3) - Future generations – from children to young adults
	Secondary	- Community Reference Group - Resident, Environment, and Industry Group Roundtable (REIGR) - Residents of Commissioners Creek and Doon Doon areas - Residents of Uki - Tweed Shire residents and ratepayers - Tweed Shire Council water customers - Community organisations, such as environmental groups like Landcare and Team Koala - Aboriginal Advisory Committee - Tweed River Committee - Council staff - Councillors - Youth Council
	Other groups	- Traditional owners - Land management groups - Schools - Community groups such as Tweed Shire Parks and Active Communities - Sporting groups
Local business and industry groups		- Business groups and chambers of commerce, including the Tweed Tourism Company and real estate agencies in Uki and Murwillumbah - Heavy industry and construction industry in Uki and Murwillumbah
Media		- Local press – online and print - Local and community radio and television - Council media department - Local social media groups

Since 2015, consultation has included group stakeholder meetings, attendance at the Local Government Week Clarrie Hall Dam Open Days, one-on-one meetings with landowners and those whose access may be impacted, and presentations to service clubs and other interested parties.

Issues raised by the community at this time included land acquisition and transition of landowners from their land when the land was purchased, access for residents upstream of McCabes Bridge (which would be inundated), provision of information on environmental studies, and future management and use of the catchment and acquired land by groups such as Outward Bound.

A timeline of the primary consultation actions is as follows:

- 15 December 2015 – Council recommended commencement of planning and acquisition phase to raise the wall of the dam.
- April 2016 – Face-to-face meetings commenced with all affected landowners.
- September 2016 – A series of letters were sent to all properties affected by access associated with the proposed inundation of McCabes Bridge, a two-lane bridge located on Commissioners Creek Road, approximately 6 km from the intersection of Kyogle and Doon Doon roads, directly south of the entrance to Crams Farm.
- 11 October 2016 – A public meeting was held at Crams Farm with landowners directly affected by the Proposal and other interested members of the public from the area. At this meeting, 24 property owners were engaged and provided permission for flora and fauna surveys, with one property owner assisting by providing boat storage and access; another was the point of contact for emergencies.
- April 2017 – The McCabes Bridge Replacement Options Report was sent to all stakeholders. As a result of further feedback, a revised options report was prepared and sent to all stakeholders prior to a second meeting held at Crams Farm in March 2018. In April 2018, the community nominated its preferred access option for recommendation of Council. Council subsequently accepted the recommendation.
- August 2017 – An Open Day was held at Clarrie Hall Dam to inform interested members of the community on the Proposal and to provide further information on various studies and assessments including cultural heritage, flora and fauna, and engineering concept design elements through the use of pop-up stands and displays.

Currently, Council has purchased 15 parcels of land, as shown in Figure 2.2.

Council operates a Clarrie Hall Dam Proposal web page titled *Raising Clarrie Hall Dam*, at <https://www.yoursaytweed.com.au/RaisingClarrieHall>

People can register their interest in the project and EIS on Council's 'Your Say Tweed' website. Currently about 70 people are registered. Council responds to Proposal enquiries from the community and maintains a database of feedback associated with the Proposal web page.

An updated Community and Stakeholder Engagement Plan was developed in May 2023, to guide consultation activities during preparation and public exhibition of the EIS (see section 5.3).

5.2 COMMUNITY VIEWS ON RECENT CONSULTATION

Between mid-February and mid-March 2021, a summary of the draft EIS was published on Council's 'Your Say Tweed' website. Community engagement was then conducted online rather than in person, due to COVID-19, through an online survey on the Council's 'Your Say Tweed' page related to the Proposal.

The online survey allowed participants to provide their responses to a range of questions, including questions about their understanding of the importance of water security for the Shire, and the raising of Clarrie Hall Dam as a preferred option as well as the alternatives.

A selection of the relevant questions and responses is provided below. Engagement with the various elements of the 'Your Say Tweed' website is summarised in Table 5-2.

Table 5-2 Summary of consultation during 2021

Consultation method	Website visits	Video views	EIS summary downloads	Downloads of timeline	Survey responses	Questions posted	Request for call-back
Number of responses	897	210	91	41	66	5	5

Responding to the question of support for the Proposal to provide longer-term water security, 78% of respondents indicated they supported the Proposal. The responses are provided in Figure 5-1.

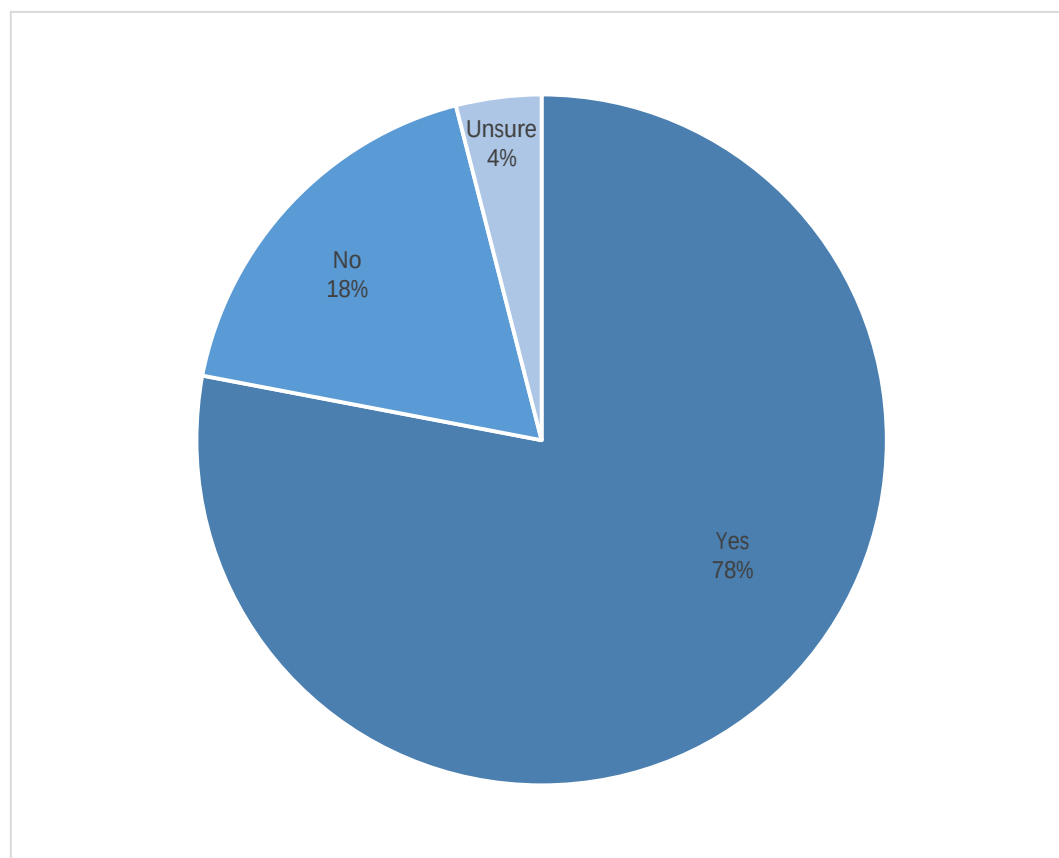


Figure 5-1 Responses to question asking about support of the Proposal

Respondents were also given the opportunity to provide their reasons for supporting the Proposal. Multiple responses were allowed. The range of responses are provided in Figure 5-2. Water security was the most popular reason, while cost efficiency and growing population were also popular reasons.

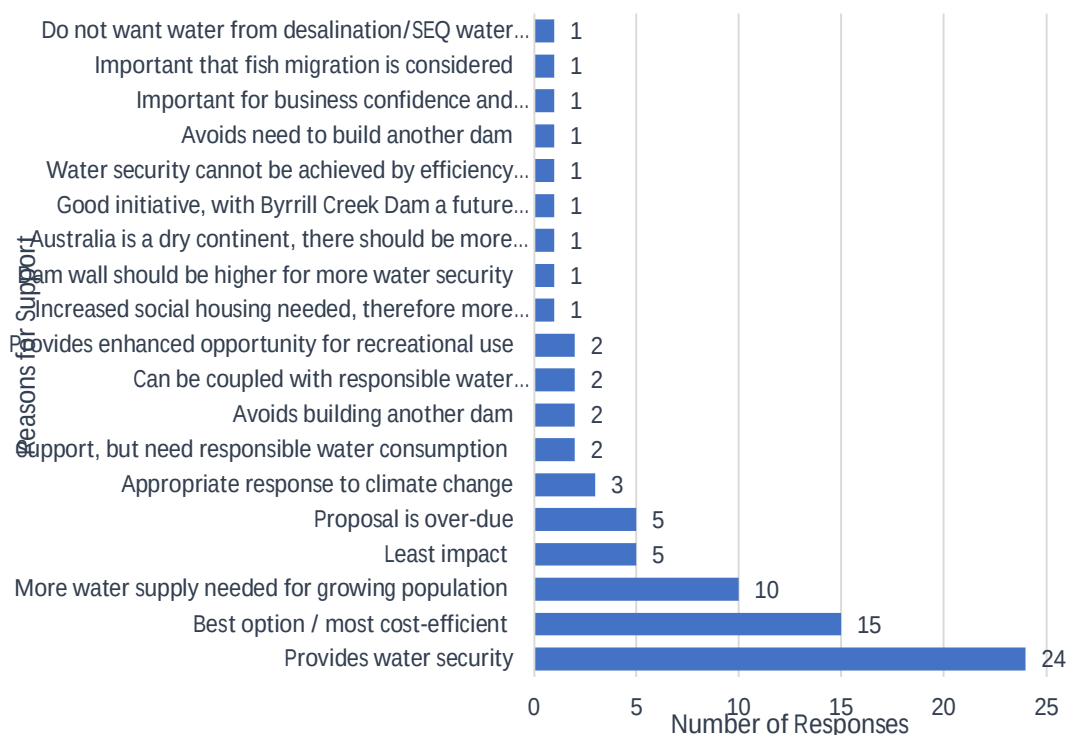


Figure 5-2 Reasons for supporting the Proposal

Participants who did not support the Proposal provided a range of responses, as shown in Figure 5-3.

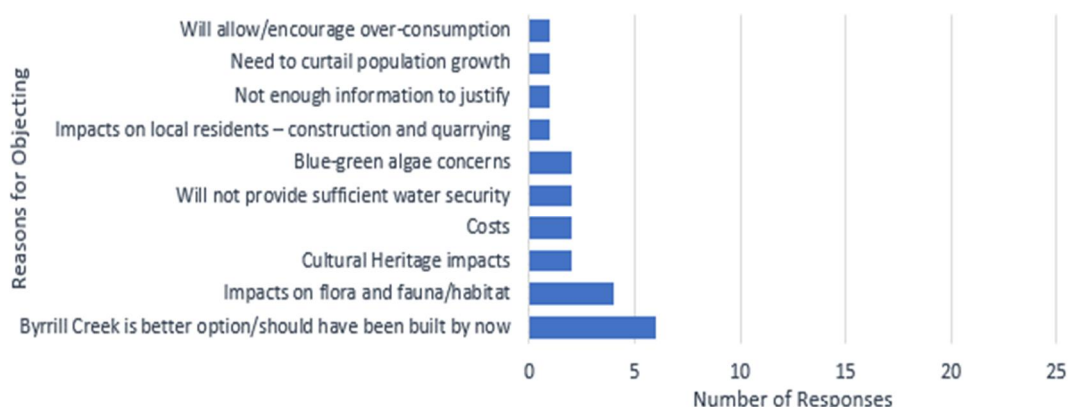


Figure 5-3 Reasons for not supporting the Proposal

Participants were also asked about their specific interests in the Proposal. Most respondents highlighted the issue of water security and being an interested resident. Responses are shown in Figure 5-4.

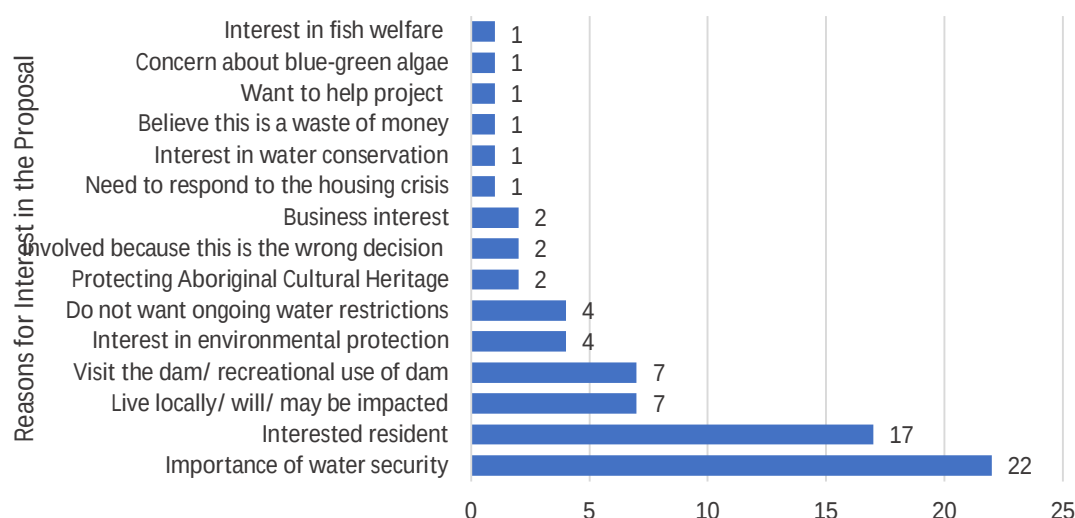


Figure 5-4 Reasons for interest in the Proposal

A summary of the matters raised throughout the consultation between 2009 and 2010 and from 2015 to 2021 is provided in Table 5-3, grouped by common themes. A summary response is provided for each matter.

Table 5-3 Summary of issues raised during consultation

Theme	Issue	Response from Council
Compensation	Compensation of inundation of property (through sale and fair dealings) and for properties impacted at the RL 77 m PMF level	The land acquisition process is underway between Council and owners of the properties identified. The land acquisition process and associated impacts are being addressed outside the scope of the EIS
Inundation / flooding	Definition of actual inundation footprint	The inundation footprint is shown and described in the Proposal description
	- Upstream flooding concerns – potential for water ‘backing up’ in high rainfall episodes/flooding - Potential collection of debris within the bridge structures, creating blockage and exacerbating upstream flooding - Ability of the new dam to mitigate downstream flooding	Upstream and downstream flood risks have been assessed and evaluated through detailed technical studies, including modelling of the PMF scenario to look at the maximum potential risk and impact profiles
	- Silt trap management - Width of the new spillway	Silt management and spillway features are described in the concept design document
Social	- Personal anxiety associated with a lack of certainty about the dam construction and timing (i.e. the future of their land, which may be a potentially impacted property) - Increased anxiety due to perceived increased flood risks	Continuation of a consultation program with communities and key stakeholders to provide information on the Proposal and to communicate information specific to concerns raised – for example, demonstrating a reduced risk of flooding compared to the existing dam

Theme	Issue	Response from Council
	Increased housing costs	The proposed local procurement strategy would give preference to the local workforce and business during construction. The benefits resulting result from that can offset the potential increase in housing cost impacts
Access	Impact on access due to inundation of existing road	Community and directly impacted stakeholders were consulted on alternative access design options (for example, McCabes Bridge); a preferred option was nominated by the stakeholder group and passed by Council resolution during 2018
	Compensate the community for bearing the 'cost' of the raised dam with no direct benefit; for example, seal and improve the local road network	- Road upgrades have been proposed to address potential impacts associated with the Proposal - Rebuilding recreational areas, investigating options for recreational activities at the dam (walking and mountain bike tracks). This is discussed further below
Environment	Impact on fauna and flora from inundation	A terrestrial biodiversity impact assessment has been undertaken to identify a range of mitigation measures to minimise impacts on fauna and flora associated with inundation
	Management of weeds and lily mass	The terrestrial biodiversity impact assessment identifies a range of mitigation measures to minimise impacts on fauna and flora associated with weeds
	Removal and beneficial use of trees before inundation	Trees would not be removed prior to inundation. Vegetation removal is to be minimised
Safety	- Residents' safety downstream from the dam - Dam failure scenarios under extreme events and earthquake	- The technical study conducted to assess flood risk associated with the Proposal concluded that the overall flood risk is reduced for the Clarrie Hall Dam (compared to the existing dam) - Dam safety and consideration of risks associated with seismic activity have been addressed in the Concept Design Report. The proposed upgrade is designed to be a 0.01% AEP earthquake event
Design	Whether there is need for new footings for the dam wall	Design considerations and specifications for the embankment and spillway are provided in the Concept Design Report (Appendix D)

Theme	Issue	Response from Council
	Whether Clarrie Hall Dam would need to be raised again (beyond this Proposal)	This Proposal is for the current upgrade plans. Council will maintain ongoing consultation regarding the Proposal and will continue to engage on feedback such as alternative options raised by stakeholders. Chapter 2 of this Scoping Report discusses alternative options to the Proposal that are considered for strategic water supply
	Whether a fish ladder is possible or needed	- The fish passage along Doon Doon Creek is currently impaired by the existing structure of Clarrie Hall Dam. There are no plans to install a fish ladder or lift on Clarrie Hall Dam, so the ability of fish to freely move between the upstream and downstream reaches would remain as it is now - Consultation with DPI Fisheries has been conducted on potentially improving the fish passage at Bray Park Weir to offset impacts to the fish passage at Clarrie Hall Dam
	'Bigger vision for the Proposal' beyond water storage only, including recreational use and trails, and revegetation	Opportunities to further enhance recreational values associated with the Proposal area have been considered and described
Construction	Potential of water lowering during construction	Some lowering of the storage would be required to allow construction of the raised embankment, possibly an approximate lowering of 300 mm below FSL
	Use and location of spoil from construction	Most of the material required for use in the upgrade of the Clarrie Hall Dam wall is to be sourced from the existing rock quarry used in the original dam construction. Investigations indicated that the quarry holds sufficient volumes of reserve material
	Cumulative impacts of construction truck movements in addition to existing truck movements associated with the water extraction industry around Uki	A traffic impact assessment and an air quality and noise assessment have been conducted to assess potential impacts associated with construction truck movements. Primarily, impacts of truck movements are attributable to traffic flow and road user safety, for which mitigation measures such as upgrades to key intersections and potential road surface upgrades in certain sections of the truck routes may be required

Theme	Issue	Response from Council
General	Amenity	- Visual amenity is not anticipated to alter significantly from the existing visual amenity impacts as a result of the Proposal. Stakeholders will be consulted during the next planning stage in relation to the detailed plans for the recreation area that would be re-established as part of the Proposal - In relation to amenity for road and Uki village users, prior to construction Council would consult with stakeholders to communicate changes to the traffic environment and how they would be managed. Council would provide support for road users to change travel plans (if required) during the construction period
	Extent and type of boundary fencing (in relation to cattle)	The area surrounding the dam has limited points where livestock could potentially access the dam. Fencing required to manage livestock access would be established in consultation with the relevant adjoining landowners at locations where livestock could potentially have access to the dam
	Implications for rail trail	The proposed Northern Rivers Rail Trail route travels from Murwillumbah, via Stokers Siding and Burringbar in a south easterly direction. The proposed route is approximately 10 km away from Clarrie Hall Dam at the closest point. Further information about both projects is available on Council's 'Your Say Tweed' website
Other options	Necessity of the Proposal and alternative water supplies	Council commissioned technical studies to identify potential alternative options for securing water supply. The options were shortlisted to 4 alternatives, when targeted consultation was undertaken to involve the community in the process of identifying a preferred option to move forward into the design phase. The alternative options considered and the justification for the selection of the upgrade to Clarrie Hall Dam will be provided in the EIS
	Preference for Byrrill Dam (others against Byrrill Dam)/ build Byrrill Dam as well	
	Preference for household water tanks instead of dams	This was not addressed as an alternative option for securing water supply

5.3 ENGAGEMENT TO BE CARRIED OUT

Key actions that Council would carry out to keep the community informed, obtain feedback and engage with stakeholders on the detailed assessment of key matters during preparation of the EIS will be consistent with DPE's *Undertaking Engagement Guidelines for State Significant Projects* (DPIE 2021a). These engagement activities include:

- implementing consultation activities as identified in the CEP (Tweed Shire Council, 2023). This includes identifying further stakeholders for future consultation through:
 - community information sessions
 - drop-in sessions at various locations such as the Clarrie Hall Dam Open Day
 - updates via the local media – newspaper and radio
- continuing to publish updates on the Clarrie Hall Dam Proposal web page 'Raising Clarrie Hall Dam' and responding to submissions.

Council will continue to seek community feedback through these consultation activities, provide responses directly to the respondent, and document in the EIS how it has considered and responded to the issues raised and how the Proposal has changed (if relevant) in response to that feedback.

6 Proposed assessment of impacts

The identification of matters for further assessment for the proposed raising of Clarrie Hall Dam commenced in May 2017 with a preliminary environmental risk identification workshop. The workshop was held at Tweed Shire Council Offices and was attended by NSW Public Works engineers and geologists, and relevant Council staff including senior water engineers, surveying staff, environmental planning and assessment staff, and cultural heritage and communication representatives.

The purpose of the workshop was to identify the potential environmental, social, economic and cultural risks and opportunities and constraints associated with risk types. The workshop was partly informed by investigations (e.g. biodiversity assessments, cultural heritage assessments and geotechnical investigations) that had commenced at that time, specialist site-specific engineering design knowledge provided by NSW PWA (due to involvement by its staff during the original construction of Clarrie Hall Dam and subsequent spillway upgrade) and the substantial community consultation that had been undertaken to date.

A second workshop was held in October 2017 that utilised the NSW DPE Draft Environmental Impact Assessment Guidance Series (DPE, 2017). It was attended by internal Council project staff. The aim of this workshop was to refine and characterise potential impacts and identify 'avoid and minimise' strategies and further assessment requirements.

In April 2023, a third risk workshop was held to review any gaps identified between the draft EIS and the SEARs that would inform the assessment methodologies going forward.

The following matters have been identified as requiring a detailed assessment in the EIS:

- water – hydrology, flooding, groundwater, geomorphology, water availability, water quality, cold water pollution and climate change
- biodiversity – aquatic ecology, terrestrial ecology and conservation areas
- heritage – Aboriginal and historic
- geology and soils – topography, contamination
- traffic and transport – access to properties and parking
- amenity – noise and vibration
- hazards and risk – coastal hazards, biosecurity, dangerous goods, environmental hazards, groundwater contamination, land contamination, land movement, waste, greenhouse gas and renewable energy, hazardous and offensive development, dam safety, bushfire and climate change
- social – way of life, community, accessibility, culture, health and wellbeing, surroundings, livelihoods and decision-making systems.

Matters that have been identified as requiring a standard assessment are:

- land use and built environment – public land, public infrastructure and private land
- economic – natural resource use, livelihood, opportunity cost

- amenity – landscape and visual
- air quality – atmospheric emissions
- sustainability.

Those matters identified for further assessment (listed further above) are discussed in this chapter. The summary for each matter includes information on the proposed level of assessment, the approach to the assessment, key factors for consideration, relevant government plans and whether specific community engagement is required.

A scoping summary table that includes relevant guidelines is shown in Appendix A. The table provides a summary of the matters for assessment and identifies the level of environmental assessment required for matters in the EIS.

6.1 WATER

6.1.1 Existing environment

Clarrie Hall Dam is located on Doon Doon Creek, a tributary of the Tweed River. The dam is situated in a steep and heavily vegetated valley surrounded by approximately 936 ha of Council-owned forested land, private land and Mount Jerusalem National Park.

The existing environment with regard to flooding, hydrology, water availability and water quality is described below.

Flooding and hydrology

Clarrie Hall Dam is categorised by the NSW Dams Safety Committee guidelines as a High C category dam. The spillway is required to have the capacity to pass at least a 1:100,000 Annual Exceedance Probability (AEP) flood. The spillway at Clarrie Hall Dam was originally designed to pass a 1:1,000 AEP flood; consequently, the spillway was upgraded in 2014 to comply with flood security requirements in the short term, while keeping in mind the Proposal to raise the dam's FSL in the future.

The dam raising and spillway would be designed based on the PMF. This would increase potential inundation levels to RL 77 m (AHD) and represents the extent of floodwaters in a PMF event. For Clarrie Hall Dam, the PMF event is beyond a 1:10,000,000-year event and has flows nearly twice that of the 1:10,000-year event.

Flood and hydraulic modelling is being completed for the Proposal, as discussed below.

Water availability

The dam has a surface area of 220 ha and an overall catchment of approximately 60 km². The maximum depth of the dam is approximately 41 m and, as noted, has a capacity of about 16,000 ML. When flows in the Tweed River fall below the 95th percentile, water is released to the Tweed River (via Doon Doon Creek) by releasing water from the dam. This water flows through to the Uki Weir Pool and Bray Park Weir, which are the raw water intake areas for Uki Water Treatment Plant (WTP) and the Bray Park WTP respectively.

The Clarrie Hall Dam Operations and Maintenance Plan (Tweed Shire Council, 2022), outlines the rules for water releases from the dam, in accordance with the *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources* (NSW Government, 2023).

Water quality

Reservoir water quality

Clarrie Hall Dam water quality data collected from July 2015 to July 2019 was reviewed and used to calibrate a three-dimensional Aquatic Ecosystem Model (AEM3D) by HydroNumerics (2021). The model was configured to simulate the hydrodynamics of the reservoir, including the temperature and stratification, the dissolved oxygen, suspended solids, nutrients (phosphorus and nitrogen) and the growth of cyanophytes and chlorophytes. The model was compared with observed data from March 2013 to December 2019 (Hunter H₂O, 2018). The observed data found high levels of chlorophyll-a (Chl-a), ammonium (NH₄), oxidised nitrogen (NO_x), orthophosphate (PO₄), total phosphorus (TP) and total nitrogen (TN) within Clarrie Hall Dam, with the median values exceeding the Australian and New Zealand Environment and Conservation Council (ANZECC) ecological trigger value for freshwater lakes and reservoirs. Observed mean dissolved oxygen was only found to be below ANZECC trigger value (<5mg/L) below 2 m. The model indicated a key potential risk associated with the raising of the dam wall was an increase in algal growth. Modelling results illustrated that the increase in algal growth is supported by an increase in the availability of PO₄ through sediment release in the enlarged hypolimnion (cold bottom layer of water) of the raised dam. In terms of trigger values this means a predicted increase in concentrations of TP, PO₄ and Chl-a, compared to the currently observed values.

Receiving environment water quality

The following water quality issues are encountered in the Tweed catchment area and typically occur in the still or slow-flowing parts of Clarrie Hall Dam and river systems:

- Cyanobacteria (blue-green algae) blooms, which can discolour water, form surface scums, produce unpleasant tastes and odours, and create problems for aquatic life. Cyanobacteria are a primary health concern in dams and waterways, as they have the potential to produce toxins. Cyanobacteria typically occur in stratified water bodies, as they are able to take advantage of the changed buoyancy conditions. Clarrie Hall Dam does not currently have a mechanism for destratification.
- Salvinia (*Salvinia molesta*), Cabomba (*C. caroliniana*), Parrots Feather (*Myriophyllum aquaticum*) and yellow waterlily (*Nymphaea Mexicana*) are all noxious aquatic weeds that disrupt aquatic ecosystems and decreases water quality by causing odours, accumulation of organic matter and stagnation of streams (Ensby, R. 2009; HWA 2011; TSC 2014).
- High manganese levels, which, if not removed in the drinking water treatment process, will result in an undesirable taste to beverages and stains to plumbing fixtures and laundry coatings. At concentrations as low as 0.02 mg/L, manganese can form coatings on water pipes that may later slough off as a black precipitate (WHO, 2020, cited in HWA, 2011).

Operational supply water quality

The Clarrie Hall Dam Operations and Maintenance Plan (Tweed Shire Council, 2022) identifies that the primary function of Clarrie Hall Dam is to provide water storage for the purpose of providing a water supply for the Tweed Shire, with an ancillary function of providing amenity as a recreational area. The Management Plan notes that there are a number of water quality guidelines that apply to the reservoir and drinking water in general.

The raw water stored within the reservoir is managed under Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and by the time water is distributed to consumers, it is required to meet the Australian Drinking Water Guidelines (ADWG) (NHMRC/NRMMC, 2011). Tweed Shire Council has prepared a Drinking Water Management System which details how Council conforms to the ADWG Framework.

Water from the Tweed River catchment is treated at the Bray Park WTP, which was upgraded in 2010 to include membrane technology used to treat algal toxins and taste compounds when algae are identified in the raw water supply. The WTP also has a potassium permanganate dosing system, which is used to remove iron and manganese when these parameters are identified in the raw water supply.

Other management measures used to maintain water quality at Clarrie Hall Dam include continued prohibition of fuel-engine boats in the reservoir, restriction on recreation uses, and restricted use of pesticides for weed and pest management (e.g. only products registered for aquatic areas).

6.1.2 Issues for consideration

The Proposal could potentially influence:

- the hydrology of Doon Doon Creek and the Tweed River
- local flooding
- surface–groundwater interactions and groundwater-dependent ecosystems
- water availability
- water quality
- cold water pollution.

These issues, as well as the potential impacts of climate change, are discussed below.

Flooding and hydrology

Changes to hydrology and flooding will occur from the Proposal. The extent of these changes includes the raised dam inundation area, as well as potential changes in upstream and downstream hydrology and flooding extents. The details of the changes are not known at this stage. The EIS will contain information from detailed studies and modelling that aims to better understand these changes.

Changes in flooding and hydrology could adversely impact aquatic ecology (section 6.2), terrestrial biodiversity (section 6.2), heritage (section 6.3), and properties (section 6.9).

To confirm the extent of upstream and downstream impacts, flood modelling (KBR, 2023) and downstream flows modelling (EMM, 2023) have been conducted.

Flood modelling

A TUFLOW (a one- and two-dimensional flood and tide simulation software package) hydraulic model of the dam and its surroundings was created for the purpose of the study. The inflows into the hydraulic model were obtained from a RORB hydrological model created by WRM (2017) to investigate the impacts of the proposed raising of the dam.

The existing and proposed spillways modelled as 'Q' channels resulted in modelled rating curves similar to that provided by the Council.

Peak flows for all design events are reduced downstream of the dam for all design events in the developed scenario as a result of the upgraded spillway and raised dam embankment. As a result, peak water levels were observed to be lower by 100 to 500 mm for all design events. Changes in flood extents are noted to be minimal downstream of the dam, with sporadic reductions in flood extents. Flood velocities in the downstream reaches are lower by 0.1 m/s.

Upstream of the dam, flood water levels are increased higher in the dam's main storage area by up to 7.8 m. This flood level increase is due to the raising of the dam's spillway by 8.5 m, which results in higher water levels applied at the start of the hydraulic simulation in the developed scenario, with starting initial water level (IWL) at 70.0 m AHD in the developed scenario compared to 61.5 m AHD in the existing scenario. The severity of the flood level rise reduces further upstream of the dam. Although higher flood levels are observed upstream of the dam, the increased flood impacts are confined to the main waterway corridors and are not considered to require any mitigation measures.

The increased flood extents encroach onto some properties situated within the vicinity of the additional storage area. However, no buildings are noted to be impacted by the increased flood extents and levels. Flood velocities in the upstream reaches are noted to be lower than in the existing case, while closer to the upstream dam wall, flood velocities are noted to have increased by up to 1.0 m/s.

Upstream of the spillway at McCabes Bridge over Doon Doon Creek, the proposed dam and bridge upgrades, and alteration in road alignment would result in increased peak flood levels and extents. The proposed bridge, which has a deck level of 72.0 m AHD, is inundated in all the simulated storm events.

Flood hazard has increased by one classification upstream of the dam and decreased at sporadic locations downstream of the dam.

The dam takes approximately 140 to 150 hours to drain to the FSL level for all design events in the developed scenario.

Flood modelling of the PMF event is shown in Figure 6-1.

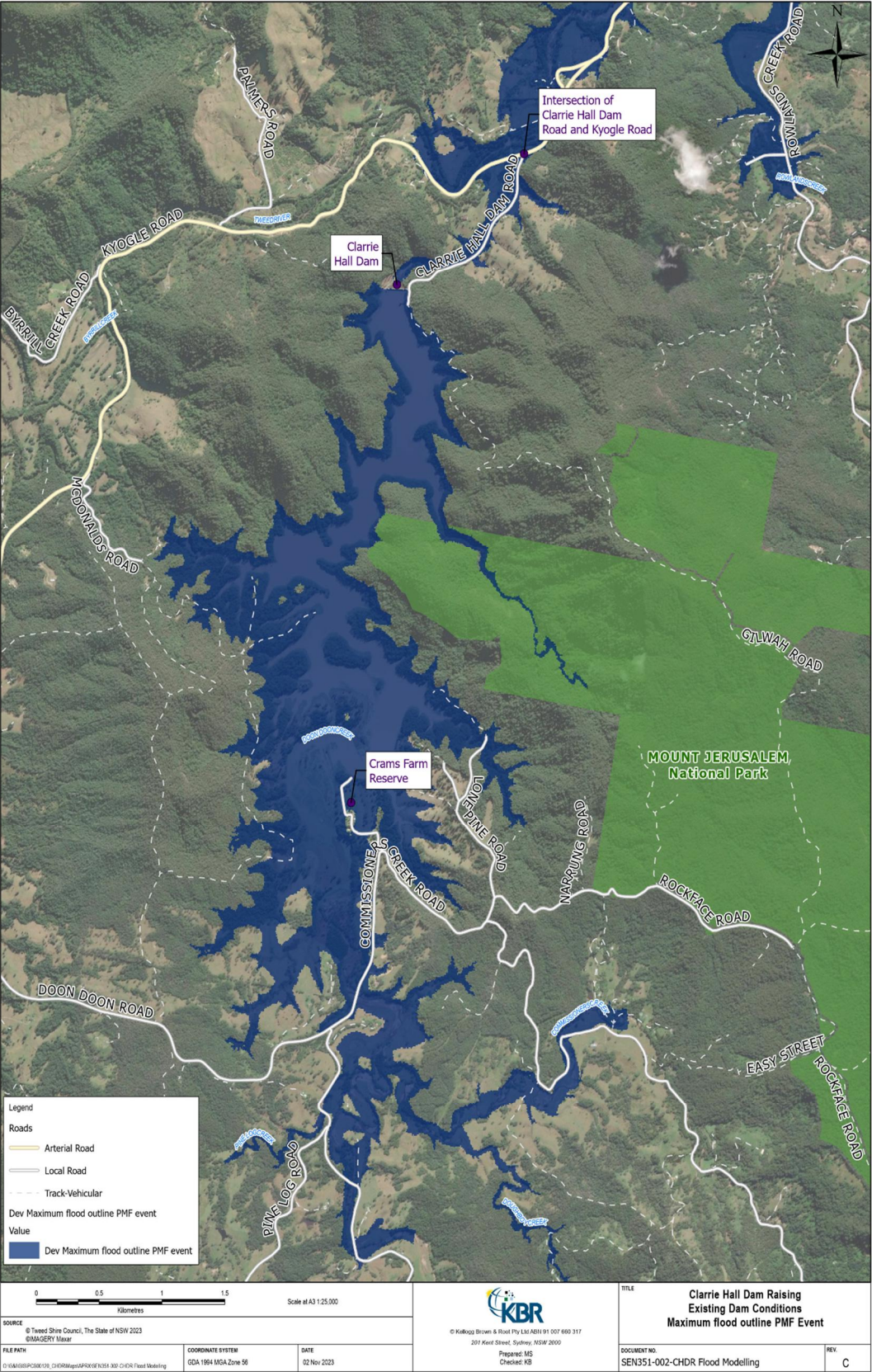


Figure 6-1 Flood modelling results for the PMF

Flows modelling

Hydrological changes in Doon Doon Creek and the Tweed River are being assessed through the use of hydrological modelling using DPE Water's Tweed River Source Model.

An analysis of the flow in Doon Doon Creek, using the historical climate data, showed that with the current dam, flows in the creek downstream of the dam are expected to average around 48 GL/year, with 90th percentile 5-year wet and dry periods averaging 93 GL/year and 32 GL/year respectively. The model illustrates low flow during the Federation Drought, Millennium Drought and the 2019 drought as expected, and significant flood flows in 1974 and 2022.

The current dam is usually full, with natural flows from the catchment flowing over the spillway and contributing to Doon Doon Creek and Tweed River flows. The larger dam would also be full most of the time, and spill would approximately be the same amount of time as occurs now (Figure 6-2).

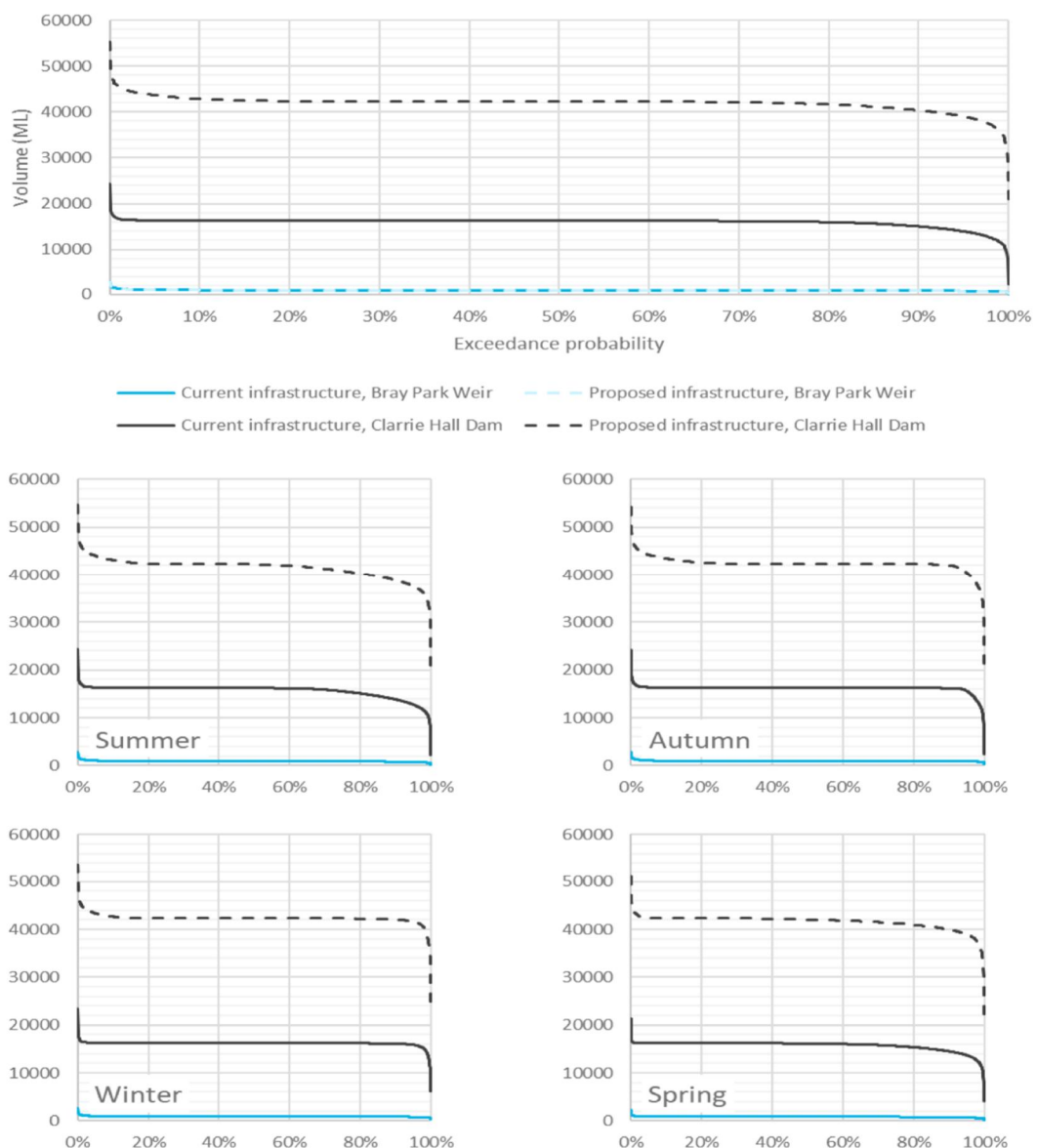


Figure 6-2 Storage volumes

Modelling results illustrating the dam storage during the Millenium Drought are shown in Figure 6-3, identifying that:

- with 2025 demands, the dam would be drawn down, but not emptied
- periods with storage above FSL occur for short periods, with the excess flow released via the spillway over a short period following the high inflow period. With the larger dam, the volume stored above FSL is larger.

That final point is worth repeating – with the larger dam, the volume which can be temporarily stored above FSL is larger, and release rates are slower. This affects release hydrographs, resulting in smaller peaks in released flood waters from the raised dam than the existing dam. This result is consistent with the flood modelling undertaken by KBR and is dependent on the spillway rating curve developed via computational fluid dynamics (CFD) modelling by others.

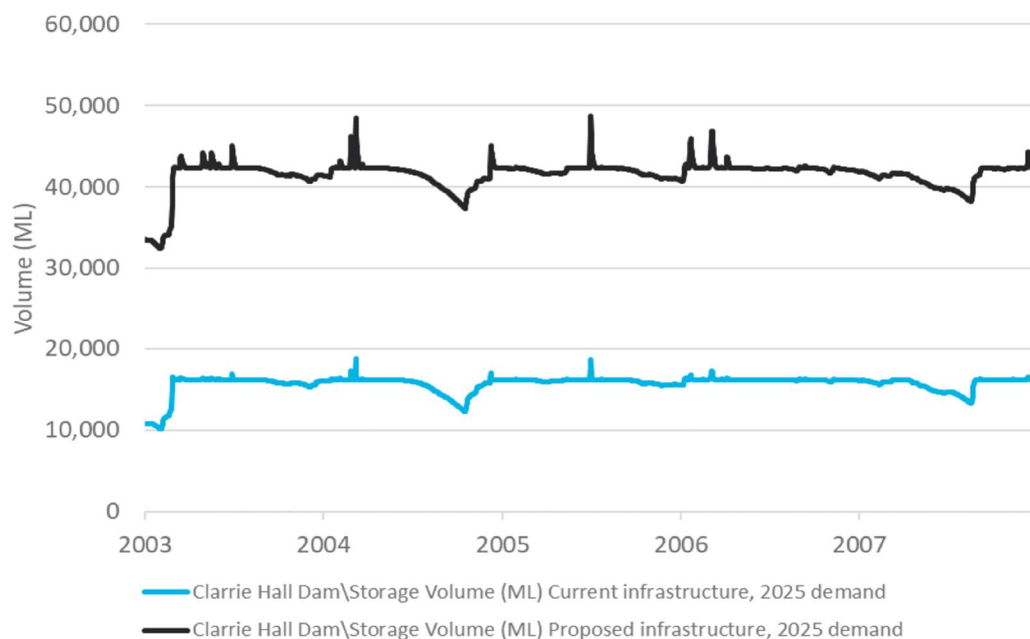


Figure 6-3 Storage volumes 2003–2008 (Millenium Drought)

Groundwater

Potential groundwater impacts include:

- possible reduction in recharge to down hydraulic gradient bores
- possible groundwater level increase up hydraulic gradient.

To assess these risks the following field data was collected:

- groundwater levels were measured in bores located near the dam (upstream)
- hand auguring of some shallow boreholes to assess the presence, type and extent of alluvium at the site.

Groundwater dependent ecosystems

A desktop assessment was undertaken to identify potential groundwater dependent ecosystems (GDEs) located within the vicinity of the study area. The desktop assessment involved:

- review of the GDE Atlas (BoM 2022)
- review of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016
- review of the Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2010
- collation of depth to groundwater information from the NSW DPE-Water database
- review of aerial photographs, topographic and geologic maps.

There are no 'high priority' GDEs listed in the WSPs. However, the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources notes high priority GDEs are currently under investigation, and some may be identified during the term of this plan.

A review of the BoM GDE Atlas (BoM 2022) shows the following potential terrestrial GDEs mapped within the study area, where the potential reliance on groundwater has been inferred from aerial imagery:

- River Oak – high potential GDE
- Wet Bangalow-Brushbox – moderate potential GDE
- Northern Moist Blackbutt – low potential GDE
- Wet Bloodwood-Tallowwood – low potential GDE
- Sub-tropical and warm temperate rainforest – low and medium potential GDE.

The Tweed River is considered to support potential aquatic GDEs owing to possible groundwater baseflow contributions.

Impacts to potential GDEs could result from changes to groundwater levels and quality. There are no high priority WSP listed GDEs in the study area, although there are some mapped areas of BoM high potential terrestrial GDEs. The most notable includes small stands of sub-tropical rainforest to the east of the dam and some River Oak trees in the project disturbance area (in the north). The River Oak GDE is likely to be directly impacted by the Proposal. The sub-tropical rainforest GDE is expected to receive more water, as it is located on the edge of the FSL inundation area.

With the exception of the River Oak GDE, impacts to potential GDEs are not anticipated due to the Proposal. This is due to an absence of potential GDEs (both terrestrial and aquatic), presumably owing to the regional high rainfall volumes, the typical depths to groundwater, and the predominance of groundwater occurrence in fracture networks.

Water availability

The purpose of the Proposal is to ensure water security for Tweed Shire Council region until approximately 2065. It is proposed to lower the water level in the existing dam during construction to 300 mm below FSL. The Proposal should not have a significant impact on water availability during construction. Furthermore, water availability would be increased during operation of the Proposal.

Flows modelling

The hydrological modelling found that dam releases are driven by demand and the volume stored in Bray Park Weir. Releases are not expected to be affected by the Proposal. However, this will be confirmed by detailed studies in the EIS.

Seemingly contrary to this expectation, flow duration curves for Doon Doon Creek immediately below the dam wall show an increase in the portion of the time that minimum releases are made, and a reduction in the median (50th percentile) daily release from 27 ML/day to 22 ML/day (Figure 6-4).

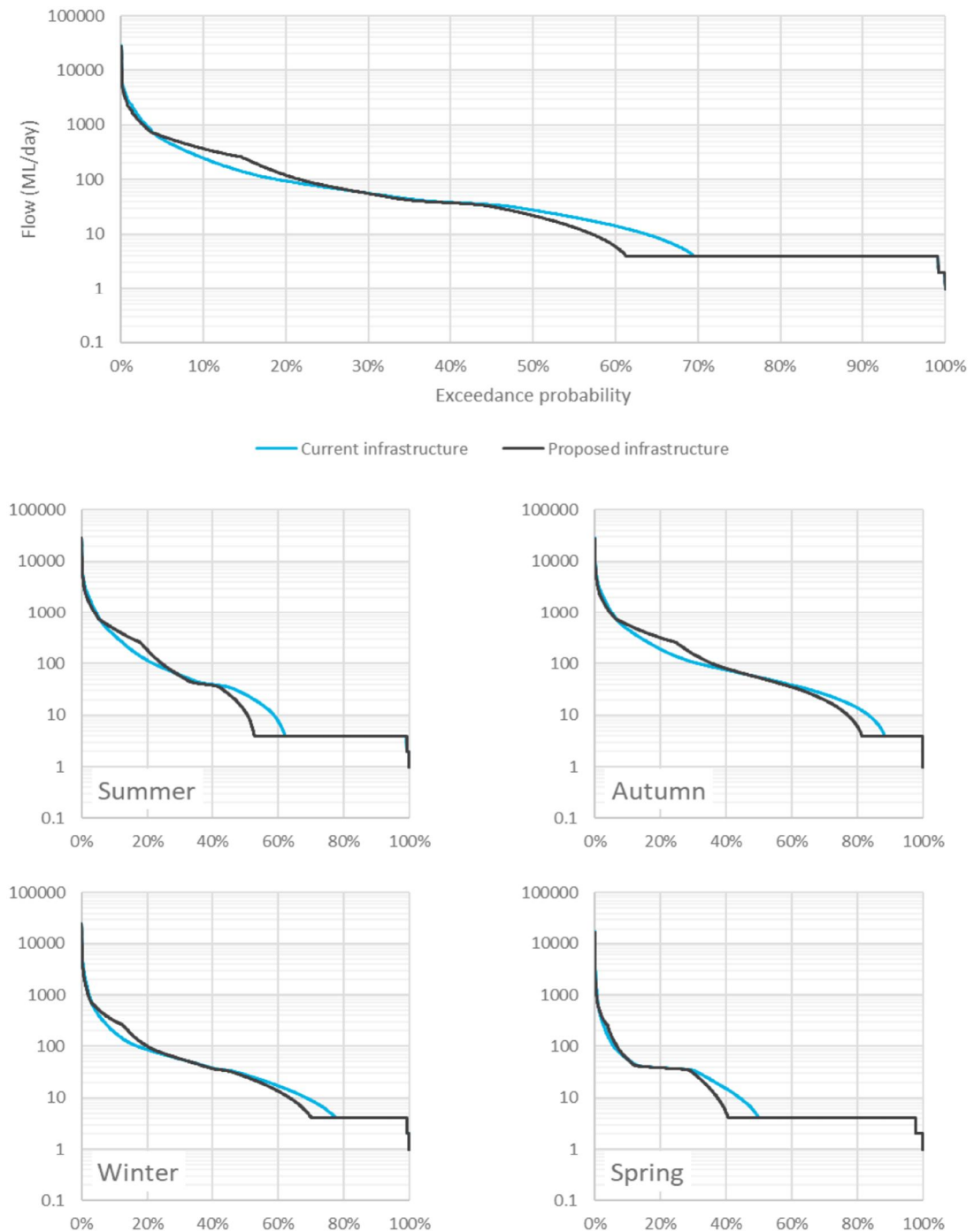


Figure 6-4 Total dam releases/flow in Doon Doon Creek downstream from Clarrie Hall Dam

These results require additional investigation to develop an understanding of the mechanisms in the model and specific flow sequences driving these changes, to allow reporting in the EIS. This investigation will occur but has not yet been completed. One potential mechanism can be seen by reference to the 1976 flood sequence presented in Figure 6-5.

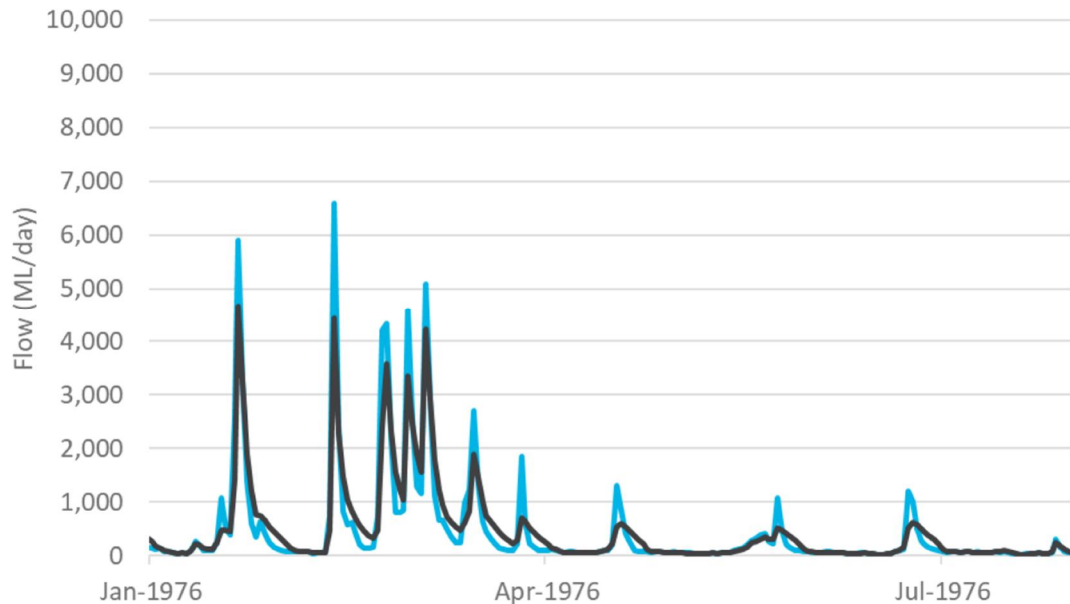


Figure 6-5 Dam releases, 1976 flood

It can be seen that flood peaks are reduced if the dam is larger. The reduction in flood peaks leads to detained flood waters being released after the flood peak and an increased number of days with high flow following the main peak (Figure 6-6).

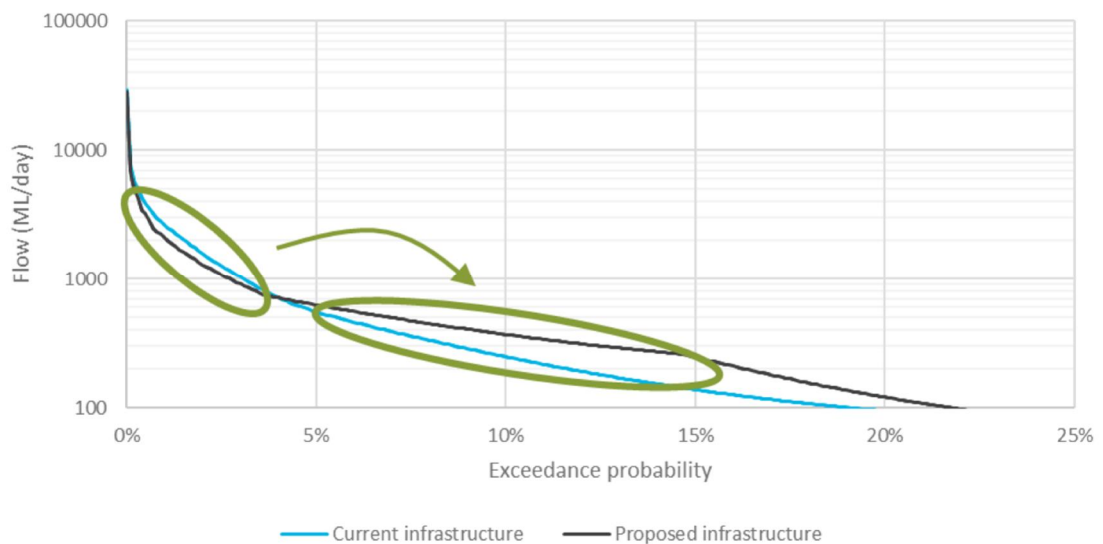


Figure 6-6 Downstream flow in Doon Doon Creek – focus on peak flow detention

In the Tweed River, the modelling showed no meaningful difference in flow percentiles at Uki and Bray Park.

Water quality

The Proposal may have impacts on water quality. These impacts can directly affect the dam area and could extend beyond the Proposal boundary. Without appropriate mitigation measures, these impacts could be significant. The Proposal could adversely impact aquatic ecology, terrestrial biodiversity and water supply consumers.

Reservoir water quality

The Proposal has the potential to impact water quality of the reservoir during operation and as it fills for the first time. Construction impacts to water quality such as risk of spills and dust pollution can be effectively managed via appropriate controls.

Receiving environment water quality

The Proposal can impact the water quality of environmental flows downstream of the dam. Any changes in water quality to the receiving environment downstream of the dam may impact aquatic ecology and potable water quality at Bray Park Weir.

Changes in nutrient loads can change the quality of environmental flows, which can impact aquatic ecology downstream of the dam.

Operational supply water quality

The Proposal is unlikely to affect delivered water quality, as Clarrie Hall Dam flows to the Bray Park Weir and all drinking water is treated at Bray Park Water Treatment Plant before it is transferred to users.

Clarrie Hall Dam would continue to operate according to the WSP for the Tweed River Area Unregulated and Alluvial Water Sources 2023. The raised dam would be required to meet the WSP objectives.

These potential water quality impacts will need to be assessed in further detail in the EIS. Additional baseline data, including DPE waterway water quality database extracts and Clarrie Hall Dam water quality and algae monitoring data, will be required to quantify and assess the potential impacts.

Cold water pollution

The Proposal may have potential impacts on ecological health by means of cold water pollution. As Clarrie Hall Dam does not have a destratification system, the dam raising has the potential to intermittently cause cold water pollution effects, which is raised in proposed action 2.3 of the FNCRWS (Figure 6-7):

Proposed action 2.3: Address cold water pollution

Between spring and autumn, the water stored in large dams can form 2 layers, with a warm surface layer overlaying a cold bottom layer. Cold water pollution – an artificial decrease in the temperature of water in a natural river – is caused when this cold water is released into rivers from large dams during warmer months. This can have serious negative effects on ecological health.

This option aims to evaluate the extent of cold water pollution impacts from existing storages in the Far North Coast and to work with asset owners to implement appropriate capital and operational responses to mitigate those impacts. This option is structured as a 5-year partnership with a scoping-study in the first phase to assess the issue and identify suitable works and project partners.

The major storages in the Far North Coast region vary in their likelihood of releasing cold water to the environment.²⁴ While Toonumbar Dam has a destratification system, the dam was identified in the NSW Cold Water Pollution Strategy as having the potential to cause moderate cold water

pollution effects. Clarrie Hall Dam does not have a destratification system and is likely to intermittently cause cold water pollution effects. Cold water pollution effects of Emigrant Creek Dam are likely to be minimal, while Rocky Creek Dam does not release water to the environment.

There is a lack of monitoring sites both upstream and downstream of storages in the region. This can make it difficult to determine the extent of cold water pollution in the region.

This action would include:

- aligning with NSW Cold Water Pollution Strategy
- assessing existing temperature metrics against best-practice frameworks for managing impacts on aquatic fauna
- examining the extent and magnitude of cold water pollution effects from Toonumbar Dam and Clarrie Hall Dam
- exploring the potential for, and feasibility of, technologies to mitigate cold-water pollution effects, such as augmentation of dam outlets, improvements to mixing regimes, and modifications to water delivery mechanisms.

Figure 6-7 FNCRWS-proposed action 2.3

Previously there was a lack of monitoring sites both upstream and downstream of the dam, and it was difficult to determine the extent of cold water pollution in the region.

Cold water pollution will be assessed in the EIS. Data for such pollution has been collected to quantify and assess the potential impacts (preliminary results are provided in section 6.1.3).

6.1.3 Approach to the assessment

A detailed hydrological and flooding assessment of potential impacts of the Proposal is required as part of the EIS, comprising:

- a baseline assessment characterising the existing hydrological conditions of the system, based on:
 - a review of background information
 - a site visit
 - modelling
- identification and assessment of potential construction impacts, including potential changes to the hydrological regime and surface water–groundwater interactions
- assessment of cold water pollution
- assessment of surface water impacts
- identification and assessment of potential operational impacts with reference to the operating rules, including:
 - changes to the hydrological regime
 - changes to groundwater
 - changes to environmental water availability and flows

- compliance with the Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources (NSW State Government, 2010)
- consideration of potential cumulative impacts
- identification of potential mitigation and management measures.

The assessments above will provide inputs to the aquatic ecology assessment. Further information on these assessments is provided below.

The assessment will be conducted in accordance with the following relevant plans, policies and guidelines (see Appendix A):

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)
- ANZECC Guidelines and Water Quality Objectives in NSW (Department of Environment and Conservation, 2006)
- Australian Drinking Water Guidelines (ADWG, 2011)
- NSW Cold Water Pollution Strategy
- Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004)
- Managing Urban Stormwater: Soils and Construction Volume 2 (Department of Environment and Climate Change, 2008)
- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (Department of Environment and Climate Change, 2008)
- Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources Order 2010
- The Far North Coast Regional Water Strategy (DPE, 2023)
- NSW Aquifer Interference Policy (DPI, 2012)
- Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Office of Water, 2012)
- NSW and ACT Regional Climate Modelling (NARCLiM): NARCLiM 1.0; NARCLiM 1.5 - using data, models, simulations, and guidance, appropriate to assessment of the Proposal impacts and risks.

Flooding and hydrology

Flood modelling and assessment

Detailed assessment and modelling of flood behaviour has been completed to determine the potential effects on flood behaviour caused by the proposed upgrade, both upstream and downstream. The assessment has collected and reviewed all available data related to the Proposal, including the existing hydrological and hydraulic model. Following the review, several models were developed, including:

- a TUFLOW model of the existing conditions of Clarrie Hall Dam
- a dam storage model using bathymetric survey and cross-checked against the stage storage relationship
- a dam spillway model using the current rating curve

- a downstream 2D TUFLOW hydraulic model based on available LiDAR and topographic survey
- flood modelling for 5%, 1%, 0.5%, 0.2% AEP and PMF baseline events for the design
- a climate change sensitivity model.

The model outputs would be reported in the EIS in consideration of flooding, safety and climate change. Consultation with flood-impacted property owners and DPE would be carried out regarding these matters during the preparation of the EIS.

Flows modelling

Modelling for flows and hydrology will continue to determine potential effects on upstream and downstream flow behaviour caused by the proposed upgrade. The assessment has collected and reviewed available data and has updated models in the following way:

- The DPE Tweed River eWater Source model was reviewed for adequacy and validated the model flow outputs to recorded gauge flow data.
- The Source model was updated to incorporate the proposed dam.
- Model simulations were run with paleo-stochastic climate data and with potential future climate data developed as per DPE recommendations for water supply projects.
- Outputs were plotted, including flow duration curves, tables of average annual flows and diversions, depth frequency curves and supply reliability statistics.
- Flow regime targets are being developed as required to meet ecological objectives and report Proposal impacts on these flow metrics.

The hydrology results have not yet been translated into an assessment of the frequency of flow events that could result in river-bank or bed movement. However, from the results presented above, it is anticipated that a reduction in flood peak flows would result in reduced frequency of erosive events and increased geomorphological stability. It is therefore unlikely that terrestrial biodiversity, heritage and other non-aquatic assessments would be required downstream.

Environmentally relevant flow sequences would be developed to inform the aquatic ecology assessment.

Groundwater

A qualitative assessment of groundwater risks and impacts would also be undertaken to further understand and quantify impacts to groundwater. This would be completed in consideration of the Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Office of Water, 2012) and NSW Aquifer Interference Policy (DPI, 2012).

Water availability

The results of the modelling would be reported in the EIS alongside a description of the modelling of changes to the long-term flow regime downstream from the dam. Water availability would be based on existing uses and the consideration of climate change and population growth for 2065.

Consultation with the local community and DPE would be carried out about the modelling results during the preparation of the EIS to ensure changes to water availability and hydrological flows are understood.

Water quality

The EIS would include a detailed assessment of water quality. It would provide a description of existing water quality and potential impacts on water quality during construction and operation phases of the Proposal.

The water quality assessment would be based on historical water quality monitoring data from DPE, Clarrie Hall Dam monitoring data from Council, and any existing limnological study reports for the existing Clarrie Hall Dam. Existing water quality data would be collected according to Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (Department of Environment and Climate Change, 2008). The water quality assessment would consider:

- the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)
- ANZECC Guidelines and Water Quality Objectives in NSW (Department of Environment and Conservation, 2006)
- Australian Drinking Water Guidelines (ADWG, 2011).

This assessment would be accompanied by water quality modelling based on recently collected data. Results of the water quality assessment would provide inputs to the aquatic ecology assessment.

Mitigation measures to reduce or eliminate risks to water quality during the construction phase would consider guidance provided in:

- Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004)
- Managing Urban Stormwater: Soils and Construction Volume 2 (Department of Environment and Climate Change, 2008).

Cold water pollution

A standard assessment of the potential for cold water pollution downstream from the dam will be completed for the EIS. This assessment will follow the guidance provided in the Far North Coast Regional Water Strategy to assess the magnitude of cold water pollution from Clarrie Hall Dam.

The cold water pollution modelling will be based on daily dam release data for the period March 2008 to February 2023.

An event analysis is summarised in Figure 6-8. It shows a range of durations from 2 days to 50 days, with flows generally 40–60 ML/day, but reaching more than 300 ML/day during several events, for example a king tide, to keep salt water out of the Bray Park Weir pool.

The cold water pollution assessment is proposed to be based on this range and pattern.

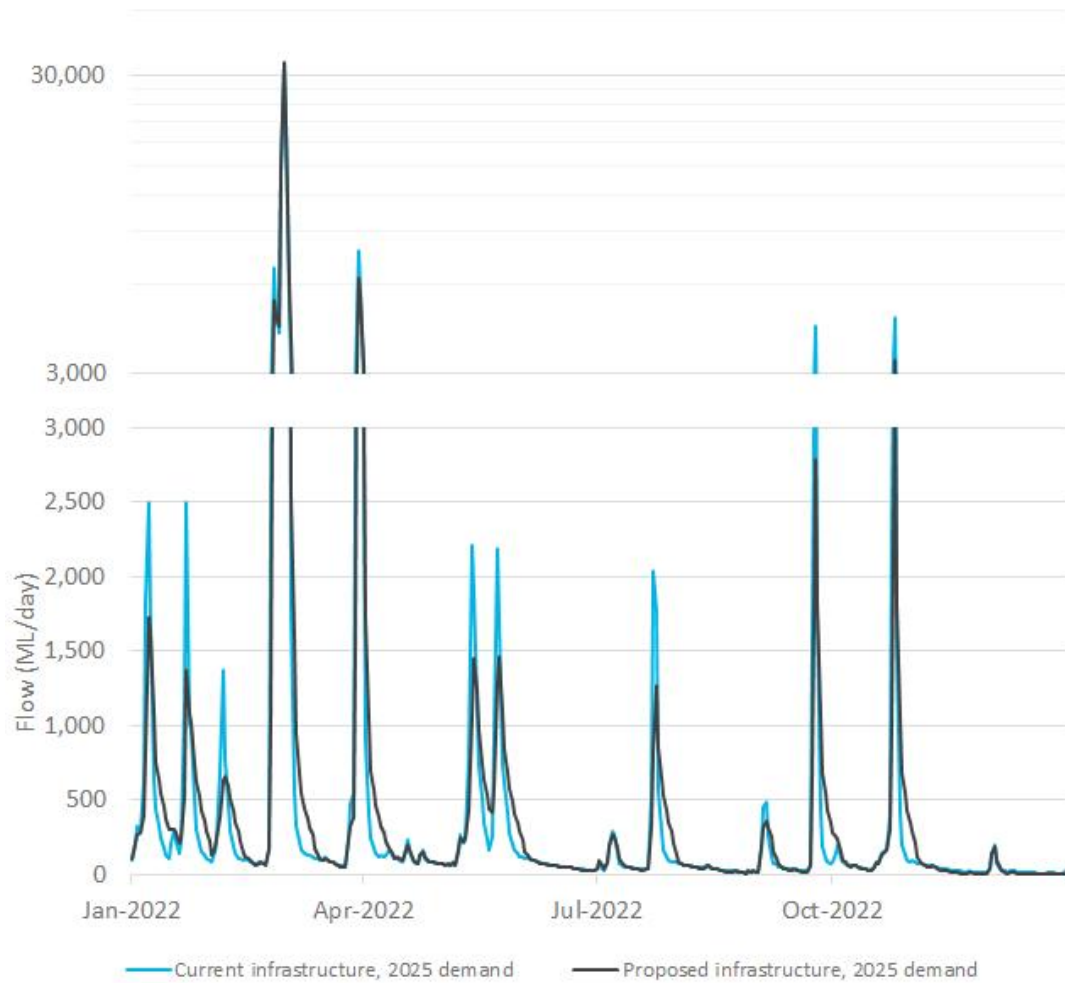


Figure 6-8 Proposed range and pattern of dam release data to be used in the modelling

On 5 April 2023, a planned flow release occurred from Clarrie Hall Dam for the purpose of collecting flow and temperature data for modelling of cold water pollution.

The locations of temperature data loggers are shown in Figure 6-9.

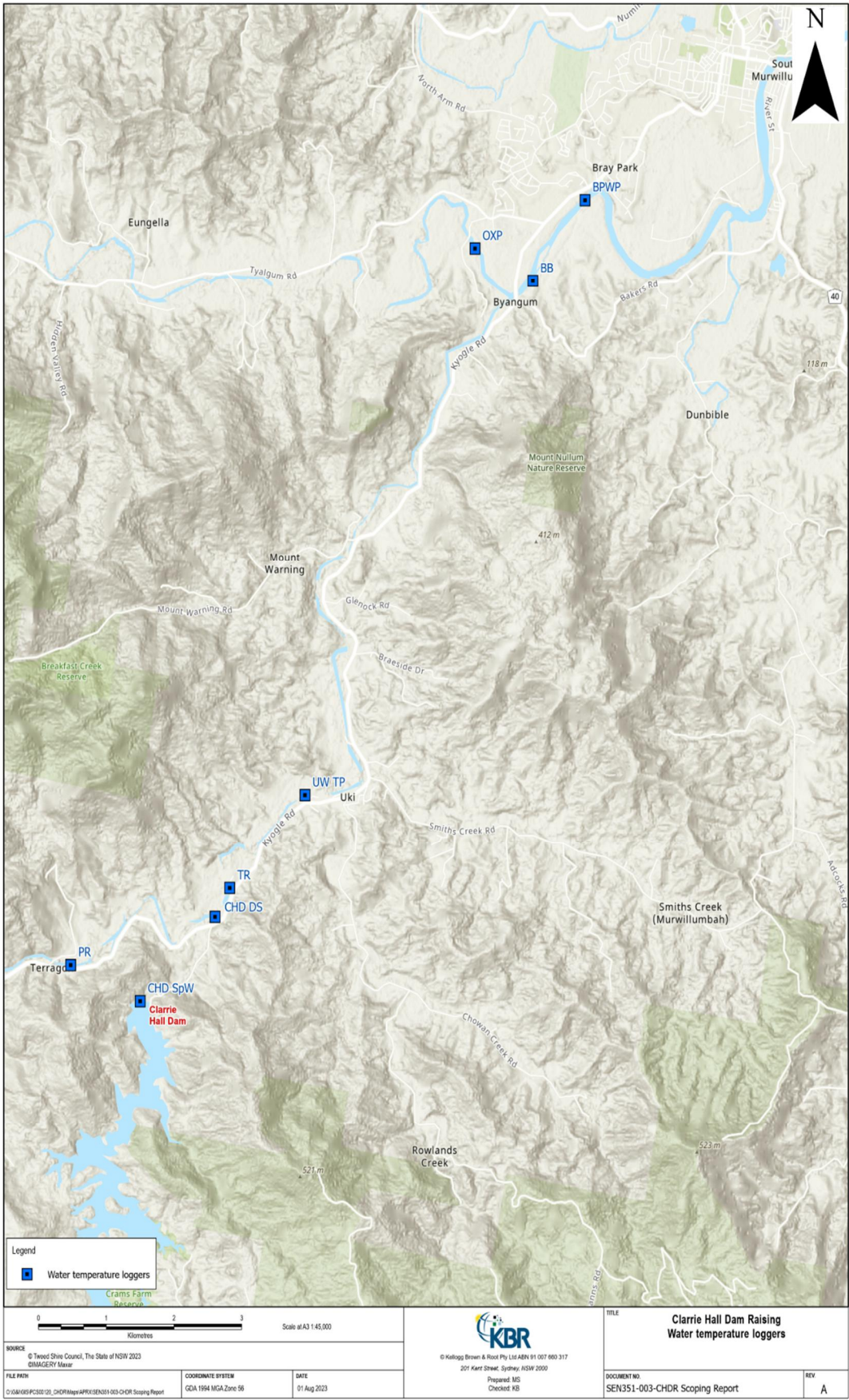


Figure 6-9 Locations of temperature data loggers

The preliminary cold water pollution modelling results (Figure 6-10) showed:

- the distance that cold water pollution may exist downstream from the dam, if there is no other flow in the Tweed River
- the change due to the proposed larger dam, which is small but positive (water temperature of 16 degrees for the current dam and 17 degrees for the larger dam) on the basis of the Hydronumerics modelling).

The planned release was in the summer, when the river temperature would have been 25 degrees.

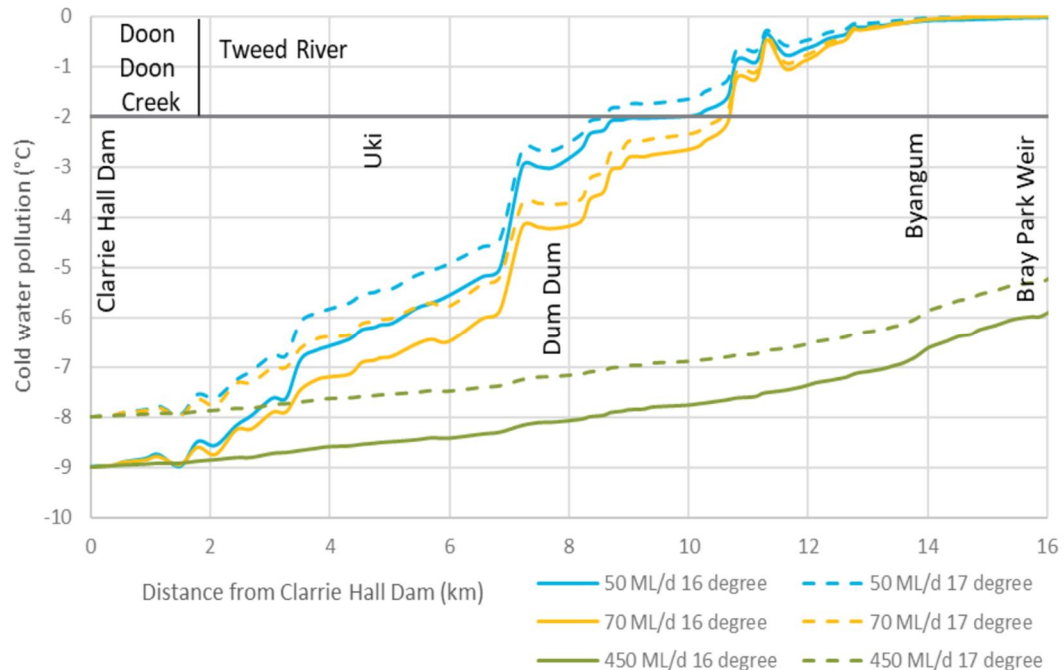


Figure 6-10 Preliminary modelling of cold water pollution

These preliminary results show that Doon Doon Creek and the Tweed River are able to quickly warm up cold water, and downstream cold water pollution effects are anticipated to be minimal.

The preliminary results have not yet accounted for air temperature or solar effects that resulted in the warming.

Climate change

The preliminary climate change modelling results shown in Figure 6-11 and Figure 6-12 indicate that the effects of climate change on river hydrology are expected to be minor, on average. Preliminary findings indicate that flows over the spillway would decrease, and regulated releases would increase in response. There is expected to be little change in flow past Uki.

The results for wetter or drier outcomes would be determined.

The climate change analysis would use data, models, simulations, and guidance from the NSW and ACT Regional Climate Modelling (NARCLiM): NARCLiM 1.0; NARCLiM 1.5 where appropriate for assessment of the Proposal impacts and risks.

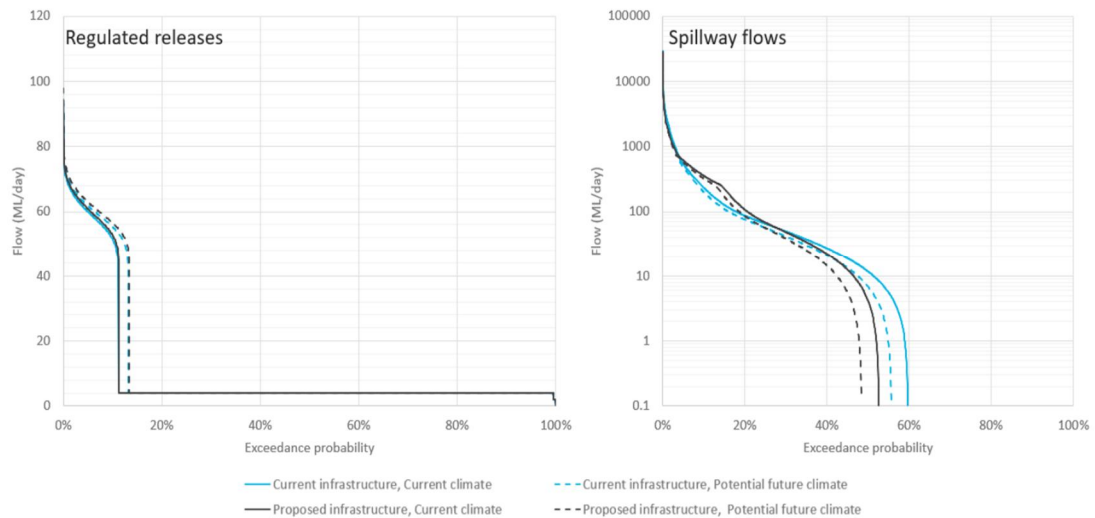


Figure 6-11 Climate change modelling results showing spillway flows and regulated releases

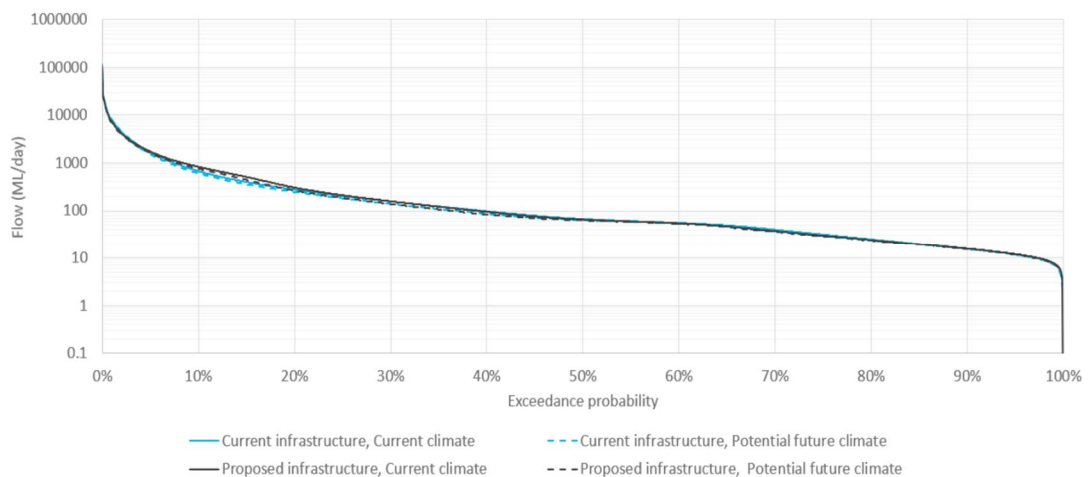


Figure 6-12 Results of climate change modelling flows

6.2 BIODIVERSITY

6.2.1 Existing environment

Conservation areas

Mount Jerusalem National Park is included in a portion of the Clarrie Hall Dam raising disturbance area along the section of shoreline that extends approximately 500 m upstream of an unnamed creek. This portion of the national park is owned by Council under a land transfer agreement.

Approximately 1.91 ha of Mount Jerusalem National Park has been revoked through the National Parks and Wildlife Legislation Amendment (Reservations) Bill 2020, which was passed by the NSW Government on 18 November 2020. The revoked land is vested in the Minister administering the *National Parks and Wildlife Act 1974* (NPW Act). In order to complete the transfer of the land to Council, Council is required to complete the necessary subdivision and title registration task.

Other conservation areas near the Proposal area include Nightcap, Wollumbin and Border Ranges national parks.

The areas within 40 m of the edges of the dam and upstream tributary are regarded as waterfront land under the *Water Management Act 2000*. These areas act as a buffer between adjacent land uses and the waterbody, helping to maintain water quality, providing corridors for wildlife and providing stabilisation of the banks of the waterbody. The waterfront land surrounding the majority of the dam is densely vegetated, with the exception of the upstream extent of the dam and the southern end of the construction disturbance area, where vegetation has been cleared for agriculture.

No biodiversity stewardship sites, private conservation lands or other lands identified as offsets would be affected by the Proposal. There are several private land conservation agreements locally (the exact location is not publicly available information). The nearest Biodiversity Conservation Trust Wildlife Refuge and In Perpetuity lands are approximately 2 km north-west of the construction disturbance area.

Terrestrial ecology

The Clarrie Hall Dam raising Proposal is within the South Eastern Queensland Interim Biogeographic Regionalisation of Australia (IBRA) region and Scenic Rim IBRA subregion.

The dominant vegetation type across the Proposal area is wet sclerophyll forest, with localised rainforest remnants present in sheltered gullies. In the southern portion of the site, cleared land includes exotic pastures and plantations comprising a Dunn's White Gum plantation, a Hoop Pine plantation as well as large paddocks.

These vegetation communities have been categorised into plant community types (PCTs) by ELA (2021a) in accordance with the Biodiversity Assessment Method (BAM). This information is currently being reviewed; however, potential PCTs within the Proposal footprint are listed below:

- PCT 770 – Coachwood – Soft Corkwood – Crabapple warm temperate rainforest of the NSW North Coast Bioregion
- PCT 827 – Flooded Gum – Tallowwood – Brush Box moist open forest of the coastal ranges of the North Coast
- PCT 1068 – Pepperberry – Giant Stinging Tree – Fig lowland rainforest in the NSW North Coast Bioregion
- PCT 1073 – Pink Bloodwood – Tallowwood moist open forest of the far northern ranges of the NSW North Coast bioregion
- PCT 1302 – White Booyong – Fig subtropical rainforest of the NSW North Coast bioregion.

ELA (2021a) has identified the following threatened ecological communities (TEC) that are within the Proposal area or are likely to occur within the Proposal footprint:

- Coastal Swamp Oak (*Casuarina glauca*) Forest of NSW and South East Queensland ecological community
- Dunn's white gum (*Eucalyptus dunnii*) moist forest in north-east NSW and south-east Queensland
- Grey box-grey gum wet forest of subtropical eastern Australia
- Subtropical eucalypt floodplain forest and woodland of the NSW North Coast and South East Queensland bioregions.

PCT 770, 1068 and 1302 are consistent with the TEC Lowland Rainforest in the NSW North Coast and Sydney Basin bioregions, listed as endangered under the BC Act, and Lowland Rainforest of Subtropical Australia, listed as critically endangered under the EPBC Act.

No important wetlands, coastal wetlands, Ramsar wetlands or local wetlands are located within or immediately adjacent to the proposed footprint.

Council and ELA (2021b) have conducted site surveys since 2018 and have identified a number of threatened flora and fauna species listed under the BC Act and EPBC Act.

Aquatic ecology

Clarrie Hall Dam and downstream Doon Doon Creek are mapped as a Type 1 Key Fish Habitat by DPI Fisheries (2016).

The Bray Park Weir, downstream of Doon Doon Creek and Clarrie Hall Dam, is essentially a saltwater barrage across the Tweed River at Bray Park, Murwillumbah. Fish passage is facilitated at the weir through the use of fish ladders. At Clarrie Hall Dam, there is no fish ladder or lift fitted.

The 141 ha Stotts Island Nature Reserve is located in the Tweed River, near Tweed Heads, approximately 17 km downstream of Bray Park Weir.

Stotts Island is listed as E1 – National Parks and Nature Reserves according to the Tweed LEP 2014. Due to its lack of proximity to Clarrie Hall Dam and Bray Park Weir, there are not expected to be any impacts to Stotts Island Nature Reserve. This is supported by hydrological studies showing no significant impacts to downstream environments after Bray Park Weir.

6.2.2 Issues for consideration

Construction and operation of the Proposal would have the potential to impact terrestrial and aquatic biodiversity – specific issues for consideration are discussed below. It would result in impacts to approximately 150 ha of native forest, 13 ha of native plantation and 70 ha of predominately cleared land. These figures are currently being revised.

Conservation areas

The completion of the Proposal would cause inundation of two sections of shoreline within the mapped area of Mount Jerusalem National Park, which is owned by Council under a land transfer agreement. The proposed new inundation area would also impact waterfront land that provides corridors for wildlife and stabilisation of the banks of the waterbody.

Terrestrial ecology

Construction and operational impacts are likely to affect threatened species predicted to occur within in the Proposal area – 13 threatened flora species and 20 threatened fauna species, including 4 migratory species listed under the EPBC Act, are identified as likely to occur and require further assessment.

The raising of Clarrie Hall Dam wall and subsequent flooding of the inundation area would lead to permanent removal of native vegetation, and threatened species and their habitats.

The Proposal may potentially intersect River Oak terrestrial vegetation mapped immediately downstream of the dam, in addition to potential sub-tropical rainforest located approximately 2 km south-east from the dam wall (at the northern extent of the

Proposal area), based on the Bureau of Meteorology (BoM) Groundwater Dependent Ecosystems Atlas (2019).

Aquatic ecology

The main impacts to aquatic ecology from the raising of Clarrie Hall Dam are predicted to occur around the current and newly inundated shorelines.

The pool beneath the spillway currently acts as a deep backwater when there is no flow over the spillway, and potentially has poor circulation under low-flow conditions. This leads to rapid oxygen consumption when there are high numbers of fish. Options for addressing this would be discussed in the EIS.

Further issues for consideration include the assessment of impacts to:

- Key Fish Habitat
- fish species assemblages
- offsets
- platypus.

See section 6.1.2 for a discussion of water quality impacts on aquatic ecology.

6.2.3 Approach to the assessment

A detailed assessment would continue, building on the surveys completed to date.

Terrestrial ecology

The assessment of terrestrial ecology impacts would consist of both upstream and downstream impact assessments (pending confirmation of the results of modelling), including site visits and additional field surveys to complete the assessment conducted to date.

The updated hydrological modelling data would be reviewed to identify an appropriate study area for the assessment of the impacts of altered downstream flows on terrestrial ecology. The assessment would consider the relationship between the Proposal and the river flow objectives and threatened species identified as being associated with the Doon Doon Creek and Mid Tweed River zones in the *Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2023 Background document* (NSW Government, 2023).

The potential impacts on vegetation and habitat suitability for threatened species within the identified inundation study area would be assessed. The inundation study area would be extracted from analysis of flooding extents and durations for upstream areas between the FSL and PMF and intervening AEP of 5%, 1%, 0.5% and 0.2%. The assessment would then identify species and communities that may be susceptible to being displaced through additional inundation.

Further surveys would be conducted to complement the existing terrestrial biodiversity assessments that have been prepared. A BDAR would be prepared to meet the requirements of the Biodiversity Assessment Method (BAM) (EES, 2020). Assessments would be conducted in consideration of the following guidelines:

- Threatened Species Survey and Assessment Guidelines (DPE, 2016)
- Revocation, Re-categorisation and Road Adjustment Policy (EES, 2017)

- Guidelines for developments adjoining land managed by the Office of Environment and Heritage (EES, 2013).

A BAM Calculator case for the Proposal will be created, and additional assessment will be conducted for downstream (if required) and temporary inundation impacts and impacts on matters protected under the EPBC Act.

EPBC Act assessments will be conducted for all EPBC listed species recorded onsite or considered likely to occur. The EPBC Offsets Policy requirements will be addressed, focusing on the use of the NSW Biodiversity Offsets Scheme to meet Commonwealth EPBC Act offset requirements. The assessment will also ensure EPBC Act assessment requirements are met and addressed in downstream impacts, indirect impacts, offsets and mitigation.

Aquatic ecology

The assessment of aquatic ecology will involve investigation of both upstream and downstream impacts of the Proposal during construction and operation.

Fish surveys would be undertaken in accordance with *Survey guidelines for Australia's threatened fish: Guidelines for detecting fish listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999* (Department of Sustainability, Environment, Water, Population and Communities, 2011). These assessments will inform the presence or absence, abundance and distribution of species occurring within the Clarrie Hall Dam and associated waterways and tributaries.

Additional eDNA assessments will inform the abundance and distribution of key listed species and the platypus through analysis of trace DNA within the aquatic environment.

Key Fish Habitat assessments will be undertaken as part of the comprehensive aquatic ecology assessment in accordance with policy and guidelines for fish habitat conservation and management (Department of Primary Industries (DPI), 2013). In-field characterisation, in combination with examination of existing stream order data, will be undertaken in accordance with DPI (Fisheries) policy by assessing 'waterway type' and 'waterway class'.

Assessment of other biotic and abiotic components such as water quality, riparian vegetation, algae (phytoplankton, periphyton), macroinvertebrates and sediment quality will be undertaken. The results from these assessments will further inform the current ecological values within the study area.

Assessments for aquatic ecology would be conducted in consideration of the following guidelines:

- Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (NSW Fisheries, 2003)
- NSW DPI Fisheries Fishway Design Guidelines 2015 – as relevant to any proposed offsetting
- Aquatic Ecology in Environmental Impact Assessment – EIA Guideline (DoP/Marcus Lincoln Smith 2003)
- Policy and Guidelines for Fish Habitat Conservation and Management – Update 2013 (DPI, 2013).

6.3 HERITAGE

6.3.1 Existing environment

Aboriginal

The Clarrie Hall Dam Proposal area is located within the traditional boundaries of the Bundjalung people. Local Aboriginal people have continued to live in the region and still hold a strong connection to the land, water, flora and fauna.

As part of the project, an Aboriginal cultural heritage assessment (ACHA) in accordance with Heritage NSW guidelines was completed by Navin Officer Heritage Consultants in 2018. This investigation undertook a field survey of some 87.5% of the project area, with remaining areas subject to targeted inspections. The assessment was done with participation of the Tweed Byron Local Aboriginal Land Council and several Bundjalung traditional owners. Some 87 objects and/or sites were identified. These included 28 stone artefact scatters (primarily low density with rarely more than 10 objects observed; 8 with potential deposits), 39 isolated stone artefacts (5 with potential deposits), 3 rock shelters (CHD-RS1, #04-1-0014, #04-1-0090), 2 grinding grooves, one gender-specific restricted site (CHD-A56), 2 potential culturally modified trees, one knapping source, one potential food processing site (sandstone pitting; CHD-A20) and 10 potential archaeological deposits.

The ACHA made several recommendations about the future management of cultural materials within the project area, one of which included further investigation of potential archaeological deposits. Subsequently, Eco Logical Australia continued the ACHA process in 2021. Its works included investigation of 19 of the previously identified Aboriginal sites. These included CHD-A1, CHD-A17, CHD-A27, CHD-A30, CHD-A35-38 inclusive, CHD-A48, CHD-A55, CHD-PAD8, and CHD- PAD1-9 inclusive. Following a program of test excavations, 7 of these sites recovered moderate to high densities of sub-surface cultural materials (ranging from 8 to 28/m²), with a total of ~1,100 stone artefacts recovered across the program, and typically in the upper 50 cm of the soil profile.

These subsequent assessments concluded that these more extensive cultural deposits were primarily found in areas that would have been close to Doon Doon Creek prior to its inundation. During the fieldwork, a further culturally modified tree and 2 surface artefact scatters were also documented. The report also provided further details of the redesign and avoidance of a culturally modified tree (CHD-ST1) near the dam that had been raised as an issue by the Aboriginal participants.

Both the ACHA and subsequent reporting provided a range of recommendations in relation to management of Aboriginal objects and sites should the Proposal be approved, including collection and/or archaeological excavation of cultural materials prior to development.

Historic

The construction of Clarrie Hall Dam was completed in 1979, requiring the inundation of the lower Doon Doon Creek.

A search of the National Heritage List, the State Heritage Register (SHR) and the *Tweed Local Environmental Plan 2014* (Tweed LEP) for cultural archaeological historic heritage items was undertaken in 2020.

These searches identified no heritage items or archaeological sites listed within the area. The searches would be updated for the EIS, including a review of Crams Farm and McCabes Bridge.

6.3.2 Issues for consideration

Aboriginal

The Proposal has the potential to impact Aboriginal heritage during both the construction and operational phase. Clearing and earthworks are likely to disrupt Aboriginal cultural materials, as is inundation of the cleared land. Currently, some 87 Aboriginal objects and/or sites have been identified by the previous assessments as being within or near the project area. These objects require consideration.

Over the last several years, interactions with the Aboriginal participants have explored a range of issues, including the need for further consideration of some significant sites – notably several rockshelters in proximity to the Proposal – and the need for additional work on the intangible and cultural values for the immediate locale.

There is an Aboriginal Land Claim (ALC) on certain parcels of crown land. The proponent is engaging with the Tweed Byron Local Aboriginal Land Council and has done so throughout the project.

There is a Native Title application over the general area.

Historic

No specific sites or places were identified during the previous assessments. However, McCabes Bridge and buildings at Crams Farm will be reviewed for their potential heritage significance. The land was predominantly used for agriculture.

6.3.3 Approach to the assessment

Aboriginal

A detailed assessment would continue, building on the draft ACHA prepared previously.

The ACHA would include:

- re-initiation of the Aboriginal consultation process, using Aboriginal Cultural Heritage Consultation requirements for proponents (DECCW, 2010), through:
 - contacting the current registered Aboriginal parties and advising them of the need to implement this process
 - contacting various government bodies seeking information on Aboriginal organisations in the region
 - notifying Aboriginal organisations identified above of the Proposal and seeking their interest to be consulted
 - providing a methodology document outlining the current status of the Proposal and any further activities, and providing an opportunity to comment
 - providing the draft Aboriginal cultural heritage assessment report (when available) for review and comment
- additional management of the rockshelter sites, identified previously, to further explore opportunities for their retention and conservation

- implementation of a cultural values mapping study to further understand the intangible and cultural values of the Proposal area, in consideration of the code of practice for archaeological investigation of Aboriginal objects in NSW (DECCW, 2010)
- a review of the hydrological studies for downstream impacts and their interaction with known/previously documented cultural materials. The preliminary results of the hydrology modelling show that a downstream assessment is not required
- a review of the ALCs and Native Title application
- development of an Aboriginal Cultural Heritage Assessment Report (ACHAR).

The Aboriginal Heritage assessment will be undertaken in consideration of the following guidelines where relevant:

- Guide to Investigating, Assessing and Reporting on Aboriginal Cultural Heritage in New South Wales (EES, 2011)
- Aboriginal Heritage Information Management System site registration form (OEH, 2011)
- Aboriginal Cultural Heritage Consultation Requirements for Proponents (DECCW, 2010)
- Code of Practice for Archaeological Investigation of Aboriginal Objects in NSW (DECCW, 2010)
- Care agreement application form for transfer of Aboriginal objects.

Historic

A detailed heritage assessment will be conducted and a statement of heritage impact prepared.

A review of the hydrological studies for downstream impacts and their interaction with known/previously documented cultural materials and where they are predicted to occur will be conducted. However, it is considered unlikely there would be any interaction with historical heritage items. The heritage assessment would consider the following guidelines where relevant:

- Assessing Significance for Historical Archaeological Sites and Relics (Heritage Branch, DPE, 2009)
- Criteria for assessment of excavation directors (NSW Heritage Council, 2011)
- NSW Heritage Manual (Heritage Office and Department of Urban Affairs and Planning, 1994)
- Assessing Heritage Significance (OEH, 2001)
- Archaeological Assessment Guidelines (Heritage Council, 1996)
- The Australia ICOMOS Burra Charter
- NSW Skeletal Remains: Guidelines for Management of Human Remains (Heritage Office 1998).

6.4 GEOLOGY AND SOILS

6.4.1 Existing environment

Geology

Due to historical geological investigations (Coffey, 2021a) the underlying regional geology of Clarrie Hall Dam is well known. The existing dam infrastructure is underlain by pink to grey coloured hard rhyolite rock with minor welded tuff sections, forming part of the Chillingham Volcanics geological unit. Rhyolite is an igneous rock, which primarily consists of silica, and is classified as ‘strong to very strong’. Weathering of rhyolite can cause separation of the banding of material. Separation is generally associated with points of weakness and therefore potential hazards.

The site is completely underlain by flow banded, slightly porphyritic rhyolite. The depth of weathering increased in the higher areas of the abutments, particularly the west side.

The existing spillway crest is founded on highly weathered rock, which is considered to be high to very high in strength.

Soil

Four soil landscapes occur within the site – Frogs Hollow (fh) and Kunghur (ku) with variants a and b (kua, kub) – while minor areas of Terania (te) and Oxley (ox) soil landscapes are also present.

Frogs Hollow and Kunghur are the dominant soil landscapes at the site, with Terania occurring in a small area of the southern inundation areas, south of McCabes Bridge, and Oxley occurring in association with the Tweed River to the north.

Australian Soil Classification soil orders around Clarrie Hall Dam are Kurosols associated with the Kunghur and Kunghur a and b variant soil landscapes, and Dermosols associated with Frogs Hollow, Oxley and Terania soil landscapes.

Landforms and topography

The site is located in a steep and densely vegetated valley along Doon Doon Creek, which forms a tributary of the Tweed River. Surrounding land uses include a national park, recreation, and rural and agricultural purposes.

Elevation of the area lies between 100 and 400 m; relief is 100 to 150 m; and slope gradients are 5% to 30%. Streams and drainages are characterised as erosional, tributary and integrated. Major drainage within the study area includes Doughboy Creek and Pine Log Creek that feed into Doon Doon Creek, which forms the centreline of Clarrie Hall Dam. To the east, Commissioners Creek also feeds into Clarrie Hall Dam.

6.4.2 Issues for consideration

The Proposal has the potential to impact both geology and soils. Forest encroachment and vegetation removal can result in destabilisation of soils, including erosion and sediment increase. Transportation of rockfill from the reopened quarry would result in dust generation and sedimentation.

The likelihood of soil contamination within the construction footprint is low. Likely sources of contamination within the study area would include cattle dip sites, agricultural sheds and associated agricultural activities, septic or illegal waste sites. Two cattle dip sites are known from the area – Gilmore’s Dip located in the footprint of the original dam inundation area, and Doon Doon Dip.

Gilmore's Dip has been decommissioned according to the NSW DPI Dip Register. The Doon Doon Dip is located at the intersection of Kyogle Road and Clarrie Hall Dam Road on Lot 7006 DP 92894.

Contamination during construction activities may impact the surrounding environment. These activities include raising the intake tower, as the structure may include asbestos-containing material. Other construction activities with potential to cause contamination, if not properly controlled, include storage of chemicals and fuels onsite, use of machinery and storage of waste onsite.

6.4.3 Approach to the assessment

Soil, geology and topography

A detailed assessment would continue, which would include a desktop assessment, field soil sampling, and erosion and geomorphology inspections within the extent of the site to assess baseline soil conditions and characteristics. These assessments would be carried out in accordance with the following relevant guidelines:

- Guidelines for Surveying Soil and Land Resources, 2nd edition
- Australian Soil and Land Survey Handbook, 3rd edition
- The Australian Soil Classification.

A land, soil and erosion assessment would be completed, which would include a description of the biophysical environment, including climate, topography, geology, existing land use and site condition as context for erosion potential. Results of the soil sampling, including physical and chemical characteristics of the encountered soil types, their potential erosion risk and salinity limitations would be analysed. Potential options and considerations would be included to mitigate any issues that are identified.

The following guidelines would be used to inform the assessment:

- Urban regional salinity – guidance given in the Local Government Salinity Initiative booklets, including Site Investigations for Urban Salinity (DLWC, 2002)
- Landslide risk management guidelines presented in Australian Geomechanics Society (2007)
- Soil and Landscaper Issues in Environmental Impact Assessment (DLWC, 2000)
- Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004)
- Managing Urban Stormwater: Soils and Construction Volume 2 (Department of Environment and Climate Change, 2008).

Contamination

Contamination would be assessed through a Stage 1 preliminary site investigation (PSI).

A PSI report will detail the assessment methodology and would include:

- identification of areas of low, medium of high risk of contamination and areas where no evidence of contamination has been identified based on the PSI
- identification of potential contaminants of concern

- assessment of source-pathway-receptor (S-P-R) linkages and presentation of a conceptual site model (CSM) to inform likelihood of contamination being present at a particular location and the consequence of contamination impacts on the construction and operation of the Proposal
- further assessment of the linkages between the risk posed by the contamination, and the mitigation measures applied, will be undertaken at each specific area of concern
- conclusions – based on the assessment of S-P-R linkages – on whether the land is likely to be contaminated and whether further assessment, remediation or management of the land is required, having regard to the ecological and human health risks posed by the contamination in the context of past, existing and future land uses.

Guidelines relevant to the contamination assessment and mitigation of potential impacts include:

- Guidelines for the NSW Site Auditor Scheme (EPA, 2017)
- Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997 (EPA, 2015)
- Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land (DUAP & EPA, 1998)
- Consultants Reporting on Contaminated Land: Contaminated Land Guidelines (EPA, reprinted 2020)
- Other guidelines made or approved under section 105 of the Contaminated Land Management Act 1997.

6.5 TRAFFIC AND TRANSPORT (ACCESS)

6.5.1 Existing environment

The site is located 36 km south-west of Tweed Heads, 15 km south-west of Murwillumbah and 35 km to the north-east of Kyogle. Previous traffic studies conducted by ELA (2021c) have provided the following information.

The communities near the Proposal area are linked by a network of state roads and local government roads managed by Tweed Shire Council. Kyogle Road forms the most direct route from Murwillumbah to Uki and would be the main transport route for material and people to Carrie Hall Dam.

Key intersections include:

- Kyogle Road and Clarrie Hall Dam Road
- Kyogle Road and Doon Doon Road
- Riverview Street and Wollumbin Street
- Alma Street and Tweed Valley Way.

Kyogle Road is a popular road to use when travelling to Clarrie Hall Dam. Traffic volume data indicates that there are less than 300 vehicles per hour at all times. The data also indicates that 90% of vehicles are light vehicles and 10% are trucks or heavy vehicles including semi-trailers.

The crash history for Kyogle Road was collected from the Centre for Road Safety Crash History Data Base for the years 2014–2018 (Transport for NSW). The section of Kyogle Road approximately 5 km either side of Clarrie Hall Dam Road was assessed, and in this period, there were 4 fatal crashes: 2 to the west of the site and 2 north of Uki. Two of the crashes were head-on type crashes – one a vehicle leaving the road and hitting an object, and one involving a crash at a T-junction. There were 15 serious injury crashes reported from the same period, of which 6 were head-on crashes. There were 35 minor, moderate injury or tow-away crashes recorded.

Public transport in the area is sparse. The Murwillumbah Bus Company operates a regular bus service between Uki and Murwillumbah on route 625. The bus service operates return journeys once a day from Murwillumbah to Uki.

6.5.2 Issues for consideration

During the construction phase it is expected that traffic volumes would increase. Traffic generated by construction would likely include:

- workers commuting to site
- transport of plant and equipment including concrete trucks, cranes, batch plant, site offices, graders and earth moving equipment
- transport of materials including steel reinforcing, and raw materials for concrete, form work and road sealing
- haulage of rockfill material.

Other access changes relate to restricting public access to Clarrie Hall Dam Road during the dam wall construction. Access to residences located on Clarrie Hall Dam Road would remain during construction. It is likely that access to Crams Farm would be restricted during certain stages of the Proposal. An assessment of McCabes Bridge would be included.

The Proposal would also inundate land with existing powerline easements. Consequently, the relocation of powerlines would be required.

6.5.3 Approach to the assessment

A detailed traffic impact assessment would be required for the Proposal and would include:

- a review of existing traffic data followed by a site inspection
- one-hour morning and afternoon peak hour traffic counts at the Kyogle Road/Clarrie Hall Dam Road intersection and the Kyogle Road/Doon Doon Road intersection
- a review of available crash data and identification of road safety implications of the Proposal
- a review of existing operational performance of the surrounding road network from the available traffic data and a desktop assessment of the site access arrangements
- traffic generation calculations for construction and operational phases of the Proposal
- trip distribution (construction and operational)

- assessment of:
 - traffic implications from the construction and operational activities for road network capacity, safety and amenity
 - potential impacts on public transport, pedestrians and bicycle riders
 - site access and internal access arrangements, including suitability of parking provision
- qualitative discussion of potential cumulative impacts of construction and operation with other concurrent development
- identification of potential mitigation and management measures
- further investigations to determine the road/intersection upgrades required to accommodate the construction and operational traffic.

The traffic impact assessment would be conducted in consideration of the following guidelines:

- Guide to Traffic Management – Part 3 Traffic Studies and Analysis (Austroads, 2017)
- Guide to Traffic Management Part 12 (Austroads)
- Complementary Roads and Maritime supplement (NSW Government Roads and Maritime Services, 2017).

6.6 NOISE AND VIBRATION

6.6.1 Existing environment

Inspections of the site were conducted in 2020 (ELA, 2021d). During the site inspection, the existing acoustic environment was observed, and nearby noise sensitive receivers (NSRs) were identified. The site was observed to be typical of a rural area with an acoustic environment that is dominated in most parts by natural sounds and local traffic and characterised by low background noise levels.

Existing activities that take place at Clarrie Hall Dam are primarily recreational and for the purpose of maintenance related to the dam.

6.6.2 Issues for consideration

The Proposal would likely create increased noise and vibration levels during construction. Impacts would include noise generated by construction activities, including excavation works, blasting operations and rock placement. Road noise would be expected to increase, especially during peak construction hours. Construction traffic would consist predominantly of deliveries, low loader trailers, truck and dog, semi-trailers and waste collection trucks.

Operational issues are predicted to be similar to existing ones such as daily operation and maintenance of the Clarrie Hall Dam and recreational areas.

6.6.3 Approach to the assessment

A detailed noise and vibration impact assessment would be prepared for the Proposal.

The assessment would:

- confirm information relevant to the proposed construction activities, including identification of sensitive receptors, construction hours and schedule, site layout, and proposed acoustically significant fixed and mobile equipment to be used onsite
- determine relevant noise and vibration goals with reference to guidelines
- carry out a construction quantitative noise assessment in accordance with the *Interim Construction Noise Guideline* (DECCW, 2009)
- consider operational impacts qualitatively in the EIS.

The assessment of impacts and recommended mitigation measures for will be provided in consideration of the following guidelines:

- Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration (ANZECC, 1990)
- Assessing Vibration: a technical guideline (DEC, 2006)
- German Standard DIN 4150-3: Structural Vibration – effects of vibration on structures
- NSW Noise Policy for Industry (EPA, 2017)
- Construction Noise Strategy (TfNSW, 2012).

6.7 HAZARDS AND RISKS

6.7.1 Existing environment

Dam safety

The latest dambreak study carried out by PWA (NSW Public Works, 2007) assigned Clarrie Hall Dam a HIGH A Sunny Day Consequence Category (SDCC) and a HIGH A to EXTREME Flood Consequence Category (FCC). As Clarrie Hall Dam has been assigned a HIGH A SDCC, the DSC prescribes the maximum design earthquake to be the 0.01% AEP (10,000 year) Acceptable Earthquake Capacity (DSC3C) event.

Workshops for hazards and risks were undertaken in 2017 (PWA, 2018) about design and construction risk and hazards of the Proposal. Design risks were further investigated relating to site-specific seismic assessments, hydraulic performance of the new spillway to cater for predicted design floods, and flood security of the dam in relation to construction stages.

Coastal hazards

The Tweed River estuary is located approximately 50 km downstream from Clarrie Hall Dam and Doon Doon Creek. Bray Park Weir, located downstream on the Tweed River acts as a barrier between the dam and the coastal waterway influences.

Bushfire

The statutory Bushfire Danger Period for Far North Coast NSW region is 1 October to 31 March each year. The greatest potential for bushfires to occur is during the hottest, windiest months of the year. Notably, the 2019–2020 bushfire danger period commenced on 17 August 2019, due to prevailing dry conditions (NSW RFS, 2019), earlier than statutorily defined. Bushfires have previously occurred within the surrounding areas of

Clarrie Hall Dam. Parts of the site and surrounding bushland were subject to a wildfire in August 2019, which started along Kyogle Road to the west of the site.

The fire burnt in an easterly direction and encroached on Clarrie Hall Dam, burning approximately 105 ha of land owned by Council (Cooper & Lollback, 2019). The total footprint of the fire was estimated to be approximately 351 ha. The fire was of a relatively low intensity and decreased in impacts as it burnt from west to east.

The Proposal area is characterised by steep topography, which consists of forest vegetation communities located upslope on the east, north-west, west, south-west and southern elevations. This vegetation is mapped as Bushfire Prone Land Vegetation Category 1. Rural landholdings locally are likely to be maintained in a low-hazard state through grazing or slashing activities. Based on the topography, vegetation and prevailing weather conditions, fire spread is likely to the east, north-west, west, and south of the site, given the extensive tracts of forest vegetation present.

Biosecurity

A total of 20 priority weed species were recorded during floristic surveys in the study area. These include 16 species that are listed in the North Coast Regional Strategic Weed Management Plan (RSWMP) as Priority Weeds under the *Biosecurity Act 2015* for the North Coast (NCLLS, 2021). Four of these species are also identified as Weeds of National Significance.

Dangerous goods

Operation of Clarrie Hall Dam requires use of hazardous substances and/or dangerous goods including:

- diesel fuel – for use in mobile equipment
- unleaded petrol – for use in mobile equipment
- lubricating and hydraulic oils and grease – for lubrication of plant and equipment
- solvents – for plant maintenance during construction.

Environmental hazards

Environmental hazards present within the Proposal area include flooding (discussed in section 6.1) and bushfire (see above). Additional hazards associated with operations and maintenance of the dam includes flooding of the worksite from valve releases, working under flood protection structures, hazardous substances, and working in and around dangerous machinery.

Groundwater contamination

Groundwater yields in the fractured and porous rock aquifers are generally low, with some localised higher yields where the rock is highly fractured and/or faulted (DPI Water, 2016). Groundwater quality in the fractured rock aquifer is reported as generally high with low salinity; however, the porous rock aquifer has been reported as having a variable quality (DPI Water, 2016).

Groundwater levels have been recorded from 0.8 to 16.2 m below ground level in the immediate vicinity of the dam wall, with recharge considered to be through direct rainfall infiltration and seepage of surface water runoff from the surrounding valley slopes (ELA, 2021e).

Groundwater in the region is generally utilised for water supply (including stock and domestic) and irrigation purposes. Salinity measurements from registered bores indicate that groundwater is fresh and suitable for human consumption, or good quality (ELA, 2021e).

Given the site history and the top-down mode of contamination, groundwater is not anticipated to be impacted during development (Coffey 2021b).

Waste

At present, there is limited waste associated with the operation of Clarrie Hall Dam, including byproducts.

Greenhouse gas and renewable energy

Council has set a target to produce 25% of its own electricity from renewable sources by 2022, and 50% by 2025.

The proposal to construct a mini-hydro-electric plant to generate electricity from discharges from the raised dam was investigated by Council for inclusion within the scope of works for the raising of Clarrie Hall Dam. The optimal mini-hydro-electric plant size was determined by comparing the frequency of various discharge and spilling flows from the dam to the operating range of various mini hydroelectric plants. It was found that the best option was a mini hydroelectric plant with a maximum output of 359 kW and a flow range of 460 to 1380 L/sec.

The cost of the mini hydroelectric plant in addition to upgrades to the transformer and electricity network to receive the power generated was estimated in 2019 to be approximately \$3 million. It was estimated the annual return would be approximately \$60,000.

As a comparison, a \$3 million investment in solar would provide a solar farm of more than 2 MW, and the return from that solar farm in terms of kilowatt hours would be 3 times that of the mini hydroelectric plant. Furthermore, a solar farm would provide energy to be used 'behind' the meter to provide further savings to Council.

Based on this assessment, constructing a mini hydroelectric plant was not considered suitable for the Proposal.

6.7.2 Issues for consideration

Dam safety

During construction, likely hazards and risks include worksite flooding including restricted access due to floods, flooding of the worksite from valve releases, working under flood protection structures, bushfire, hazardous substances, and working in and around dangerous machinery. An interim Dam Safety Emergency Plan (approved by the NSW Dams Safety Committee) for the construction period taking into account the changed conditions and operation of the dam during the works would be required.

Hydrological studies for a critical 2-hour PMF storm event were conducted to ensure that the flood was successfully passed by the new concept design for Clarrie Hall Dam.

Coastal hazards

The Proposal would be unlikely to cause any changes to coastal hazards, as the end point of the Proposal would be expected to be Bray Park Weir.

Bushfire

During construction there would be increased ignition risk from construction activities including, but not limited to:

- machinery movement in long grass
- hot work activities, including welders and grinders
- the storage of waste and combustible materials onsite, including cleared vegetation
- storage of flammable liquids
- cigarette butts disposed of carelessly onsite and from cars travelling along roads
- electrical faults.

Bushfire management and evacuation procedures would be required for implementation during the construction period to ensure the health and safety of site personnel.

Inundation at the FSL and clearing of vegetation would be likely to change the bushfire risk upon completion of the works.

Biosecurity

Transport of machinery and materials to the Proposal site could spread weeds and pathogens onto the site. Management of priority weeds during the construction and operational stages of the Proposal would be included in the EIS.

Dangerous goods

The Proposal would require the transport, use and storage onsite of hazardous materials and dangerous goods. Due to the nature of the Proposal, the transport, use and storage of hazardous materials would largely be associated with the construction phase of the Proposal.

The following dangerous goods and hazardous substances would be required for the construction of the Proposal:

- diesel fuel – for use in mobile equipment
- unleaded petrol – for use in mobile equipment
- lubricating and hydraulic oils and grease – for lubrication of plant and equipment
- solvents – for plant maintenance
- explosives – for blasting during construction
- ammonium nitrate – for blasting
- industrial grade acetylene – various applications, such as hot works
- industrial grade oxygen – various applications, such as hot works
- epoxies – various applications
- retardants for concrete – for concrete pouring/finishing.

Equipment malfunction, accidental mishandling or incorrect storage or use of these materials may result in their release into the air, soil, surface water or groundwater, posing a risk to human health, property or the environment.

Environmental hazards

Bushfire hazards during construction and operation are discussed in the above section.

Flooding

Flooding during the construction phase is a potential risk, and an emergency response plan would be required.

Operational flooding impacts to upstream and downstream residents are discussed in section 6.1.2.

Groundwater contamination

Groundwater contamination is unlikely to occur as a result of the raised dam wall. However, construction activities have the potential to cause contamination to soil and groundwater. Activities capable of causing contamination include dumping of waste, asbestos in site structures, and surrounding site activities such as agriculture within the vicinity of the Proposal disturbance footprint.

Geological investigations undertaken prior to the construction of Clarrie Hall Dam indicated a shallow water table, less than one metre below ground level in areas) in the vicinity of the dam wall (Coffey, 2021c). The investigations also indicated areas of highly fractured rock and pockets of weak and fractured rock along the proposed spillway. Therefore, ground excavation and installation of piling during construction could cause contamination of shallow groundwater.

Hazardous and offensive development

Under the NSW Hazardous and Offensive Development Application Guidelines, a number of Hazardous Industry Planning advisory papers (HIPAPs) and guidelines have been issued to guide the assessment and planning of potentially hazardous industries. This includes State Environmental Planning Policy (Resilience and Hazards) 2021 (DPE). The Resilience and Hazards SEPP sets out the requirements and processes to undertake a risk screening and preliminary hazard analysis as part of the planning and assessment of potentially hazardous and offensive developments.

Based on the information currently available, this SEPP would be unlikely to apply to the Proposal, as no bulk storage of hydrocarbons or other hazardous substances are anticipated during construction or operation. Further, the use of such materials would largely be limited to well-understood and well-managed fuel and hydrocarbon products used primarily for the purpose of supporting the operation of equipment required during construction. Therefore, the Proposal is unlikely to be considered a potentially hazardous or offensive industry.

However, the principles of the Resilience and Hazards SEPP would be applied to the Proposal to inform the assessment of the potential impacts and inform development of appropriate management and mitigation measures.

Land movement

Soil instability can be caused by construction of the raised dam wall and associated ancillary works. Impacts and risks are more strongly associated with excavation, moving and blasting of rockfill for the dam wall raising and in the quarry. The concept design of the raised dam wall has been extensively checked for stability, including consideration of seismic activity to ensure safety.

Waste

The primary waste source to be assessed further in the EIS is the management of construction-generated waste. This may include liquid waste from concrete cutting, concrete wash, hazardous wastes (e.g. fuels and oils, gas cylinders, aerosols and batteries) and putrescible and non-putrescible general solid waste. The nearest licensed waste disposal facility is the Stotts Creek Resource Recovery Centre at Stotts Creek via Murwillumbah.

Greenhouse gas and renewable energy

Construction activities are expected to produce greenhouse gas emissions related to land vegetation clearing for quarry access, haul roads and the Clarrie Hall Dam Road realignment, and the operation of construction plant and equipment. Other greenhouse-gas-emitting activities would include site electricity consumption and transportation of materials and waste to and from the construction area.

During operation, indirect greenhouse gas emissions may include maintenance activities, including machinery required for weed control, release of methane associated with water releases, and the use of electricity for the operation of water intakes and security lighting.

6.7.3 Approach to the assessment

The following detailed assessment would be conducted for hazards and risks.

Health and safety

A health and safety risk assessment would be conducted, based on:

- Environmental Health Risk Assessment – Guidelines for assessing human health risks from environmental hazards, Commonwealth of Australia (enHealth, 2012)
- Health Impact Assessment: A practical guide (NSW Health, 2007)
- Health Impact Assessment Guidelines, Commonwealth Department of Health and Aged Care (enHealth, 2017).

The risk assessment would include inputs from other specialist studies, including air quality, safety and bushfire. The air quality assessment methodology is detailed in section 6.12.

Dam safety

A dams safety specialist would check that the proposed works have been designed in reference to Dams Safety Committee guidance. This guidance consists of Dams Safety Committee Guidance and archived Dams Safety Committee Guidance Sheets, including but not limited to, DSC2A (Dam Safety Management System) and DSC2B (Documentation and Information Flow Over Dam Life Cycle).

Bushfire

Bushfire risk assessment would involve assessing the bushfire risk toward the primary asset, identifying ignition sources and detailing bushfire protection measures and fire suppression capabilities that could be implemented to reduce the bushfire risk of the Proposal area. The bushfire protection assessment would be prepared in a format that can inform emergency management planning. The assessment would be completed in consideration of the following studies guidelines:

- Planning for Bushfire Protection 2019 (NSW RFS)
- Clarrie Hall Dam Bushfire Strategic Study
- Bushfire Risk Management Plans (BFRMP) for the LGA.
- Hazardous Industry Planning Advisory Papers (HIPAPs)
- State Environmental Planning Policy (Resilience and Hazards) 2021.

Waste

Information on the predicted waste generated from the Proposal during construction and operation would be provided in consideration of Waste Classification Guidelines (EPA, 2014) and NSW Waste Management Guidelines, and would include:

- estimates of the quantity of each classification of waste expected to be generated
- management of waste, including storage location and volume of stockpiles
- details on how and where waste is stored, handled, treated, reused, recycled and/or disposed of
- handling of waste including measures to facilitate segregation and prevent cross-contamination
- contingencies for the above, including managing unexpected waste volumes.

No significant changes in waste are expected as a result of the Proposal once operational.

Greenhouse gas and renewable energy

A greenhouse gas (GHG) impact assessment would be undertaken to determine the impacts of the Proposal. GHG emissions produced from construction and operation of the Proposal would be calculated.

This includes relevant and material scope 1, 2 and 3 GHG emissions. The assessment will then identify and quantify all reasonable and feasible energy efficiency opportunities and mitigation options to reduce the GHG emissions associated with construction and operation of the Proposal.

6.8 SOCIAL

6.8.1 Existing environment

Factors such as land use, traffic and noise and vibration are discussed in previous sections with regard to the immediate environment of the Proposal, including the townships of Uki and Murwillumbah. Further details of the social environment and a broader overview of the Tweed Shire region are discussed in this section.

The 2021 Australian Census (ABS, 2021) provides a social baseline analysis of the Tweed Shire community, which indicates the following:

- The estimated population of Tweed Shire was 97,151 in 2021.
- The population is growing by an average of 680 people per year.
- Growth is forecast to continue within the region, with the population estimated to reach 132,221 by 2041 (TSC, 2021).

- The median age of the population at 47.3 is higher than the Australian median age of 38 (ABS, 2021).
- In the 2021 Census 4,329 people identified as Indigenous, representing 4.4% of the population.
- Tweed Shire has a higher number of properties owned outright – 41.5% compared to 31.5% for NSW.
- The 7.1% unemployment rate within the Tweed Shire is higher than the NSW rate of unemployment of 6.3% (ABS, 2021).
- The median annual income for residents of Tweed Shire excluding government pensions and allowances is \$34,216, which is below the Australian median of \$41,860 (ABS, 2021).
- Construction is a key industry within the Tweed Shire labour force.
- The overall level of education within the Tweed Shire is lower than the average education level in NSW – 58% of the Tweed Shire population having no qualifications, compared to 39.6% in NSW.
- Crime on average is less prevalent in the Tweed Shire, compared to the whole of NSW (BOCSAR, 2022).

The original inhabitants of the Tweed Shire are the Bundjalung nation, which comprised 3 groups: the Tul-Gi-Gin people of the Northern area, the Goodjinburra people of the Tweed coast area and the Moorang-Moobar people of the Southern and Central areas around Wollumbin (Mt Warning). The Bundjalung nation has a strong cultural connection to the land and environment.

Murwillumbah District Hospital is the closest health care facility to the Proposal (NSW Health, 2019). Tweed Hospital is located approximately 20 km north-east of Murwillumbah District hospital and is the major regional referral hospital. A new major regional referral hospital, Tweed Valley Hospital, is currently being constructed in Kingscliff and is scheduled to open in 2024, leading to the transfer of all hospital services from the existing hospital in Tweed Heads.

Local industry in the region is built around health care and social assistance, retail, construction and hospitality. Capacity for sustainable economic activity was being driven by agriculture and tourism; however, agriculture has been seen as a declining industry due to rural land being converted to residential properties. A construction workforce is available in both the Uki and Murwillumbah areas and would likely be interested in working on the Proposal. Short-term accommodation facilities in the area consist of small bed and breakfasts, motels and cabins. Tourism peaks in the Tweed hinterland in the winter months, with Clarrie Hall Dam a popular destination with locals in summer.

Clarrie Hall Dam itself is not considered a significant asset for businesses in Uki and Murwillumbah, but businesses are strongly linked to surrounding national parks, including Wollumbin (Mt Warning), and the nature-based recreational activities such as bush walking and bike tracks. Crams Farm provides economic activity through weddings and other functions, such as filming of entertainment and advertising.

Many considered that it was affordable to live in the Uki and Murwillumbah community; however, relocation from larger population centres is increasing the house prices, making it less affordable.

Rural land is becoming more expensive, because lifestyle properties and home-based work/businesses have become more desirable, especially since the COVID-19 pandemic. The Murwillumbah rental housing market is tight, and many residents travel to Tweed Heads or the Gold Coast for goods, services and employment. The proximity to the Gold Coast and Brisbane has led to continued high levels of tourism in the region. The recent change in demographics and land use, with people from urban centres relocating into the region for lifestyle reasons, has brought money and investment into the area.

Previous stakeholder consultation by Coffey Services Australia (2021d) identified that the local communities of Uki and Murwillumbah are strongly linked to the natural environments and have a strong sense of community, as shown in their participation in volunteer organisations. Previous consultation has identified that the community want to secure a long-term water supply in the region and have associated concerns regarding potential price changes to water rates. A current issue within the community is the lack of employment and education opportunities for a younger generation, leading the younger generation to leave the region.

In the study area there are locations that hold significant value for local communities. This includes Crams Farm, which would be directly impacted by the Proposal. The site is used by recreational visitors for walks, picnics, kayaking and events. Clarrie Hall Dam and the surrounding area is used for bushwalking and fishing. These built and natural environments were identified through stakeholder engagement and are important to local community identity. Locally, there is a strong involvement in local volunteering including at cultural and arts events, environmental restoration groups and the State Emergency Service.

The Tweed Shire has historically been affected by severe flooding events. The impacts of these floods have been felt most recently in 2017 and 2022. The recency of the last flood event is relevant to the Proposal, with impacts still currently affecting communities.

6.8.2 Issues for consideration

Way of life

The Proposal would require workers during the construction phase, which may lead to a short-term increase in local populations. Population increases can place pressure on community services (e.g. health care, childcare) and facilities (e.g. gyms, restaurants) within the area. Any population increases would also likely result in increased road traffic, which would be amplified by planned construction traffic. These impacts would most likely affect the local communities of Murwillumbah and Uki. All impacts can decrease the amenity and access to services for the local community. It is essential that stakeholders are not disadvantaged.

Housing impacts are likely to be felt during the construction phase of the Proposal, which would require an estimated 130 workers. While the Proposal should endeavour to source local workers, accommodation for any workers from outside of the region would raise the demand for accommodation.

The need for accommodation for workers may decrease the availability of short-term accommodation (e.g. hotels) and long-term accommodation (e.g. rentals). This is most likely to occur in towns closest to the construction site and would include Uki and Murwillumbah, both of which are already demonstrating low vacancies and limited availability of rental properties.

Operation of the raised dam would impact private landowners due to land inundation from FSL and acquisition of land by Council (see section 6.9 regarding mitigations for private land use). Changes to land use for private property would have mild impacts on the way of life for residents. No relocation or resettlement of buildings is required for Crams Farm, which only requires relocation or reinstatement of some recreational facilities such as the boat ramp and pontoon.

Community

Throughout the development of the EIS, community consultation will remain an essential component of impact assessment to ensure the community is well informed about the Proposal and feels listened to. As a result of construction activities, there may be short-term shifts in population age after a likely influx of workers to the construction site. Completion of the Proposal is unlikely to impact the population age in the Tweed Shire.

Accessibility

Construction works are likely to impact accessibility of recreational areas at Crams Farm and Clarrie Hall Dam spillway. These areas are of importance to the community for their natural and cultural significance. Traffic delays are to be expected during construction, but this would not limit access to health, educational and community services.

After construction, accessibility would be restored for roads and recreational facilities.

Culture

The inundation area at FSL and PMF are likely to impact sites of significance for local Aboriginal peoples. Consultation with the affected communities and parties is described in section 6.3.3.

Construction of the dam wall and associated ancillary works is likely to have some effect on culture within the local region in consideration of values and beliefs associated with the locality, and cultural and spiritual loss, due to changes in land use.

Health and wellbeing

During construction, potential environmental impacts include noise and dust pollution. Any pollution can reduce the quality of life and amenity of the surrounding region for residents and landowners. The current construction method includes blasting and concrete production; however, as the dam is located away from town centres, the impacts would mostly be felt by landowners and residents located near the construction site. It will be important to review and reduce any impacts on local landowners. Noise and vibration impacts will be assessed. Temporary restricted access to recreational facilities at the dam and Crams Farm are also expected to have some impact on the psychological wellbeing of the community.

The operation of the raised dam wall would be unlikely to directly affect residents and businesses in the region but could support an increase in water consumption. This could be beneficial for communities, who would experience less anxiety about water security for the wider region.

Surroundings

The construction and operation of the raised dam wall and spillway would impact the landscape in this area. Temporary impacts on visual landscapes and aesthetic values of the construction disturbance footprint would also occur due to removal of vegetation and

construction activities. Revegetation and land rehabilitation efforts post-construction would greatly reduce the visual impact on surroundings for the local community.

The Proposal would result in an increase of the FSL, which would encroach on the Mount Jerusalem National Park, leading to a loss of vegetation and size. The impacts of construction would also be felt on the amenity of Carrie Hall Dam and walking trails around the dam, which have been highlighted by the community to be key sites.

Crams Farm is an important place of natural beauty and recreation in the community. The inundation area at FSL would also impact the aesthetic value of the recreational area. Gaining waterfront views can be seen as a positive outcome of raising the dam wall, whereas loss of vegetated land to inundation can be seen as a negative outcome by the community.

Upon completion of the project, access to water would improve due to the availability of a larger water supply storage. Detailed analysis of operational downstream flows, discussed in section 6.1.3, will inform impacts of water availability within Doon Doon Creek and Tweed River.

Livelihoods

The Proposal can potentially create employment opportunities in the region. This can be an incentive to decrease the higher-than-average rate of unemployment. The Proposal also provides an opportunity to onboard apprentices and educate local workers through the construction phase. This can upskill workers and further develop the region's ability to undertake infrastructure projects. All opportunities can encourage a younger generation to stay in the region, where historically they have left to pursue employment and education opportunities. This is a challenge identified in the current community through the stakeholder consultation.

The Proposal can create benefits for local industries and businesses by generating opportunities to provide their skills and materials for construction. This can be achieved by lowering any barriers to entry for competitive and capable firms, and thereby encouraging engagement with the Proposal. This would result in flow-on benefits into the local economy, by providing employment opportunities and education opportunities.

Currently, the local construction workforce is strongly involved in rebuilding properties and communities damaged in recent flood events (in 2022). It is important to ensure that any workers for the Proposal would not be taken from current key projects within the region.

The construction phase of the Proposal can increase the risk of workplace accidents. This would place a higher demand on local health and emergency services. It is important that these impacts do not affect the local community and that the emergency and health services are not overburdened.

Temporary economic impacts may occur for Doon Doon Hall if temporary closures of Crams Farm are required. Temporary traffic disturbances are expected to have mild impact on residents travelling for employment, goods and services.

Residents and rural agricultural land upstream of the dam would be impacted by land inundation at the FSL, and some landowners may be impacted by the PMF inundation level. All affected landholders have been approached by Council to discuss property acquisitions or boundary adjustments. To date, Council has either acquired, and/or has under contract, all or a subdivided portion of 15 of the 17 identified affected properties.

Impacts on residents downstream of the dam will be investigated by hydrological studies.

Decision-making systems

Community decision-making systems have been in place regarding the Proposal for extended periods of time. Community surveys and consultation sessions have been conducted to ensure that all residents' concerns are considered. Part of the community consultation plan will include grievance and remedy mechanisms. The [Your Say Tweed](#) web page is available to residents to express their thoughts and concerns regarding the Proposal, and the [Tweed Link newsletter](#) is used to keep residents informed about the Proposal.

6.8.3 Approach to the assessment

A detailed social impact assessment (SIA) would be carried out in accordance with the *Social Impact Assessment Guideline for State Significant Projects* (DPE, 2023). The SIA would include:

- a detailed investigation into the social locality to establish the social baseline
- a program of targeted consultation with key stakeholders affected by the Proposal
- identification and assessment of socio-economic impacts and benefits
- identification of mitigation and management measures.

6.9 LAND USE AND BUILT ENVIRONMENT

6.9.1 Existing environment

The Proposal is located within the Tweed Shire LGA to which the Tweed Local Environmental Plan 2014 (Tweed LEP 2014) applies, as discussed in section 4. Land use zones are shown in Figure 4-1. Land ownership is shown in Figure 2-2.

Public land

Clarrie Hall Dam is located in a relatively remote rural setting and does not experience high volumes of recreational users, possibly due to the passive recreational requirements at the dam. Recreational access to Clarrie Hall Dam is either via Clarrie Hall Dam Road to the spillway end of the dam, or from Crams Farm via Doon Doon Road and Commissioners Creek Road at the southern end of the reservoir. Clarrie Hall Dam is open to the public from 7 am to 5 pm (6 pm during daylight savings) all year round. Access is via security gates at the two access points – at the entrance to Crams Farm and at the intersection of Kyogle Road and Clarrie Hall Dam Road.

Permitted recreational uses at the dam include bushwalking, nature appreciation (bird watching, nature photography), picnicking, recreational fishing, sailing, canoeing, kayaking and rowing, motor boating (electric motors only – fuel motors must be removed from boats), and special uses approved by Council (such as fuel motorboats for research and monitoring). Camping and overnight stays are prohibited.

Recreational facilities at the spillway area include an amenities facility, shade shelters, a viewing area to the dam wall and spillway consisting of seating and interpretive signage, walking paths, visitor car parking, a boat ramp and security fencing. The public can walk across the top of the dam wall towards the spillway. Recreation infrastructure at Crams Farm includes an amenity building, shade structures and barbeques, a boat ramp and adjacent pontoon, a sealed access road and informal car parking. Two buildings identified as having local heritage significance, Doon Doon Hall and the Crams Farm complex, are

also located at Crams Farm. Doon Doon Hall is used for functions, with bookings managed by Tweed Shire Council.

Public infrastructure

McCabes Bridge is located at the southern end of the dam on Commissioners Creek Road and is used to access Crams Farm and nearby surrounding private properties. The raising of the dam would result in the inundation of McCabes Bridge and parts of Commissioners Creek Road, effectively severing access to properties further along Commissioners Creek Road. A new bridge and approaches would be completed as part of the Proposal.

Other access changes relate to restricting public access to Clarrie Hall Dam Road during the dam wall construction. Access to residences located on Clarrie Hall Dam Road would remain during construction. It is likely that access to Crams Farm would be restricted during certain stages of the Proposal.

The Proposal would also inundate land with existing powerline easements. Telstra assets would require relocation. Consequently, the new alignment would need to be investigated and liaison with property owners conducted about the relocation of these powerlines.

Private property

The proposed raising of Clarrie Hall Dam would require the acquisition of inundated land and would include a 7 m horizontal maintenance zone above RL 77 m. All affected landholders have been approached to discuss full property acquisitions or boundary adjustments, including fencing realignments and temporary leases. Many of the private properties are rural dwellings and agricultural land.

6.9.2 Issues for consideration

Public land

During construction of the Proposal, access to recreation facilities at the spillway end of the reservoir and at Crams Farm would be limited due to construction works at the dam wall, Clarrie Hall Dam Road and Kyogle Road intersection and Commissioners Creek Road at McCabes Bridge and Crams Farm. Essential access to nearby townships would be maintained throughout the construction period.

Following completion of the Proposal, the recreation area at the spillway end of the dam would be re-established for public use, including an amenities facility, shade shelters, a viewing area to the dam wall and spillway consisting of seating and interpretive signage, walking paths, visitor car parking, a boat ramp and security fencing. Public opening times of 7 am to 5 pm (6 pm during daylight savings) all year round would be reinstated following completion of the works.

A portion of Crams Farm would become inundated at the new FSL, which would result in the loss of some of the public recreation area and require installation of a new boat ramp and pontoon at the new FSL level for public use.

Re-establishing public recreation facilities at both the spillway end and Crams Farm end of the reservoir would mitigate operational impacts of public land access and use.

Doon Doon Hall and other buildings on Crams Farm should not be impacted by the new FSL inundation area and would remain open and operational following completion of construction.

Public infrastructure

During construction, sections of Clarrie Hall Dam Road, Kyogle Road and Commissioners Creek Road would close for periods of time due to ancillary works that are required to support construction of the dam wall raising. Disruption of power services is to be expected during realignment of power easements. Access to essential services and private property would be maintained throughout construction of the works.

Upon completion of works, access to and safety of public infrastructure would be improved due to the upgrade of Clarrie Hall Dam Road, Kyogle Road and McCabes Bridge and the Commissioners Creek Road realignment.

Private property

The Proposal would have direct impacts for current landowners located in the footprint of the Proposal.

The raising of Clarrie Hall Dam would result in the complete or partial inundation and hence acquisition of some rural properties. Consultation with property owners is ongoing.

During construction, access to properties affected by the main works and ancillary works would be maintained.

6.9.3 Approach to the assessment

A standard land use assessment would be required for the Proposal and would include:

- a baseline assessment including:
 - assessment of current land use using publicly available information such as NSW DPE land use data
 - identification of any important or strategic agricultural land potentially impacted
 - land classification
 - a cumulative impact assessment focusing on any major projects in the vicinity of the Proposal
- assessment of Crown Reserves, Travelling Stock Reserves, and mineral resource and exploration activities at and near the Proposal site
- documentation of social and economic costs through a qualitative assessment of impacts on private land and community resulting from inundation, including:
 - a review of data available from the Australian Bureau of Agricultural and Resource Economics and Sciences, and agricultural census data published by the Australian Bureau of Statistics
 - overall impacts on regional agricultural production
 - analysis of the agricultural production and value by commodity and supporting infrastructure, and determination of the effect on agricultural production at the site
 - third party impacts such as impacts on upstream users
 - identification of potential construction and operational impacts and mitigation measures.

6.10 ECONOMIC

6.10.1 Existing environment

The two main townships closest to Clarrie Hall Dam are Uki and Murwillumbah.

Uki is a small community village of 685 people (ABS, 2021). The township consists of several local business shopfronts along the main road through town, Kyogle Road. Shops and services in the town include a grocery store, several cafes and restaurants, a petrol station, dentist, psychologist, post office and a community hall. The village has a rural fire brigade and two schools. Uki is well serviced by a range of businesses that operate from within and nearby Uki, including electricians, plumbers, carpenters, auto mechanics, paediatric occupational therapist, alternative and allied health care providers, and food and beverage service providers. The town of Uki and nearby Mount Warning also have several short-term accommodation businesses, primarily focused on retreat-style tourism experiences.

Murwillumbah is a much larger township, with 9,501 residents (ABS, 2021). It is the commercial centre of the Tweed hinterland region, with a large retail sector. Businesses and services in the town include a hospital, other medical and health services, banks, professional services, several art galleries, restaurants and cafes, and tourist accommodation facilities. The town has 5 primary schools, 4 secondary schools and a police station.

Both Murwillumbah and Uki have a strong art scene, and residents strongly feel that their identities are connected to the surrounding natural landscape.

Median house prices in Uki, Murwillumbah and surrounding areas have steadily increased since 2015. Weekly rental prices in Doon Doon are significantly lower than those in Uki and Murwillumbah (ABS, 2021). Data indicates that during the 2021 Census, households in the region were likely experiencing similar trends in mortgage and rental affordability stress as the rest of NSW (ABS, 2021).

A review of the labour force indicators shows a 7.1% unemployment rate within the Tweed Shire (2021) has risen since 2016 and is higher compared to the NSW rate of unemployment of 6.3% (ABS, 2021). The Tweed LGA region had an unemployment rate of 3.8% in 2016 (ABS, 2016).

Census data of 2021 (ABS, 2021) shows the key industries in the area are health care and social assistance, retail trade, accommodation and food services and construction. The main occupations in the study area are technicians, trade workers and professionals. Tourism, hospitality and agriculture are key industries in the Tweed Shire.

6.10.2 Issues for consideration

Natural resource use

The construction of the raised dam wall and ancillary works would consume natural resources. To reduce importation of rockfill for the raised dam wall, the quarry used to construct the original dam would be used. In addition, approximately 38,000 m³ of rock from the spillway excavation would be suitable (and therefore hauled) for fill placement on the raised embankment, thus reducing the amount of rock required for excavation from the quarry. Rock would be delivered progressively to the dam site from the quarry along the haul roads through the left bank. It is estimated that approximately 95,000 m³ of rock would be transported from the quarry for placement on the raised embankment.

Other natural resources used for the construction of the raised dam wall and ancillary works would include concrete, asphalt, fossil fuels, steel and associated utility materials. Resource outputs from activities such as vegetation clearance within the construction disturbance footprint are also to be considered for assessment and management, to reduce the volume and impact of waste. Further assessments of procurement of sustainable and alternative materials are also to be considered within sustainability assessments.

Livelihood

Land inundated by the new FSL would impact private landowners. Activities have been carried out by Council to mitigate livelihood impacts to property owners. Temporary disruptions to services such as power during the realignment of utilities are likely to impact some local residents. Mitigation measures for the impacts will be considered in the EIS.

As many residents travel from Uki and Murwillumbah to Tweed Heads or the Gold Coast for goods, services and employment, it is important to maintain access to local roads during construction to avoid impacts on residents' livelihoods. This is discussed in greater detail in section 6.5.

If temporary closure of Crams Farm during construction is required, this would have an economic impact due to loss of bookings for functions at Doon Doon Hall.

During construction, an increase in personnel required to work on the dam would lead to increased economic activity in the surrounding towns.

Opportunity cost

Options for improving water security within the Tweed Shire LGA were thoroughly investigated by Council between 2009 and 2015. It was found that raising Clarrie Hall Dam would be the preferred option for future water security, as it was the most resource- and cost-effective method of securing water supply for the Tweed Shire region until 2065.

Cost estimates were completed for each option for the dam wall and spillway construction. They showed that the single construction option was far more economical than raising the dam in stages. The ancillary works of McCabes Bridge and the intersection of Clarrie Hall Dam Road and Kyogle Road are required as part of the main works for safety and access requirements for both residents, visitors and construction crew.

PWA recently provided Council with an updated capital investment value (CIV) of \$90 million for the construction of the Proposal.

6.10.3 Approach to the assessment

A standard economic assessment would be completed as part of the SIA, which includes a community engagement strategy. The assessment would investigate social impacts on livelihoods, considering employment and business opportunities, distribution of benefits and traditional owner sustenance.

A resource consumption assessment would be completed as part of the sustainability scope of the Proposal, which would investigate and assess natural resource use as part of construction. The assessment would propose suitable mitigation measures and options for reducing use of natural resources where appropriate and be conducted in consideration of the following guidelines:

- NSW Waste Management Guidelines
- Waste Avoidance and Resource Recovery Act 2001 (NSW) (WARR Act)
- NSW Government Resource Efficiency Policy (State of NSW and EES, 2014)
- Infrastructure Sustainability Rating Tool Scorecard relating to energy and carbon for large infrastructure projects (ISCA).

Previous assessments of opportunity cost for the dam wall raising and associated ancillary works have been completed by both concept designers and Council.

The economic assessment would also consider the following guidelines and background documents:

- Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2010 Background document
- DPE Social Impact Assessment Guideline (November 2023).

6.11 LANDSCAPE AND VISUAL

6.11.1 Existing environment

The dam wall and associated infrastructure dominate the landscape in this area.

The region surrounding the Proposal area is characterised by moderately steep hills and ridges, with elevation varying from 25 m to 300 m above sea level. The site is located entirely in the 'Mount Warning Exhumed Slopes' NSW landscape and includes portions of Mount Jerusalem National Park. The Nightcap and Border Ranges national parks and the Wollumbin State Conservation Area are located in the vicinity of the site, along with several private land conservation agreements.

Crams Farm site complex contains 3 buildings and some exotic plantings. The buildings include a farmhouse, dairy and a piggery constructed in the 20th century. This area is a popular picnic and recreational area. Recreational facilities include an extensive area for recreation with electric barbecues, picnic facilities, an amenity building with toilets, shade structures and barbecues, a boat ramp and adjacent pontoon, a sealed access road and informal car parking.

6.11.2 Issues for consideration

The raising of Clarrie Hall Dam by 8.5 m would result in an increase in inundation and would change the visual amenity.

Construction activities, plant and equipment may be visible to sensitive visual receptors such as landowners, recreational users and roads in the immediate vicinity. These impacts would be limited in their extent and duration, given the remote location of the Proposal and relatively small construction footprint.

The works would be set back from nearby roads and would be generally screened from public viewpoints by trees.

Once the raised dam wall is constructed, the operational visual amenity impact of the increased dam wall height and inundation area would be limited due to the lack of sensitive receivers near the structures.

Other infrastructure such as the intake tower would be visually similar to what is seen now.

6.11.3 Approach to the assessment

A standard visual impact assessment would be required for the Proposal to assess the visual amenity impact at private receptors and public vantage points. This would comprise a qualitative assessment, in keeping with the remote location and would include:

- identifying local landscape features
- analysing impacts to views and vistas
- identifying the settings of heritage items that may be impacted
- assessing impacts to public recreation areas
- identifying potential mitigation and management measures.

6.12 AIR QUALITY AND EMISSIONS

6.12.1 Existing environment

The Proposal is located on the north coast of NSW, where the climate is classed as subtropical, characterised by warm humid summers, mild winters and high rainfall (BoM 2023a). The Bureau of Meteorology (BoM) collects climatic information in the vicinity of the Proposal. The closest BoM station is approximately 12.5 km to the north-east at Murwillumbah and has collected long-term climate data since 1972. Maximum summer temperatures recorded at the station are between 29.0°C and 29.6°C, and minimum winter temperatures are between 8.6°C and 9.9°C. Annual average rainfall over the period was 1,580 mm. Rainfall was at its lowest during September (39.7 mm) and at its highest during February (232.5 mm). Annual relative humidity ranged from 50% during winter for the 3 pm reading to 83% in summer for the 9 am reading (BoM 2023b).

No long-term ambient air quality data is available for the immediate vicinity of the Proposal. The closest stations recording air quality data are operated by the Queensland Government Department of Environment and Science (DES) approximately 60 km to the north. Given the existing land use and the absence of heavy industry or urban air quality sources, air quality in the existing environment surrounding the Proposal is likely to be very good.

6.12.2 Issues for consideration

Temporary air quality impacts have the potential to occur during the construction phase. Site establishment, construction, reopening the quarry, blasting and rock placement would generate dust emissions. Construction vehicle movements on unsealed roads would also create dust.

Air quality impacts during the operation of the Proposal are expected to be minimal and would include vehicle emissions associated with maintenance and inspection of Proposal infrastructure and light vehicle use.

Greenhouse gas emissions are discussed in section 6.7.

6.12.3 Approach to the assessment

A standard air quality and greenhouse gas assessment would be required for the Proposal and would include:

- qualitative assessment of current air quality and potential construction and operational impacts

- quantitative assessment of potential scope 1, 2 and 3 greenhouse gas emissions
- identification of management measures to reduce dust and greenhouse gas emissions.

The assessment would be undertaken according to the following guidelines:

- Approved methods for the modelling and assessment of air pollutants (NSW EPA, 2022)
- Guidance on the assessment of dust from demolition and construction (Institute of Air Quality Management, 2016).

6.13 MATTERS REQUIRING NO FURTHER ASSESSMENT

Access to port, airport and rail facilities would not be impacted by the Proposal, due to the location being inland and away from ports and airports. No significant construction or operational impacts are predicted to occur in relation to these areas.

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Tweed Shire Council

CLARRIE HALL DAM RAISING

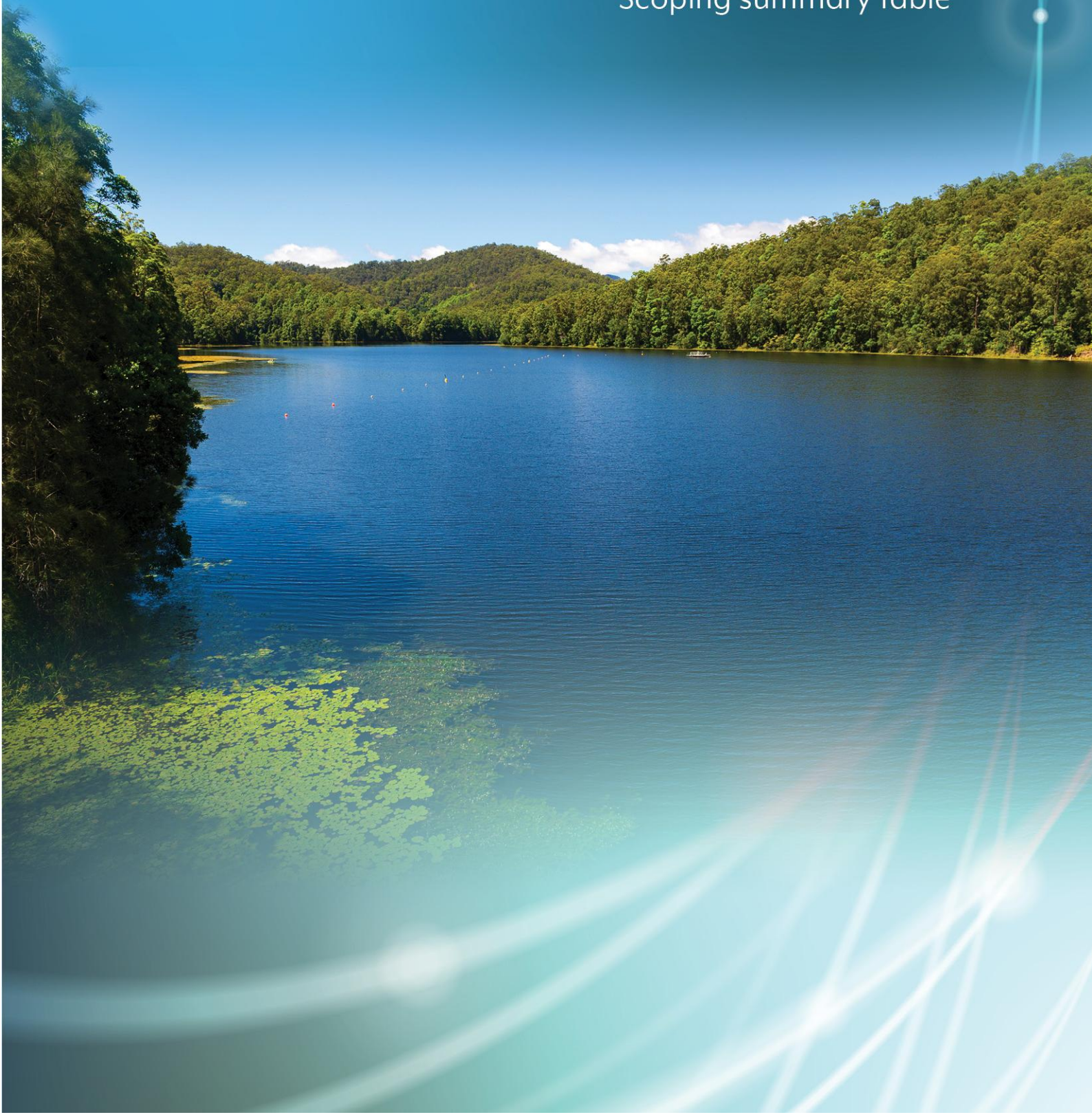
State Significant Infrastructure
Application – Scoping Report

PART TWO



APPENDIX A

Scoping summary table



Scoping summary table

Level of assessment	Matter	CIA* (Y/N)	Engagement	Relevant government plans, policies and guidelines	Scoping report reference
Detailed	Water – hydrology, flooding, groundwater, geomorphology, water availability, water quality, cold water pollution	Y	Specific	• Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000) • ANZECC Guidelines and Water Quality Objectives in NSW (Department of Environment and Conservation, 2006). • Australian Drinking Water Guidelines (ADWG, 2011) • NSW Cold Water Pollution Strategy • Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004) • Managing Urban Stormwater: Soils and Construction Volume 2 (Department of Environment and Climate Change, 2008) • Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (Department of Environment and Climate Change, 2008) • <i>Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources Order 2023</i> • The Far North Coast Regional Water Strategy (DPE, 2023) • NSW Aquifer Interference Policy (DPI, 2012) • Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Office of Water, 2012) • NSW and ACT Regional Climate Modelling (NARCLiM): NARCLiM 1.0; NARCLiM 1.5 – using data, models, simulations, and guidance, appropriate to assessment of the Proposal impacts and risks.	Section 6.1
Detailed	Biodiversity – terrestrial ecology, aquatic ecology, conservation areas	Y	Specific	• Biodiversity Assessment Method (EES, 2020) • Policy and Guidelines for Fish Habitat Conservation and Management – Update 2013 (DPI, 2013) • Threatened Species Survey and Assessment Guidelines (DPE, 2016) • Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (NSW Fisheries, 2003)	Section 6.2

Level of assessment	Matter	CIA* (Y/N)	Engagement	Relevant government plans, policies and guidelines	Scoping report reference
				- NSW DPI Fisheries Fishway Design Guidelines 2015 – as relevant to any proposed offsetting - Aquatic Ecology in Environmental Impact Assessment – EIA Guideline (DoP/Marcus Lincoln Smith 2003) - NSW Biodiversity Offsets Scheme under the Biodiversity Conservation Act 2016 - Guidelines for developments adjoining land managed by the Office of Environment and Heritage (EES, 2013) - Revocation, Re-categorisation and Road Adjustment Policy (EES, 2017)	
Detailed	Heritage – Aboriginal, historic	Y	Specific	- Guide to Investigating, Assessing and Reporting on Aboriginal Cultural Heritage in New South Wales (EES, 2011) - Aboriginal Cultural Heritage Consultation requirements for proponents (DECCW, 2010) - Code of practice for archaeological investigation of Aboriginal objects in NSW (DECCW, 2010) - NSW Skeletal Remains: Guidelines for Management of Human Remains (Heritage Office 1998) - Aboriginal Heritage Information Management System site registration form (OEH, 2011) - Archaeological Assessment Guidelines (Heritage Council, 1996) - Care agreement application form for transfer of Aboriginal Objects - Assessing Significance for Historical Archaeological Sites and Relics (Heritage Branch, DPE, 2009) - Criteria for assessment of excavation directors (NSW Heritage Council, 2011) - NSW Heritage Manual (Heritage Office and Department of Urban Affairs and Planning, 1994) - Assessing Heritage Significance (OEH, 2001) - The Australia ICOMOS Burra Charter	Section 6.3

Level of assessment	Matter	CIA* (Y/N)	Engagement	Relevant government plans, policies and guidelines	Scoping report reference
Detailed	Geology and soils – topography, contamination	N	General	- Guidelines for Surveying Soil and Land Resources, 2nd Edition - Australian Soil and Land Survey Handbook, 3rd Edition - The Australian Soil Classification - Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land (DUAP & EPA, 1998) - Consultants Reporting on Contaminated Land: Contaminated Land Guidelines (EPA, reprinted 2020) - Guidelines for the NSW Site Auditor Scheme (EPA, 2017) - Guidelines on the Duty to Report Contamination under the <i>Contaminated Land Management Act 1997</i> (EPA, 2015) - Urban regional salinity – guidance given in their Local Government Salinity Initiative booklets, including Site Investigations for Urban Salinity (DLWC, 2002) - Landslide risk management guidelines presented in Australian Geomechanics Society (2007) - Soil and Landscaper Issues in Environmental Impact Assessment (DLWC, 2000) - Other guidelines made or approved under Section 105 of the <i>Contaminated Land Management Act 1997</i> - Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004) - Managing Urban Stormwater: Soils and Construction Volume 2 (Department of Environment and Climate Change, 2008)	Section 6.4
Detailed	Traffic and transport – access to property and parking	N	General	- Guide to Traffic Management – Part 3 Traffic Studies and Analysis (Austroads, 2017) - Guide to Traffic Management Part 12(Austroads) - The complementary Roads and Maritime Supplement.	Section 6.5
Detailed	Noise and vibration – amenity	N	General	- Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration (ANZECC, 1990) - Assessing Vibration: a technical guideline (DEC, 2006)	Section 6.6

Level of assessment	Matter	CIA* (Y/N)	Engagement	Relevant government plans, policies and guidelines	Scoping report reference
				- German Standard DIN 4150-3: Structural Vibration - effects of vibration on structures - NSW Noise Policy for Industry (EPA, 2017) - Interim Construction Noise Guideline (DECCW, 2009) - Construction Noise Strategy (TfNSW, 2012).	
Detailed	Hazards and risk – dam safety, bushfire, climate change	N	General	- Dams Safety Committee Guidance and archived Dams Safety Committee Guidance Sheets, including but not limited to, DSC2A (Dam Safety Management System) and DSC2B (Documentation and Information Flow Over Dam Life Cycle) - Planning for Bushfire Protection 2019 (NSW RFS) - Clarrie Hall Dam Bushfire Strategic Study - Bushfire Risk Management Plans (BFRMP) for the LGA - AS/NZS 31000:2009 Risk Management – Principles and Guidelines - Australian Government's Climate Change Impacts and Risk Management – A Guide for Business	Section 6.7
Detailed	Risks and hazards – coastal hazards, biosecurity, dangerous goods, environmental hazards, groundwater contamination, land contamination, land movement, waste, greenhouse gas and renewable energy, hazardous and offensive development	N	Specific	- Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards, Commonwealth of Australia (enHealth, 2012) - Health Impact Assessment: A practical guide (NSW Health, 2007) - Health Impact Assessment Guidelines, Commonwealth Department of Health and Aged Care (enHealth, 2001) - Hazardous Industry Planning Advisory Papers (HIPAPs) - Waste Classification Guidelines (EPA, 2014) - NSW Waste Management Guidelines - State Environmental Planning Policy (Resilience and Hazards) 2021)	Section 6.7
Detailed	Social – way of life, community, accessibility, culture, health and wellbeing, surroundings,	Y	Specific	DPE Social Impact Assessment Guideline (November 2023)	Section 6.8

Level of assessment	Matter	CIA* (Y/N)	Engagement	Relevant government plans, policies and guidelines	Scoping report reference
	livelihoods, decision making systems				
Standard	Land use and built environment – public land, public infrastructure, private land	N	Specific	· <i>Tweed Local Environmental Plan 2014</i> · Re-categorisation and Road Adjustment Policy (OEH, 2017)	Section 6.9
Standard	Economic – natural resource use, livelihood, opportunity cost	N	General	· <i>Water Sharing Plan for the Tweed River Area Unregulated and Alluvial Water Sources 2023 Background document</i> · DPE Social Impact Assessment Guideline (November 2023)	Section 6.10
Standard	Landscape and visual – amenity	N	General	· Refer to Social Impact Assessment	Section 6.11
Standard	Air quality and emissions	N	General	· Institute of Air Quality Management Guidance on the assessment of dust from demolition and construction 2016 · Approved methods for the modelling and assessment of air pollutants (NSW EPA, 2022)	Section 6.12
Standard	Sustainability	N	General	· NSW Waste Management Guidelines · Waste Avoidance and Resource Recovery Act 2001 (NSW) (WARR Act) · NSW Government Resource Efficiency Policy (State of NSW and EES, 2014) · Infrastructure Sustainability Rating Tool Scorecard relating to energy and carbon for large infrastructure projects (ISCA)	Section 6.10
Requiring no further assessment	Access – airports, port and rail facilities	N	Not required	N/A	-

* Cumulative Impact Assessment (CIA)

APPENDIX B

Demand Forecast –
Hydrosphere Consulting, 2021



Assessment of Impact of 2019/20 Drought on Demand

Tweed District Water Supply

Disclaimer:

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Acknowledgement of Country:

Hydrosphere Consulting recognises the generations of local Aboriginal people of the Bundjalung Nation who have lived in and derived their physical and spiritual needs from the forests, rivers, lakes and streams of the Tweed Valley over many thousands of years as the traditional owners and custodians of the land discussed in this report.

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**JOB 21-037: TWEED CLIMATE CHANGE AND DEMAND ASSESSMENT
ASSESSMENT OF IMPACTS OF 2019/20 DROUGHT ON DEMAND – TWEED DISTRICT WATER
SUPPLY**

REV	DESCRIPTION	AUTHORS	REVIEW	APPROVAL	DATE
0	Draft for client review	R. Campbell, K. Menzies	M. Howland	M. Howland	23 Aug 2021

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1. INTRODUCTION

Tweed Shire Council (TSC) is undertaking strategic planning and investigations to ensure future water supply security. A long-term demand forecast (Hydrosphere Consulting, 2020) was prepared in September 2020 for the three TSC water supply areas (Tweed District, Uki and Tyalgum) from the present to 2070. The demand forecast was developed from demand data (raw water extraction and treated water production) and customer consumption data between 2010/11 and 2018/19. A drought period was experienced in the region during Spring and Summer of 2019/20 after the demand forecast was prepared.

The main aims of this report are to determine if the assumptions relating to current average and dry year demand in the 2020 demand forecast are still considered appropriate for strategic planning purposes based on the recent climate and demand experienced. TSC has requested a review of the 2019/20 drought to see if there are any discernible differences between production in the 2019/20 drought and previous dry/hot periods and on how that may influence demand as compared to other factors. TSC has also requested commentary on the assumptions used in the demand forecasts and the applicability and suitability of those assumptions in the forecasting of demand as impacted by climate change, based on the outcomes of the review.

2. SUMMARY OF 2020 DEMAND FORECAST

The 2020 demand forecast used data on raw water extraction and treated water production between 2010/11 and 2018/19. The following information from the 2020 demand forecast for Tweed District water supply is relevant to this analysis:

- The average demand (treated water production) between 2011 and 2019 was 8,727 ML/a and varied from 5.8% below the average (in 2011/12) to 7.3% above the average (in 2019). The maximum demand was 9,380 ML/a in 2019.
- The forecast average demand (treated water production) in 2019/20 was 8,830 ML/a.
- The average demand for each customer type was assumed to remain static throughout the 50-year period and average year and dry year consumption rates were applied.
- Climate correction analysis was undertaken to identify key climate-influencing factors such as rainfall, temperature and evaporation and evaluate changes in production due to periods of dry/hot climate. This was used to estimate the unrestricted dry year consumption per connection as a percentage increase over the average consumption per connection (4.3% for Tweed District).
- Although it was acknowledged that non-climate factors would also influence demand, these factors were not considered in the 2020 demand forecast as they were not quantifiable.
- The number of connected properties in 2018/19 and the dry year demand was used to estimate the maximum demand for each customer type. As there were no drought restrictions in the period of data analysed, this was considered to approximate the 2018/19 unrestricted dry year demand.
- An allowance for increased water carting demand in unrestricted dry years was included in the demand forecast (498 ML/a) based on the supply of minimum (emergency) water requirements to all customers not serviced by the town water supplies.
- The forecast dry year unrestricted demand (treated water production) in 2019/20 was calculated as 9,783 ML/a (4.3% higher than the maximum annual demand between 2011 and 2019).

3. DATA AND ANALYSIS – CLIMATE AND DEMAND

This report provides an analysis of demand (daily treated water production) experienced in the Tweed District water supply during the 2019/20 drought as well as the climate experienced during the drought period and over the period of record. This analysis has been undertaken to determine whether the demand experienced during the 2019/20 drought had an appreciable impact on total annual demand compared to previous years. Consumption data have not been analysed in this report as metered customer demand is only available on a quarterly basis (not coinciding with the drought period).

Data used in this report are:

- Climate (daily rainfall, maximum temperature and Morton's shallow lake evaporation) between 1/7/1970 (1971) and 30/6/2021 (2021) for the SILO grid point at Tweed Heads South (Lat: -28.20, Long: 153.55) to represent the demand centre of Tweed District water supply.
- Daily raw water extraction and treated water production (1/7/2011 (2012) – 30/6/2021 (2021)), corrected for metering anomalies and missing data.
- Potable water carting volumes (generally monthly) between July 2015 and June 2021.

Level 2 water restrictions were introduced by TSC on 13 December 2019 and lifted on 10 February 2020 (60 days).

3.1 Summary of Daily Demand and Climate Data

A summary of daily demand data between 2012 and 2021, daily climate data between 1971 and 2021 and the Spring/Summer periods of 2018/19 and 2019/20 are shown in Table 1. The 2018/19 year was drier and hotter on average than 1971 – 2021. The 2019/20 year was wetter than 2018/19 with similar temperatures. On average the daily demand was higher in 2018/19 and 2019/20 compared to the period of record.

Rainfall has a higher variability than evaporation and therefore will be used to indicate the dependence of demand on dry/wet weather in this report.

Table 1: Summary of demand and climate data

Data	Minimum	10 th percentile	Average	Median	90 th percentile	Maximum
<i>Climate (1971 – 2021)</i>						
Daily rainfall (mm)	0	0	4.8	0	12.4	431
Maximum daily temperature (°C)	13.4	20.3	24.8	24.9	29.1	39.5
Daily evaporation (mm)	0.5	2.1	4.3	4.1	7.0	9.1
Net rainfall (mm, rainfall – evaporation)	-9.1	-6.8	0.5	-3.1	8.8	429

Data	Minimum	10 th percentile	Average	Median	90 th percentile	Maximum
<i>Climate (2018/19)</i>						
Daily rainfall (mm)	0	0	3.5	0	9.7	81
Maximum daily temperature (°C)	16.5	21.1	25.6	25.6	30.3	34.9
Daily evaporation (mm)	1.0	2.0	4.2	3.8	7.0	8.2
Net rainfall (mm, rainfall – evaporation)	-8.2	-7.0	-0.8	-3.1	7.1	78
<i>Climate (2019/20)</i>						
Daily rainfall (mm)	0	0	5.3	0	9.9	284
Maximum daily temperature (°C)	16.4	21.0	25.6	25.8	30.0	35.9
Daily evaporation (mm)	0.8	2.0	4.3	4.0	7.0	8.0
Net rainfall (mm, rainfall – evaporation)	-8.0	-6.9	1.0	-3.4	5.5	279
<i>Treated water production (ML/d)</i>						
Treated water production (2012 – 2021)	0	18.3	24.1	23.7	30.4	47.1
Treated water production (2019)	11.3	19.5	25.7	25.3	32.7	42.8
Treated water production (2020)	6.3	19.3	24.7	24.5	30.9	39.7
Treated water production (level 2 restrictions: 13/12/19 – 10/2/20)	6.3	21.9	26.7	24.6	29.5	38.7

3.2 The 2019/20 Drought

The Tweed region experienced low rainfall generally between July 2019 and December 2019 (194 mm for the 5-month period compared to the long-term (1971 – 2021) average of 629 mm). During this period, the average maximum temperature (24.4°C) was 1.0°C above average. Significant rainfall was experienced on 18 January 2020 (197 mm) with 284 mm in January 2020 and 952 mm in February 2020 (284 mm on 9 February 2020) effectively breaking the drought, although temperatures remained above average until February 2020. The annual rainfall in 2019/20 was 1,922 mm compared to the long-term average of 1,711 mm.

Treated water production, rainfall and average maximum temperature during Spring and Summer periods between 2012 and 2020 are shown on Figure 1 and Figure 2 respectively. The Spring of 2019/20 was dry and hot but not as dry as 2014/15 nor as hot as 2013/14. The demand in Spring of 2019/20 was higher than other years. The Summer of 2019/20 was wetter than other years and not as hot as 2013/14, 2015/16, 2016/17, 2017/18 and 2018/19. The demand in Summer of 2019/20 was lower than most other years (level 2 restrictions for 60 days of this 90-day period).

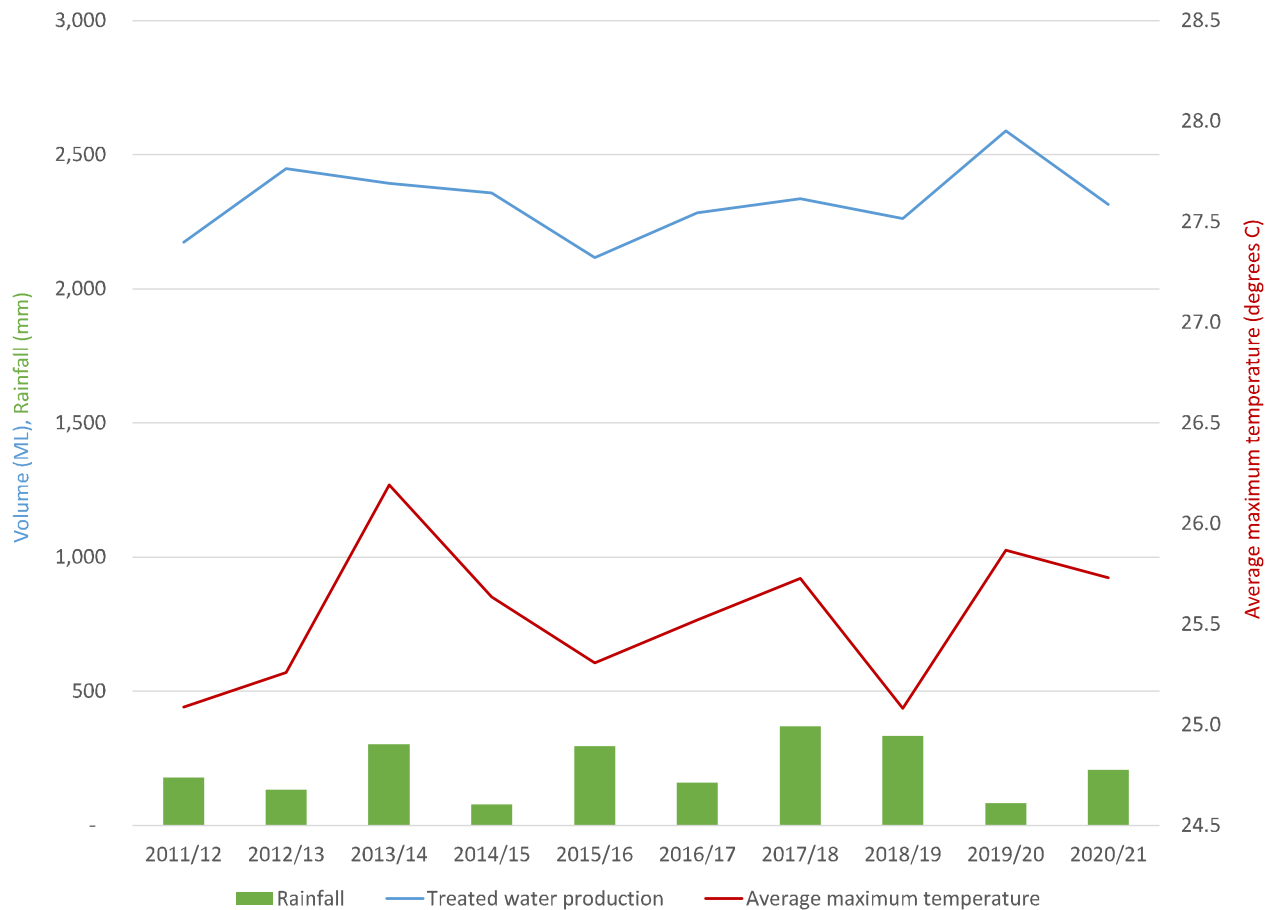


Figure 1: Treated water production, rainfall and average maximum temperature: Spring (2012 – 2021)

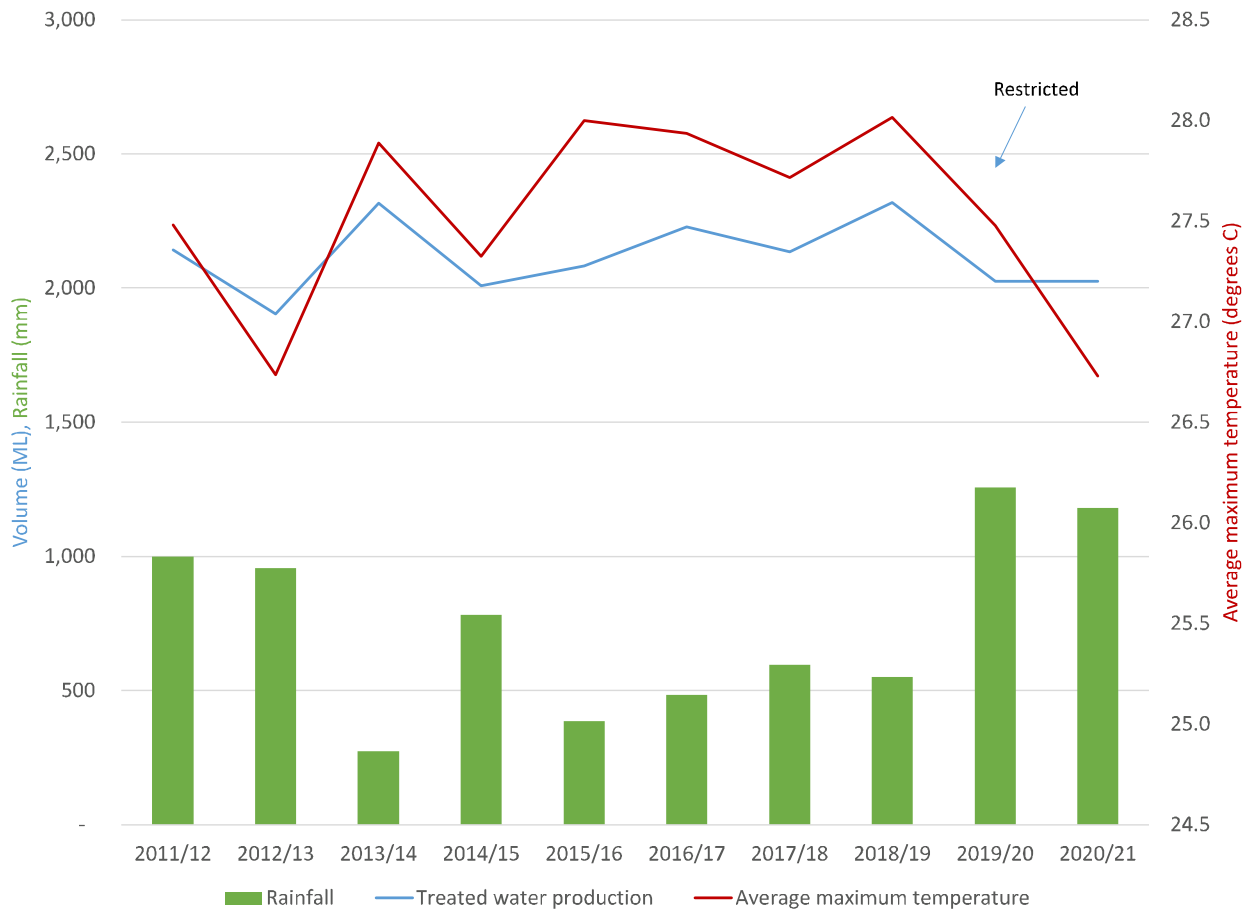


Figure 2: Treated water production, rainfall and average maximum temperature: Summer (2012 – 2021)

3.3 Annual Demand

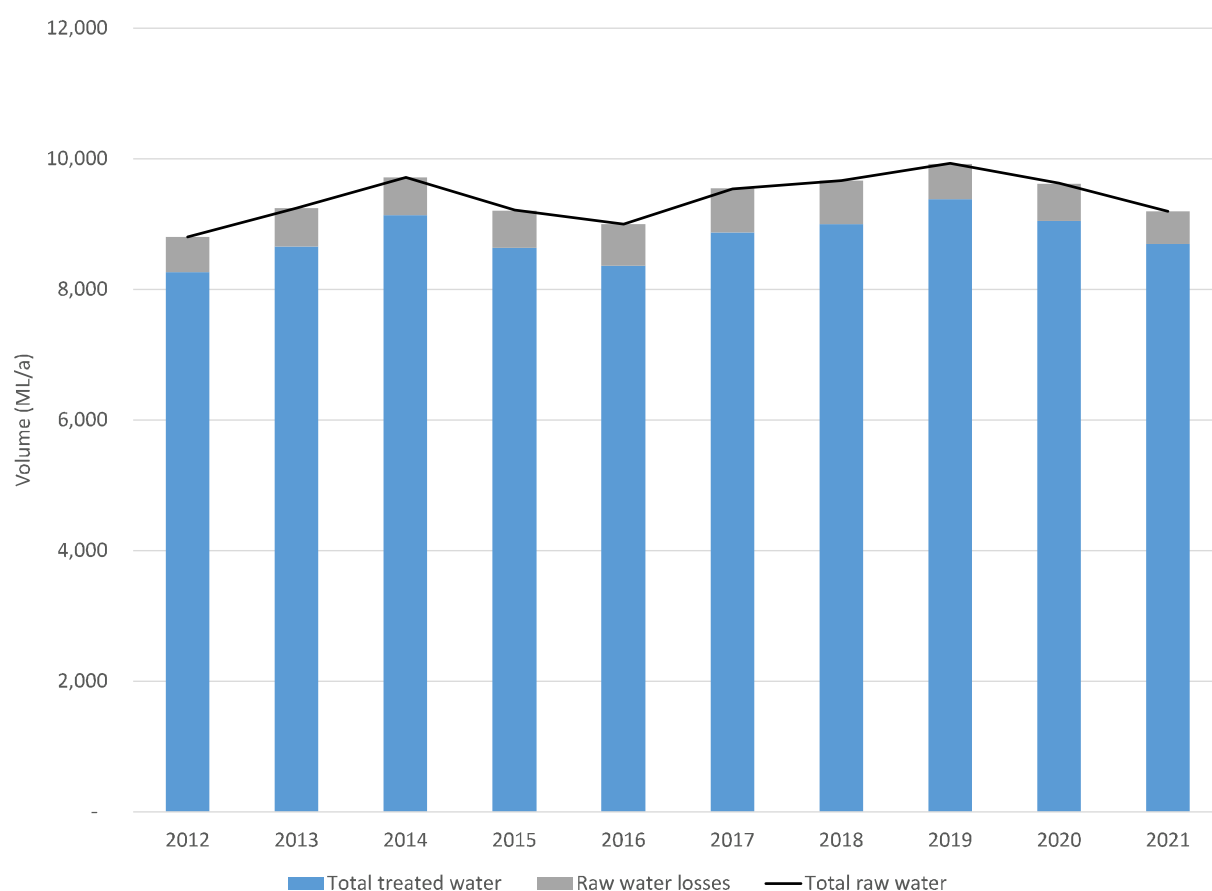
The annual demand data are shown in Table 2 and Figure 3 including data for 2020 and 2021.

Between 2012 and 2021, the maximum treated water production was experienced in 2018/19 (9,380 ML/a). The 2019/20 treated water production was the third highest experienced in this period of record and was 2.5% higher than the predicted treated water production from the 2019/20 demand forecast (8,830 ML/a).

Raw water losses have generally decreased over the last 4 years (6.3% p.a. on average). The 2019/20 demand forecast assumed raw water losses would be 6.4% of raw water extraction in future. The reason for the slight decrease in losses is unknown although it is expected that future water loss reduction measures would further decrease the losses. This would result in lower raw water extraction than forecast in 2019/20.

Table 2: Raw water extraction, treated water production and raw water losses: Tweed District

Data (ML/a)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Raw water extraction	8,751	9,213	9,713	9,208	8,998	9,541	9,656	9,923	9,620	9,194
Treated water production	8,221	8,626	9,134	8,610	8,358	8,871	8,995	9,380	9,049	8,699
Raw water losses	531	587	579	599	641	670	661	544	571	495
Raw water losses (% of raw water extraction)	6.1%	6.4%	6.0%	6.5%	7.1%	7.0%	6.8%	5.5%	5.9%	5.4%

**Figure 3: Raw water extraction, treated water production and raw water losses: Tweed District (2011 – 2021)**

The longer-term trend in treated water production is shown on Figure 4 with the average and dry year unrestricted demand from the 2020 demand forecast. Annual treated water production has remained relatively stable since 1991 with no increasing or decreasing trend. Per capita treated water production for the Tweed Shire is shown on Figure 5. Per capita demand has decreased significantly since 1991 (average of 1.5% p.a. over the 30-year period) but appears to be stabilising.

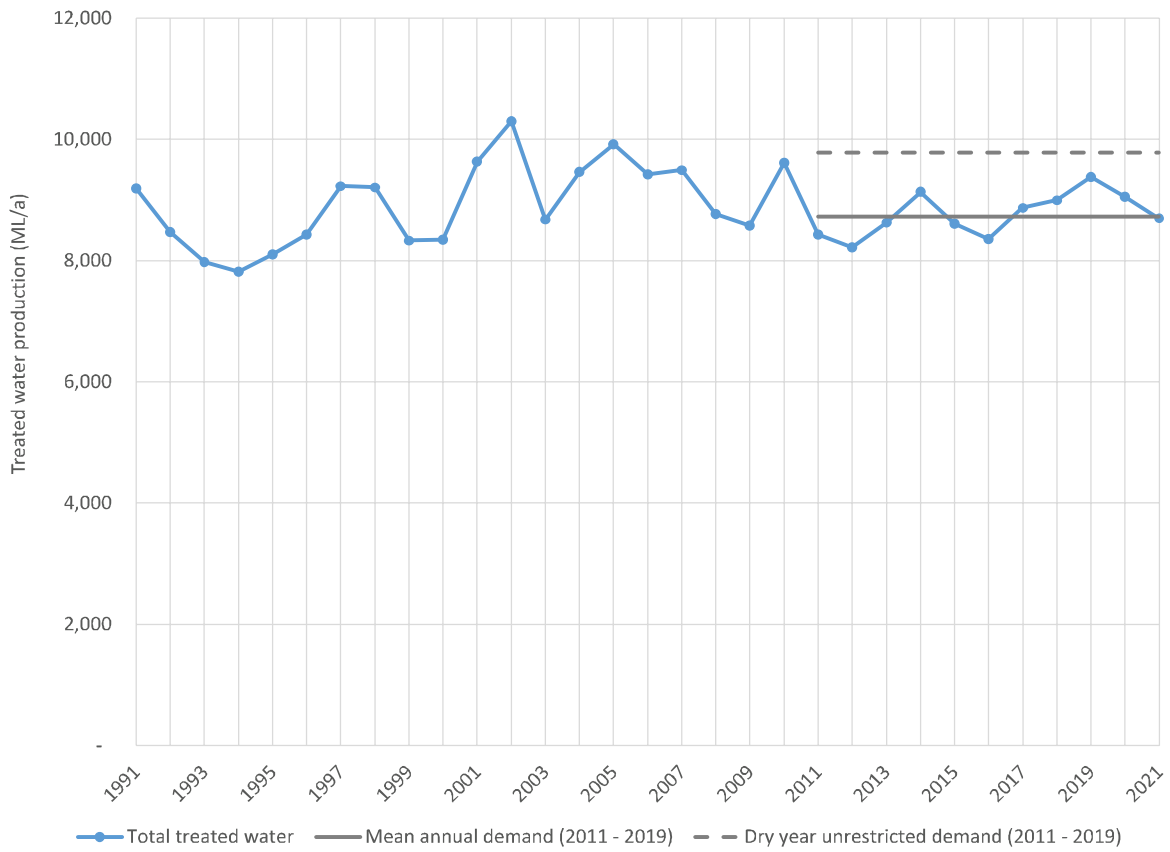


Figure 4: Treated water production: Tweed District (1991 – 2021)

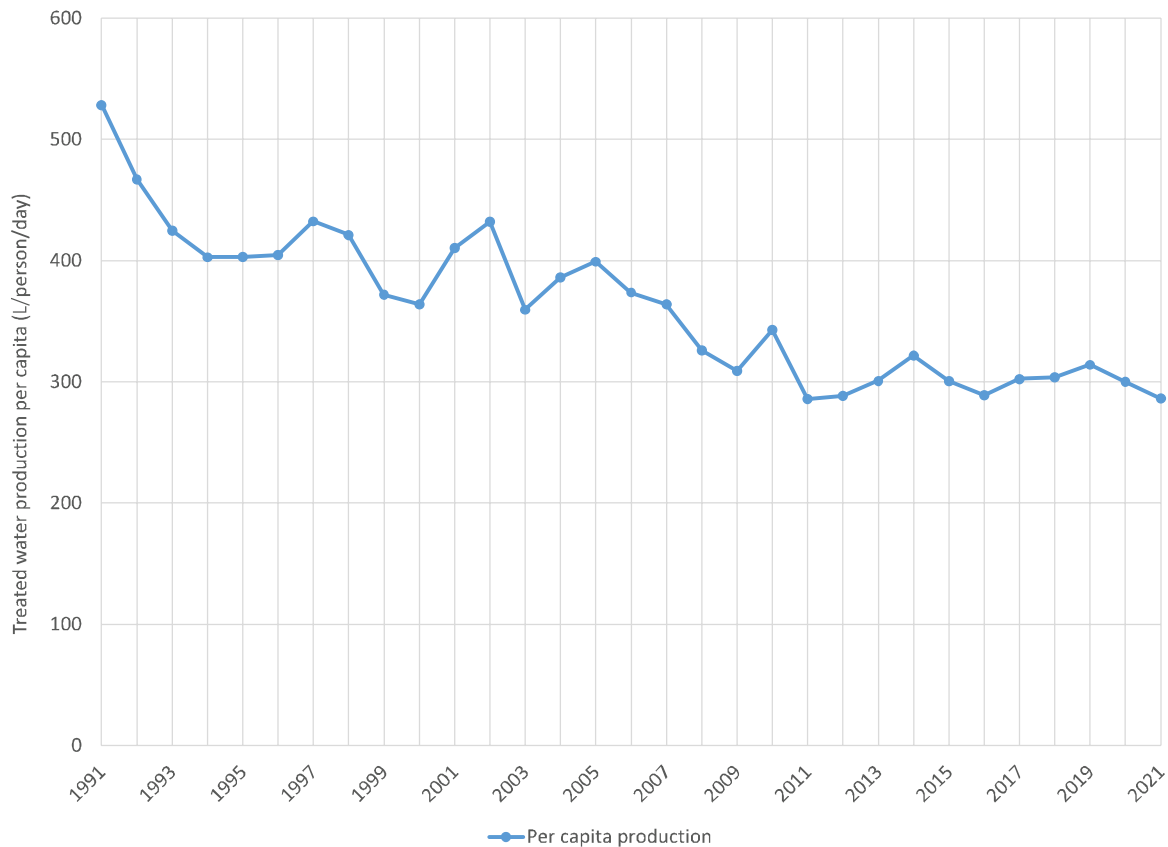


Figure 5: Treated water production per capita: Tweed Shire (1991 - 2021)

3.4 Monthly Demand

Monthly treated water demand between 2012 and 2021 is presented in Table 3. The monthly rainfall and average maximum temperature are shown on Figure 6 to Figure 8 for the same period. The hot and/or dry months (compared to the climate experienced between 1971 and 2021) are also indicated in Table 3.

Table 3: Monthly treated water production and hot and/or dry periods

Monthly treated water production (ML)	2011/ 12	2012/ 13	2013/ 14	2014/ 15	2015/ 16	2016/ 17	2017/ 18	2018/ 19	2019/ 20	2020/ 21
July	675	639	609	728	640	680	683	716	720	678
August	684	726	709	703	659	681	714	799	786	717
September	700	803	787	668	665	649	907	727	837	700
October	707	837	857	835	742	791	736	740	829	803
November	767	808	748	853	709	845	692	794	924	812
December	708	803	856	790	735	834	816	852	827	798
January	784	880	892	747	766	809	924	1,041	769	752
February	652	622	780	617	719	798	703	831	645	649
March	671	656	807	717	669	709	720	773	689	690
April	645	625	729	674	696	723	712	714	691	687
May	655	649	687	646	720	683	703	712	689	707
June	620	606	672	626	638	671	687	681	644	706
Total annual ¹	8,267	8,653	9,134	8,605	8,358	8,871	8,995	9,380	9,049	8,699

1. 1. The minor differences in annual demand in Table 2 and Table 3 are due to corrections of daily data undertaken for this report.

Level 2 restriction period (13/12/2019 – 10/2/20)	
Minimum monthly rainfall (1971 – 2021)	Maximum monthly average temperature (1971 – 2021)
<10 th percentile rainfall (1971 – 2021)	Average maximum temperature >1.5°C above monthly average maximum temperature (1971 – 2021)
=10 th percentile rainfall (1971 – 2021)	Average maximum temperature >1.0°C above monthly average maximum temperature (1971 – 2021)

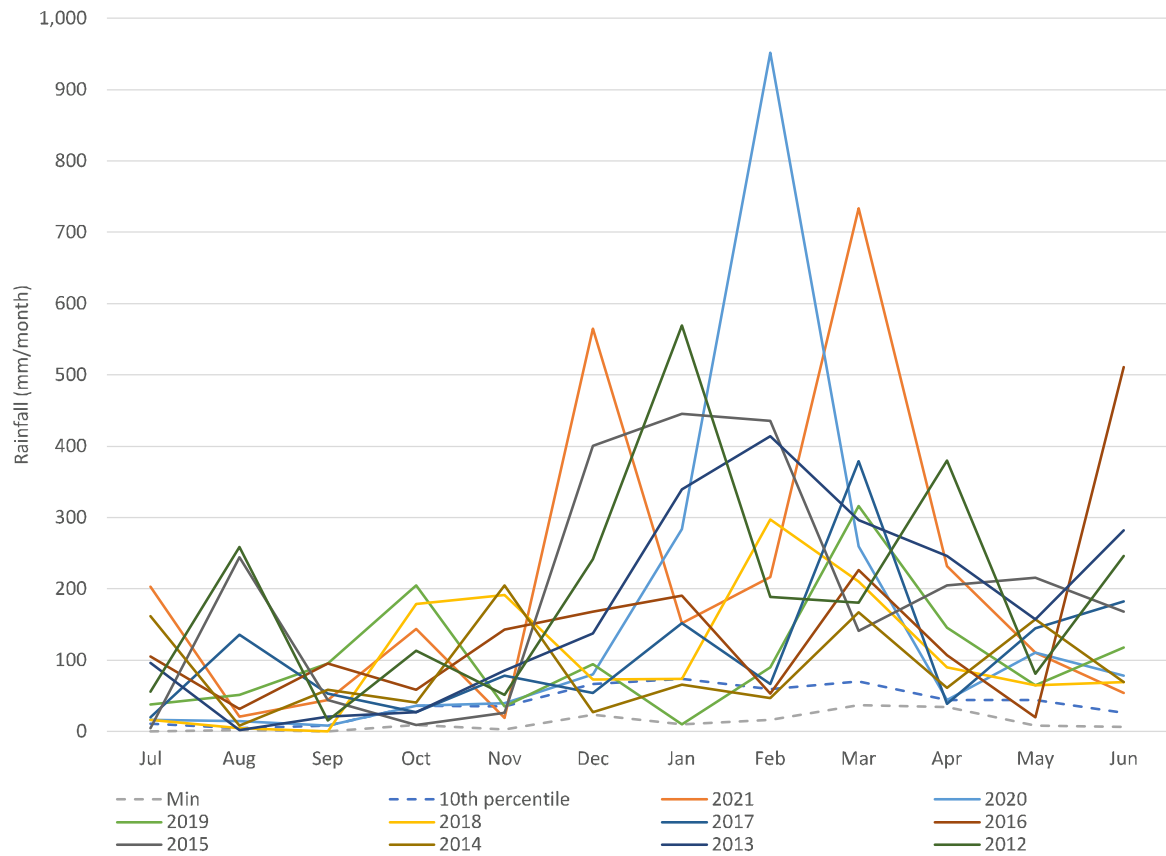


Figure 6: Monthly rainfall for each year since 2011/12

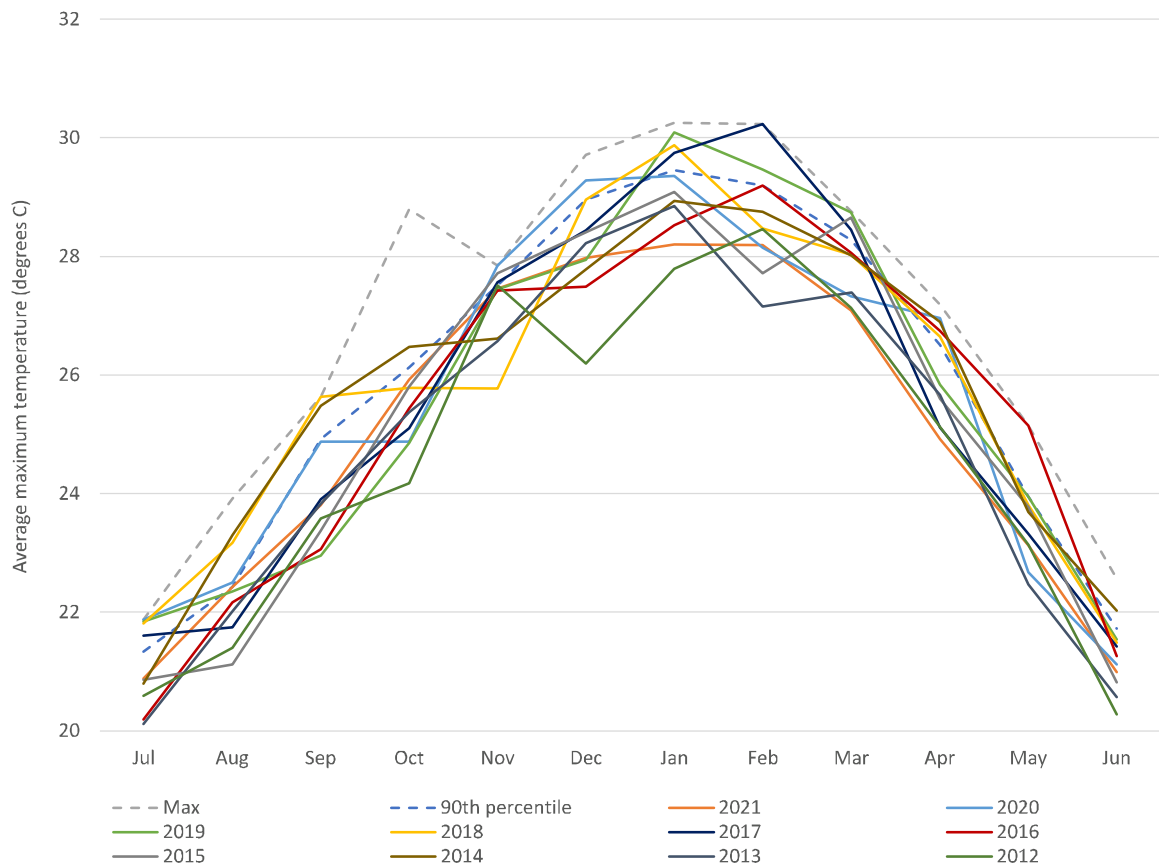
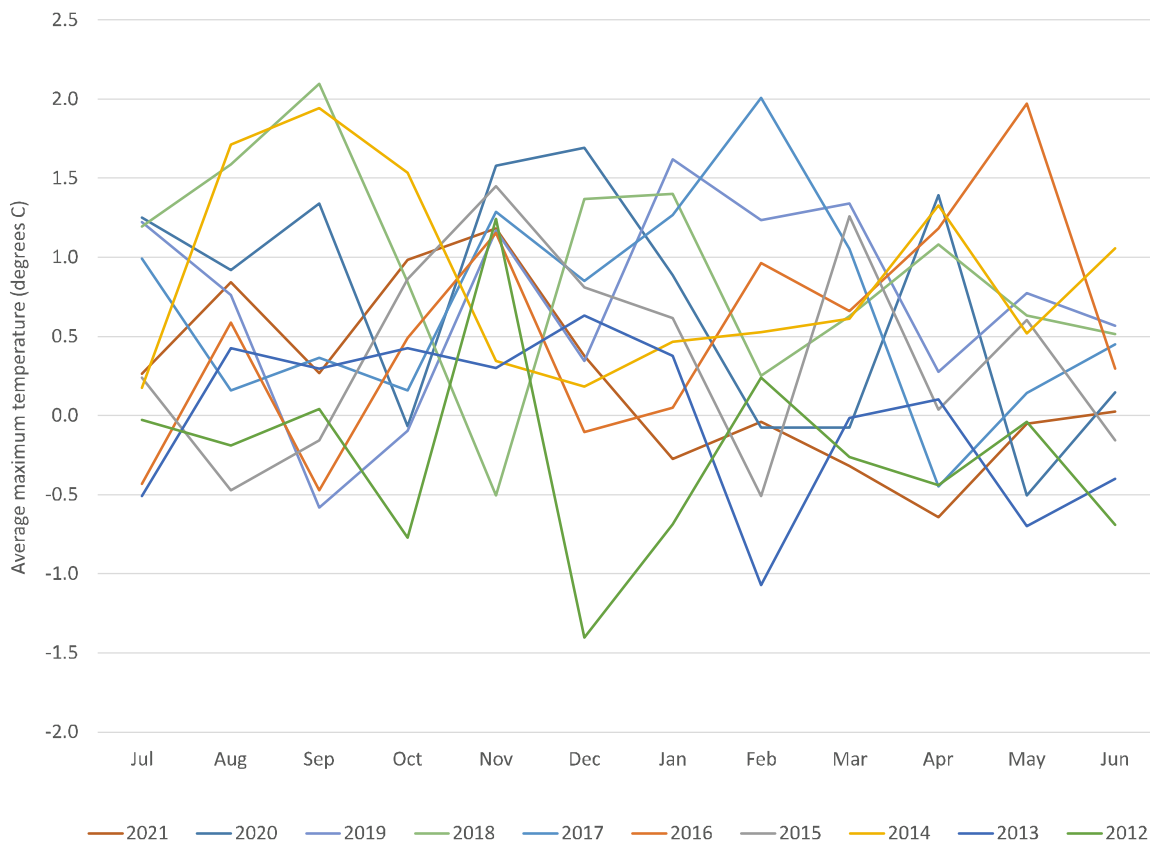


Figure 7: Monthly average maximum temperature for each year since 2011/12**Figure 8: Deviation from monthly average maximum temperature for each year since 2011/12**

The periods with at least three consecutive hot and/or low rainfall months are:

- August – October 2013/14 ($>1.5^{\circ}\text{C}$ hotter than average) with demand of 2,354 ML compared to the average of 2,250 ML (4.6% above average).
- October – March 2016/17 ($<10^{\text{th}}$ percentile rainfall and $>1.5^{\circ}\text{C}$ above the monthly average temperature or maximum monthly average temperature) with demand of 4,786 ML compared to the average of 4,633 ML (3.3% above average).
- July – September 2017/18 (10^{th} percentile rainfall and $>1.0^{\circ}\text{C}$ above the monthly average temperature or maximum monthly average temperature) with demand of 2,304 ML compared to the average of 2,139 ML (7.7% above average).
- January – March 2018/19 (minimum monthly rainfall and $>1.0^{\circ}\text{C}$ above the monthly average temperature) with demand of 2,645 ML compared to the average of 2,248 ML (17.7% above average).
- September – December 2019/20 (10^{th} percentile rainfall and $>1.5^{\circ}\text{C}$ above the monthly average temperature or maximum monthly average temperature) with demand of 3,417 ML (including Level 2 restrictions for 19 days during this period) compared to the average of 3,129 ML (9.2% above average).

In the 2019/20 Spring/Summer period, there was relatively low rainfall in September and October 2019 and relatively hot weather in September, November and December 2019. The monthly treated water production was above average in September, October, November and December 2019 (coinciding with dry and/or hot weather) but below average in January and February 2020 (restriction periods).

The period of hottest/driest weather which had the most influence on demand was January – March 2019. The highest annual demand was also experienced in 2018/19.

3.5 Weekly Demand

The rolling weekly demand between 2012 and 2021 is shown on Figure 9 with data for 2018/19 (highest demand year) and 2019/20 (drought/restricted year) shown on Figure 10 and Figure 11 respectively. The highest weekly demand was experienced in January 2019, prior to the Spring/Summer drought of 2019/20.

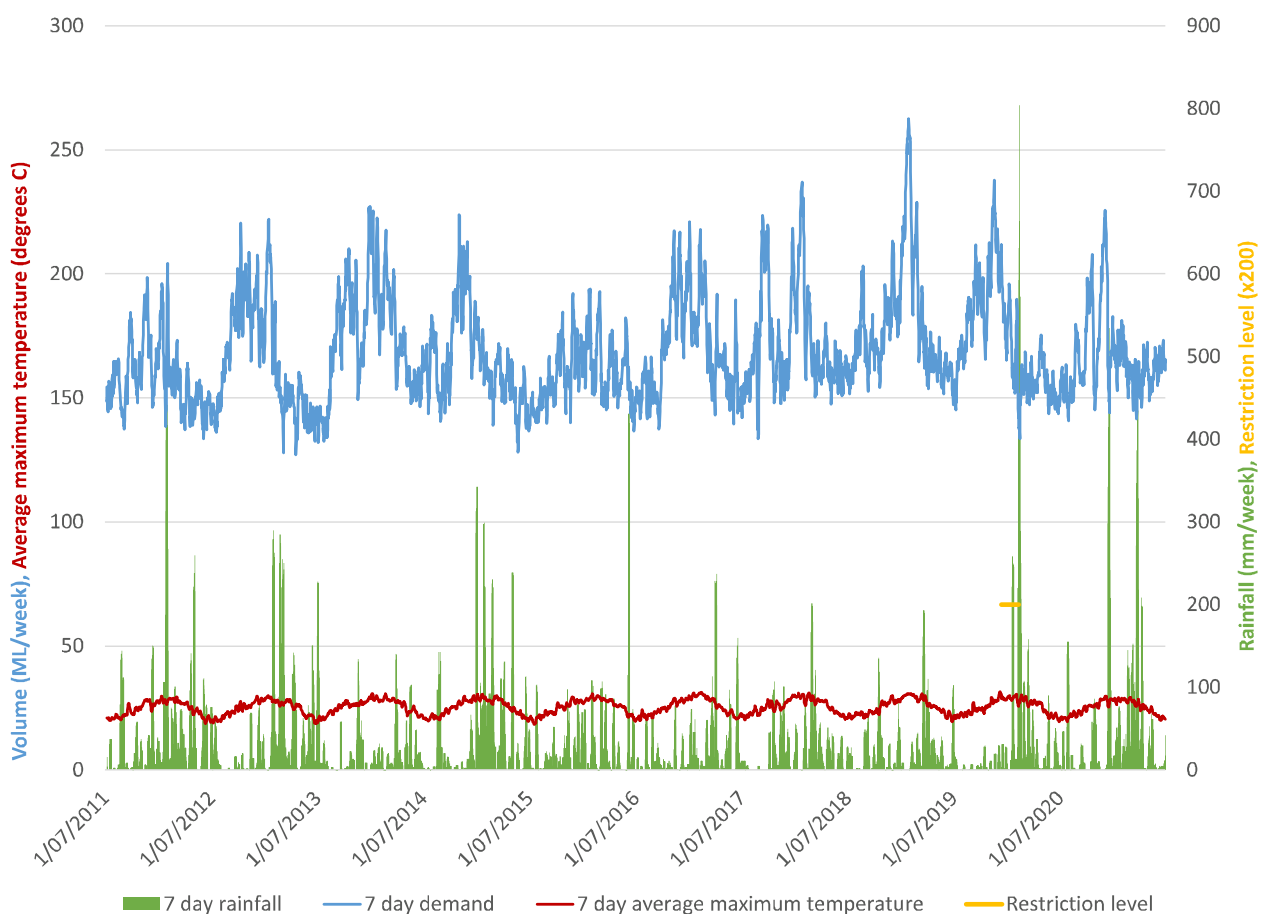


Figure 9: Demand, rainfall and average maximum temperature over 7-day period (2012 - 2021)

Assessment of impacts of 2019/20 drought on demand

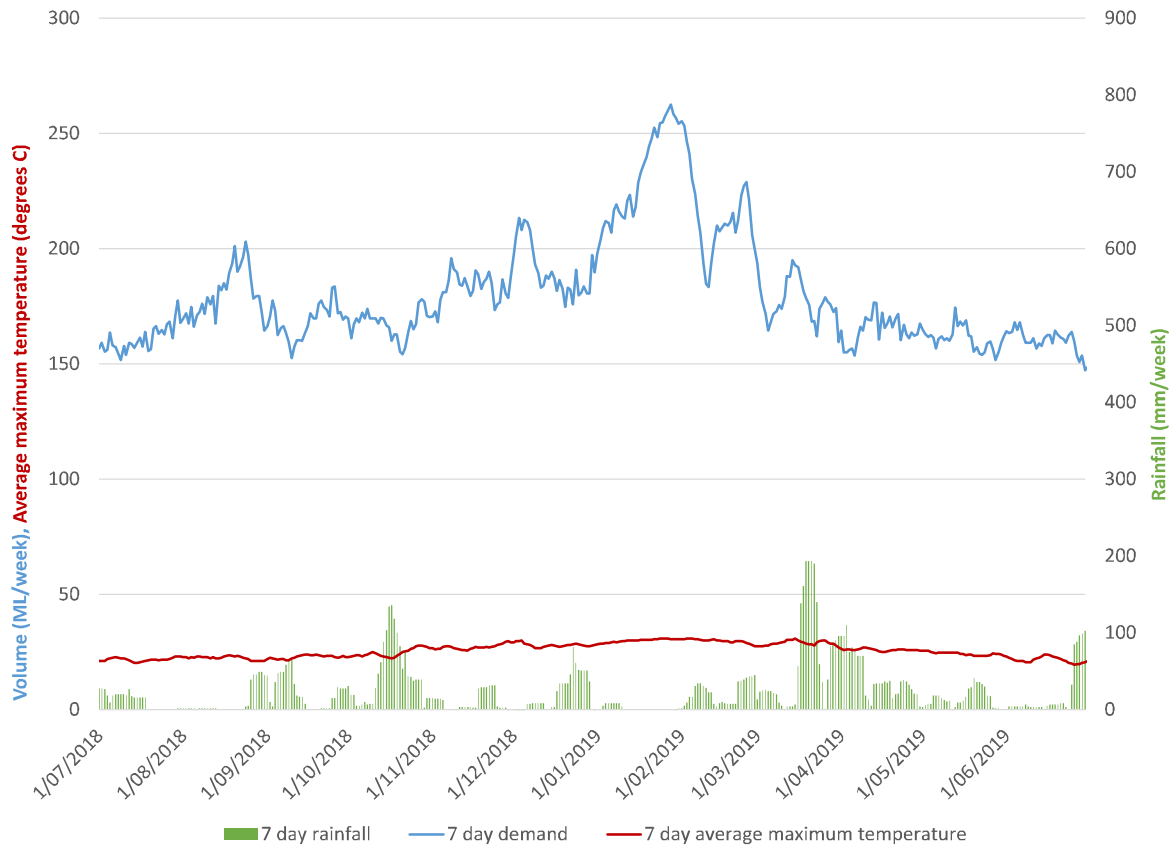


Figure 10: Demand, rainfall and average maximum temperature over 7-day period (2018/19)

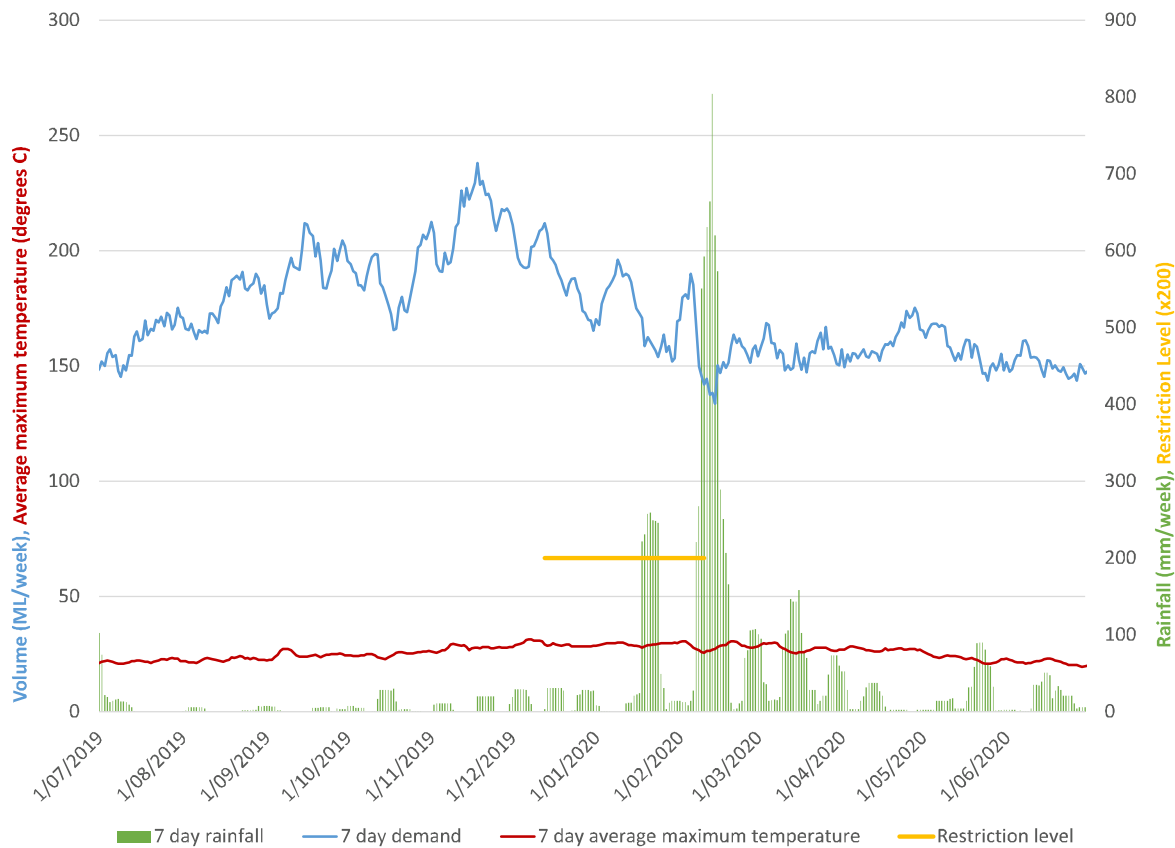


Figure 11: Demand, rainfall and average maximum temperature over 7-day period (2020)

3.6 Daily Demand

Daily treated water production, average treated water production (each month) and restriction periods between 2012 and 2021 are shown on Figure 12. The highest daily demands were experienced in January 2014 (47.1 ML/d) and November 2015 (46.3 ML/d). The highest daily demand in 2019/20 was 39.7 ML/d on 15 September 2019 following a period of increasing temperature and low rainfall since the end of June 2019 (Figure 13).

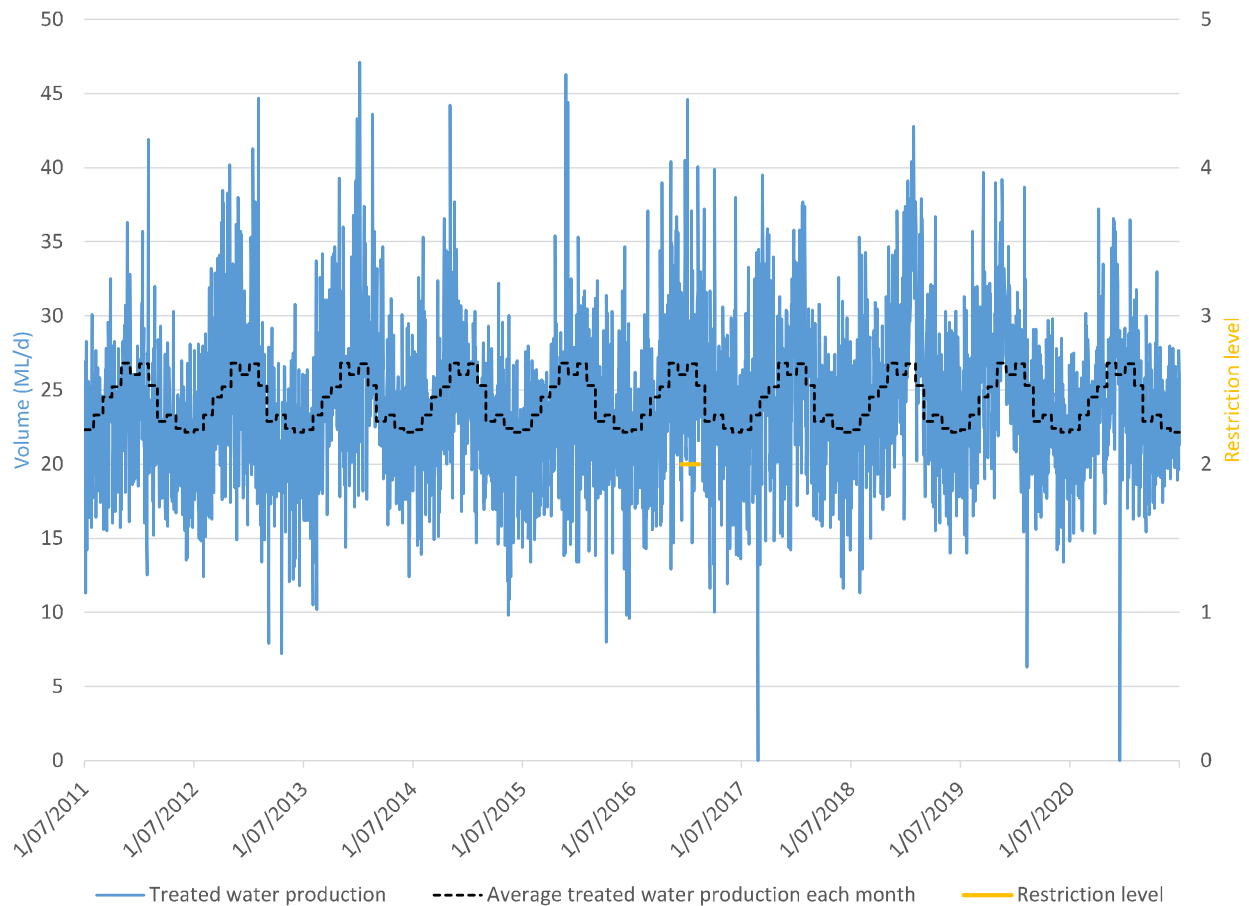


Figure 12: Daily treated water production (2011 – 2021)

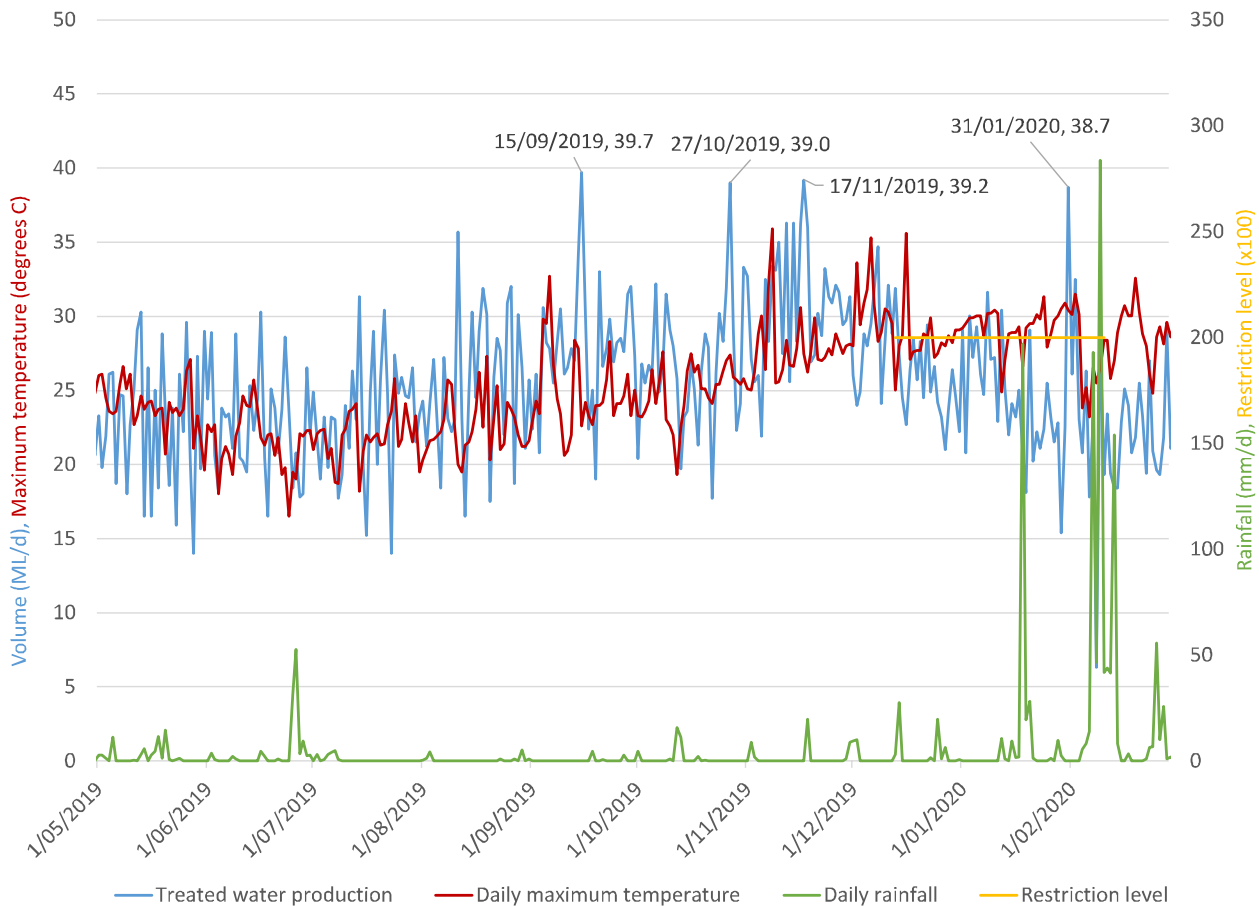


Figure 13: Daily treated water production, rainfall, temperature and restriction periods (May 2019 – February 2020)

3.7 Climate Correction

Modelling was undertaken as part of the 2020 demand forecast to correlate key climate influencing factors (rainfall, evaporation and temperature) to changes in demand using daily bulk water supply (treated water production) data from 2014 - 2019. This was then used to estimate unrestricted demand in a “worst case” year. Climate data from 1900 - 2020 were analysed to determine which year had the most hot/dry weather days. Results from the 2020 demand forecast analysis of the dry weather increase in demand are shown in the first row of Table 5.

This analysis has been repeated using updated daily bulk supply data from 2011 - 2021 to determine the changes in climate thresholds that correlate to increases in demand (Table 4).

Climate data from 1970 - 2021 were re-analysed to determine the “worst case” year during this period. Results from this analysis are shown in Table 5 and Figure 14 to Figure 16. As shown in Table 4 and Table 5, the proportion of days that met the hot/dry threshold considered to trigger increased water use in 2018/19 (31% of the time) was similar to the average for the 1970 - 2021 period (32% of the time). This indicates that climate influences in 2018/19 were similar to those of an average year (despite the increase in demand experienced). Climate influences in 2019/20 occurred 46% of the time (more than average, which is consistent with the data analysis provided in previous sections).

The climate correction analysis undertaken for the 2020 demand forecast suggests that the dry year demand is 4.3% higher than the average demand. Based on the new analysis of climate and demand data, this is still considered to be appropriate as the predicted increase in dry weather demand in 2020 and 2021 was lower than this.

Table 4: Proportion of days that meet climate thresholds

% of days that meet threshold	Rain	Temperature	Evaporation	Total
1970 – 2021	6%	14%	22%	32%
2012 – 2021	7%	19%	19%	32%
2018/19	3%	23%	21%	31%
2019/20	19%	22%	20%	46%
Threshold	≤ 76 mm of cumulative rainfall over a period of 54 days	≥ 28°C for 2 days or more	≥ 4.5 mm for 2 days or more	-

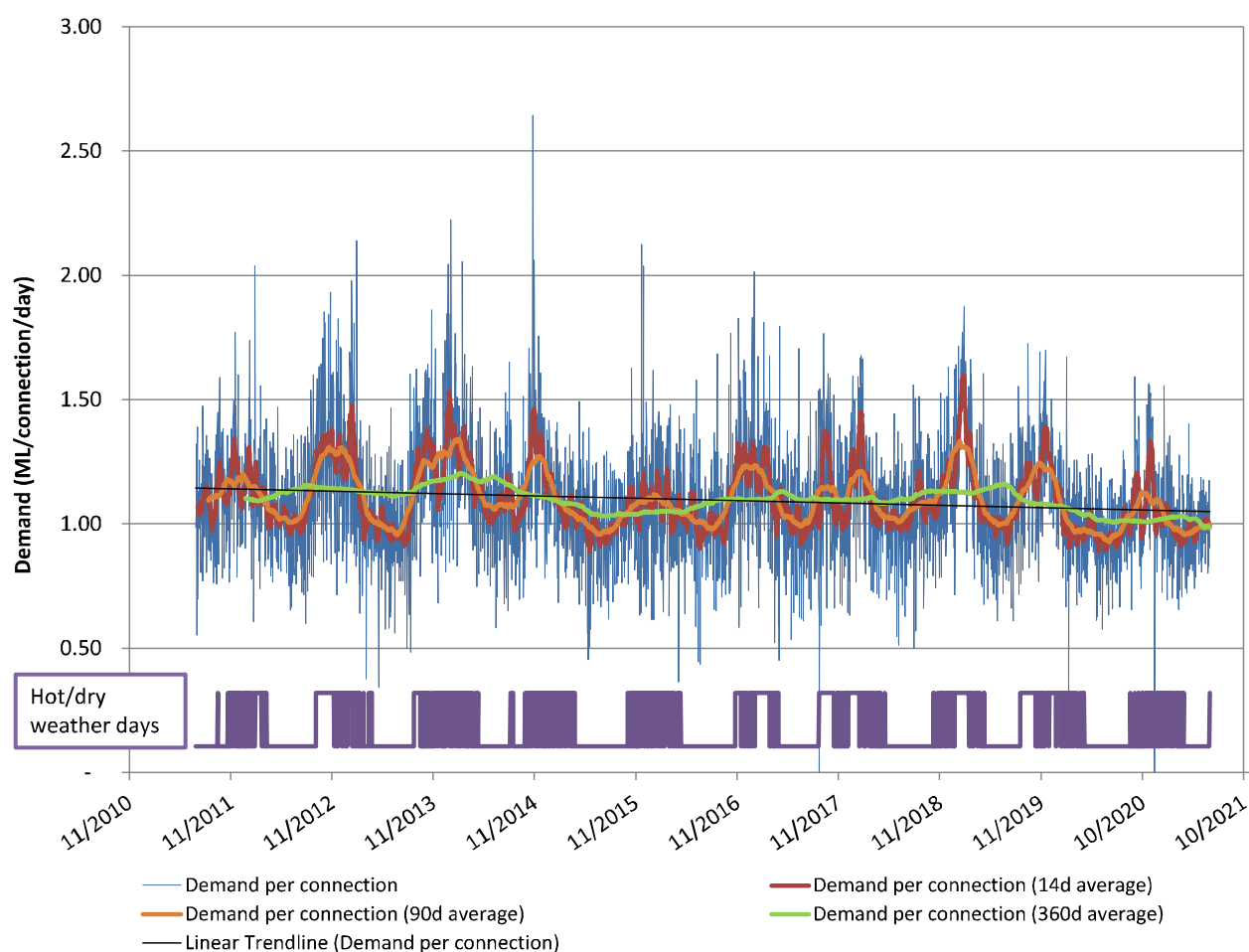


Figure 14: Climate correction analysis: Tweed District (2012 – 2021)

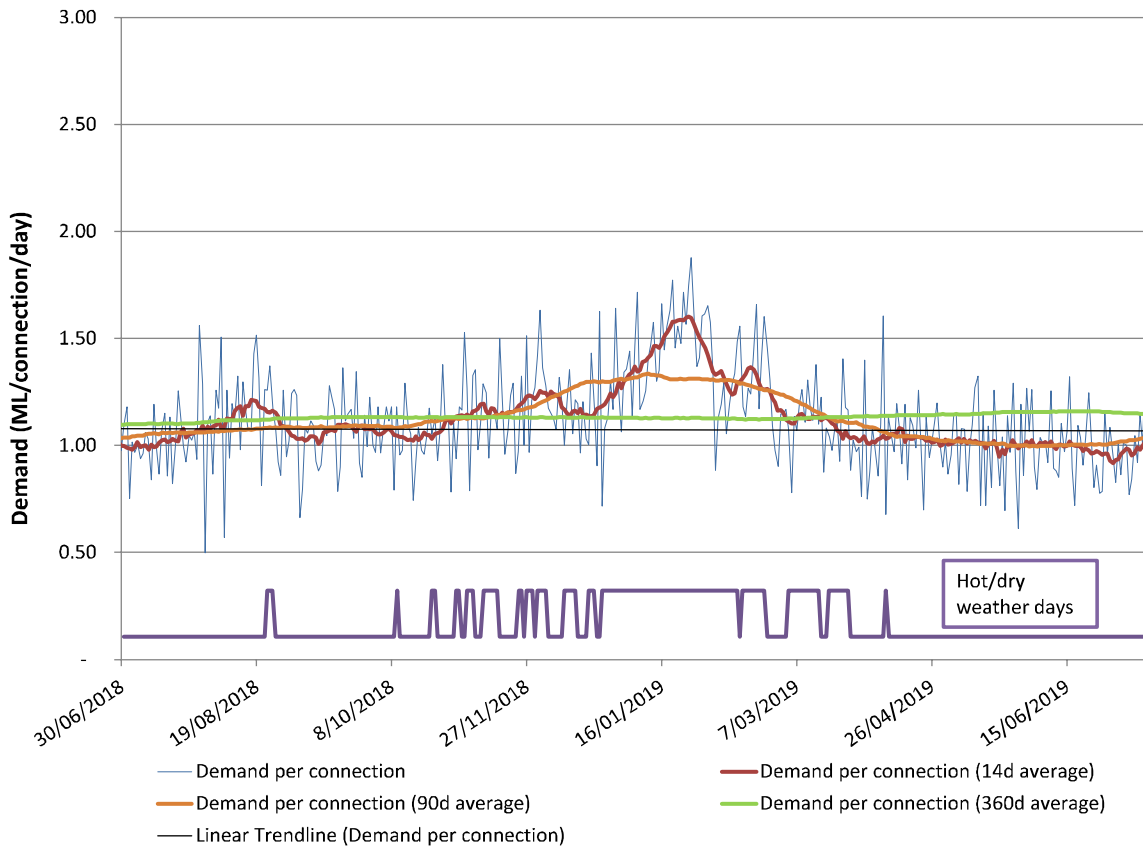


Figure 15: Climate correction analysis: Tweed District (2018/19)

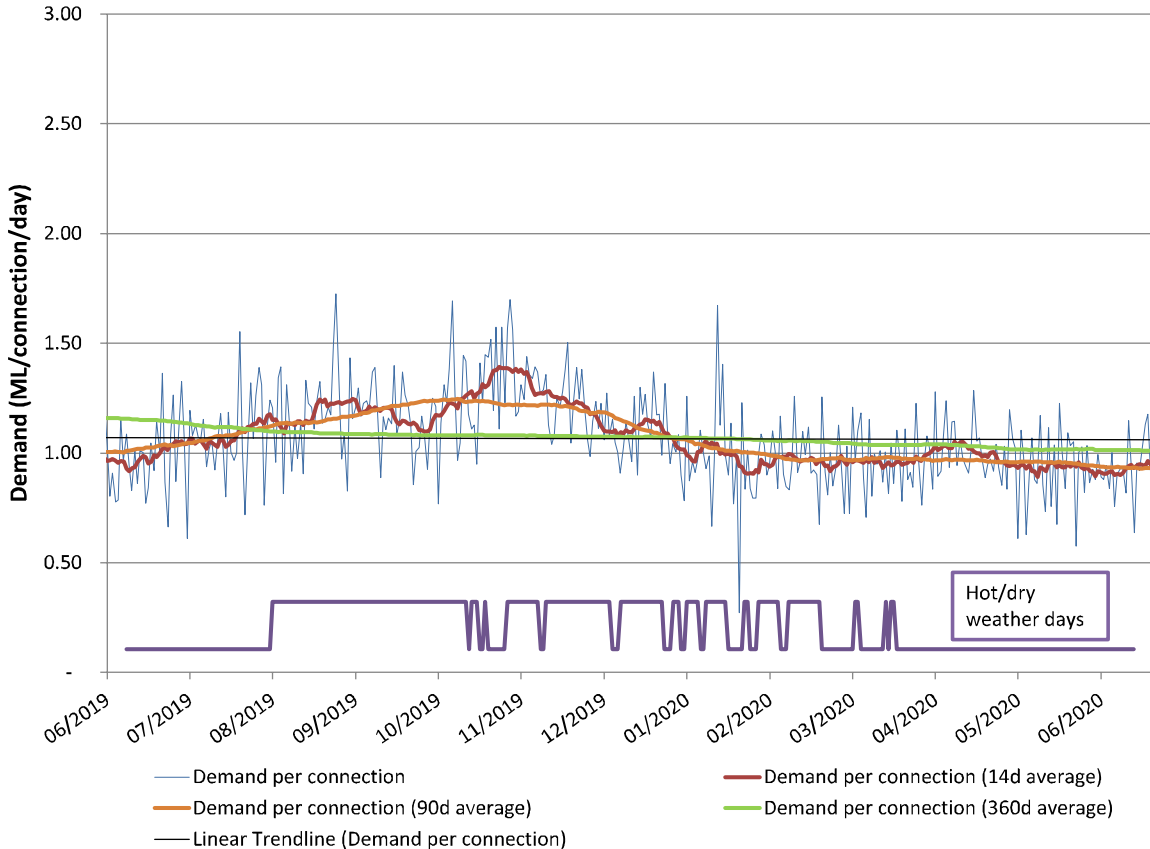


Figure 16: Climate correction analysis: Tweed District (2019/20)

Table 5: Climate correction data, parameters and results updated with recent data: Tweed District

Climate data	Bulk supply data	Average % of time with hotter/drier weather events (%) ¹	Additional usage during peak times compared to non-peak usage (%) ^{2,3}	% correlation of prediction ⁴	% of time with hotter/drier weather events in “worst case” year ^{3,5}	Predicted “dry weather” increase in demand in a “worst case year” (%) ⁶
1/1/1900 to 14/07/2020	1/7/2014 – 30/6/2019	30%	20%	80%	52% (1905)	4.3 %
1/7/1970 – 30/6/2021	1/7/2011 – 30/6/2021	32%	22%	79%	50% (2009/10 - worst) 31% (2018/19)	4.0% in 2009/10 No increase in 2018/19 as hot/dry weather events occurred less than average.
					46% (2019/20 – 2nd worst)	3.2% in 2019/20

1. For all years of climate data.
2. For all years of production data.
3. ‘Peak’ usage is defined as when the 14-day average daily demand per connected property is greater than the average demand per connected property for the entire data set and the 90-day average demand is greater than the 360-day average demand per connected property.
4. % of time that “hotter/drier weather events” (based on the climate variables selected) accurately predict periods of increased water demand.
5. “Worst case” year is the year with the highest number of days of “hotter/drier weather events”.
6. Additional usage during peak times x additional time with hotter/drier events in a “worst case” year compared to average.

3.8 Water Carting Demand

Data on volume of potable water carted (generally metered and recorded monthly since 2016) are shown on Figure 17. The maximum monthly demand was experienced in December 2019 (8.3 ML/month compared to the average December demand of 2.2 ML/month). This is expected as it followed the period of dry weather experienced in Spring 2019. With the significant rainfall experienced in the Summer of 2019/20, the potable water carting demand decreased significantly (1.0 ML in January 2020 and 0 in February 2020).

The annual demand in 2019/20 was 28.1 ML/a compared to the average annual demand of 21.0 ML/a. In January 2019, when total potable demand was highest, water carting demand was 2.0 ML/month (0.19% of demand).

The 2019/20 Demand Forecast assumed a dry year unrestricted water carting demand of 498 ML/a based on the supply of minimum (emergency) water requirements to all customers not serviced by the town water supplies (average 41.5 ML/month) and this is still considered to be an appropriate conservative estimate.

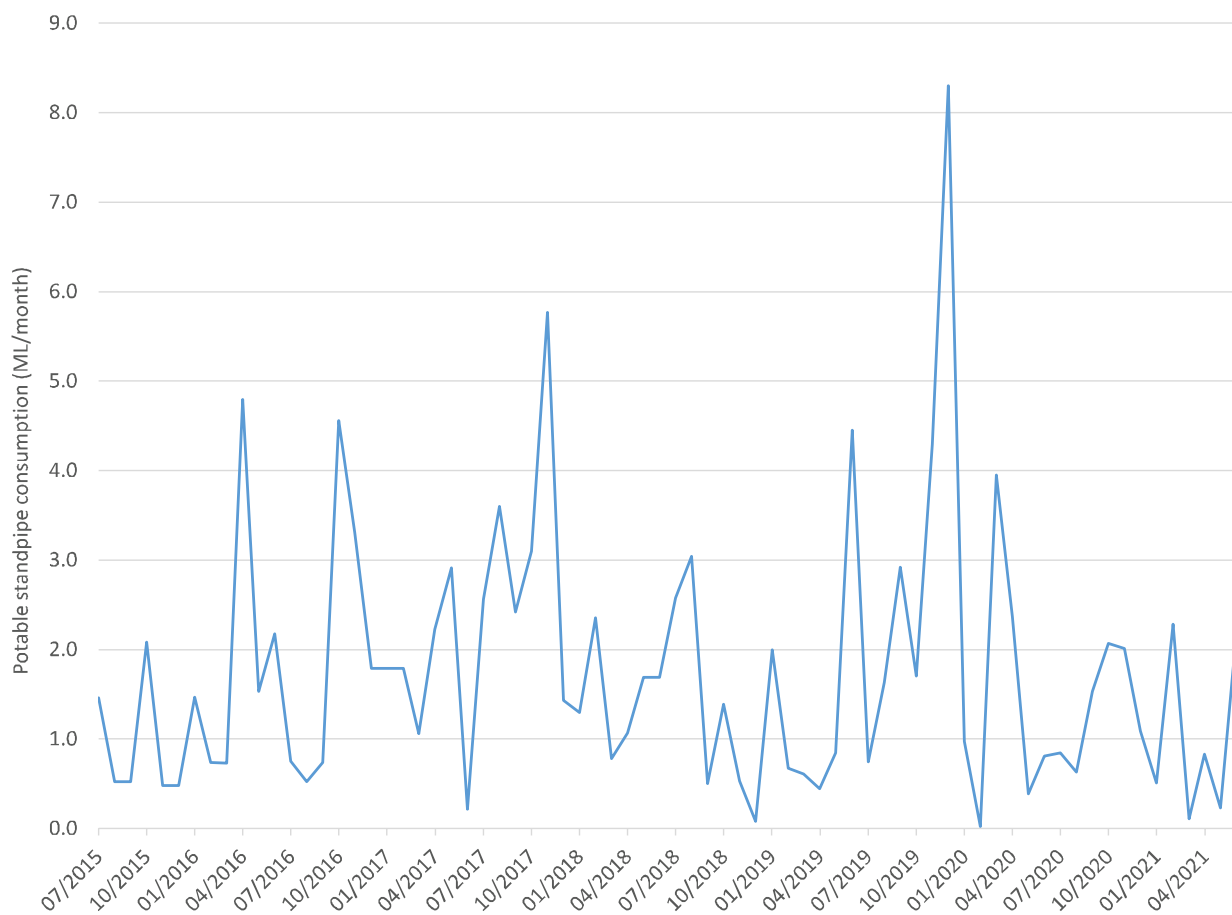


Figure 17: Monthly potable water carting demand (2016 – 2021)

3.9 Discussion

The data analysis has shown that:

- 2019/20 was not particularly hot or dry compared to other years of record. However, the Spring of 2019/20 was hotter and drier than other Spring periods. Conversely, the Summer of 2019/20 was not particularly hot nor dry. The decision to introduce restrictions in Summer 2019/20 was due to the reduced inflows and storage level in Clarrie Hall Dam, rather than the demand experienced during that time (or climate experienced at the demand centre). An analysis of the climate dependency of dam inflows has not been undertaken for this report.
- Between 2012 and 2021, the highest annual, Spring, Summer, weekly and daily demands were experienced in 2019 although annual, Spring, weekly and daily rainfall were higher than average (Summer rainfall was lower than average). Average annual, Summer and weekly maximum temperatures in 2018/19 were higher than average (Spring maximum temperatures were lower than average). The period of hottest/driest weather which had the most influence on demand was between January and March 2019 although rainfall was not particularly low in February or March 2019 but temperatures were higher than average. This suggests that factors other than climate influenced the high demand in 2019.
- The Spring 2019/20 demand was above average but not the maximum. The Summer 2019/20 demand was lower than average which would be influenced by the Level 2 restrictions in place for 60 days.
- The highest daily demands were experienced in 2014 and 2015. The longer-term trend in demand suggests that total demand is remaining relatively stable, despite significant population growth (with per capita demand decreasing significantly since 1991). This is likely to be due to changing consumption patterns, increasing regulation and demand management.

The 2020 demand forecast was based on the average demand between 2011 and 2019 and an increase in demand during dry periods. Based on the climate and demand experienced in 2019/20 and 2020/21, the more recent climate was not hotter or drier than the 2011 – 2019 period and there was no discernible increase in demand that would alter the basis of the 2020 demand forecast.

4. THE INFLUENCE OF NON-CLIMATE FACTORS ON DEMAND

As discussed in the 2020 demand forecast, daily water demand patterns are highly variable and are likely to be influenced by a broad range of factors other than climate. The 2020 demand forecast uses a static demand for each customer type over the next 50 years as the influence on non-climate factors had not been quantified.

A qualitative discussion of non-climate variables (which have intuitive links to consumption patterns but have not been incorporated in the demand forecast) and the predicted influence on demand for each connection type is provided in Table 6. Each factor has been considered in isolation of other factors which are often inter-related. The predicted future impact of each variable on per connection demand is indicated as an

increase, decrease, neutral or unknown.

TSC has committed to implementing a range of demand management measures (including education and engagement, incentives, smart metering and potable water substitution) and this has been considered in the predicted influence on future demand per connection.

From this analysis, it is concluded that it is more likely that per connection demand will decrease rather than increase although there is insufficient data to predict any future changes with certainty. There are no non-climate factors that have been identified to increase demand in future (apart from year-to-year fluctuations that have occurred in the past). The adoption of a static demand for each customer type over the next 50 years is therefore conservative but still considered to be appropriate when forecasting future demand.

A major influence on future demand will also be the rate and quantum of growth and development. The 2020 demand forecast relied on the forecast of future population and dwellings in the Tweed Shire (undertaken by id. Forecasts for 2016 – 2041) based on 2016 Census data, development experienced since then and the land available for development in future. The NSW Government forecasts published in 2020 are higher than id. Forecasts in the short-medium term but significantly lower in the long-term (Hydrosphere Consulting, 2020). The 2020 demand forecast also considered the type of future residential development (BASIX/efficient and proportion of multi-residential or single residential development). Non-residential growth was estimated from the residential growth rates in the 2020 demand forecast.

Although there is significant uncertainty whether the adopted growth rates will be realised, the total number of connections (and resulting demand) in future is expected to remain a valid assumption, even if the ultimate population is experienced either earlier or later than expected.

Table 6: The expected influence of non-climate variables on demand

Variable	Discussion	Predicted influence (increase or decrease per connection demand in general and in future)					
		Residential	Commercial	Industrial	Municipal – public parks	Other municipal	Rural
Household occupancy	The larger the household size, the higher the demand. The average occupancy for Tweed Heads South is 2.1 people per household ¹ (336 L/day) ² while the average occupancy in Murwillumbah is 2.4 people per household ¹ (384 L/d) ² . Household occupancy is expected to decrease in future with an increase in higher density housing and an ageing population.	Higher occupancy – increase. Lower occupancy – decrease. Future - decrease	Neutral	Neutral	Neutral	Neutral	Higher occupancy – increase. Lower occupancy – decrease. Future - decrease
Personal behaviour	People who have long showers or waste water (e.g. by leaving taps running) will have higher demand than others. Businesses that are aiming to be sustainable will attempt to reduce water demand. Education programs are predicted to reduce water wastage/ discretionary use of water.	Water conscious – decrease. Water wasters – increase. Future - decrease	Water conscious – decrease. Water wasters – increase. Future - decrease	Water conscious – decrease. Water wasters – increase. Future - decrease	Water conscious – decrease. Water wasters – increase. Future - decrease	Water conscious – decrease. Water wasters – increase. Future - decrease	Water conscious – decrease. Water wasters – increase. Future - decrease
House/ building age	Older houses and buildings tend to be less water efficient (more leaks, non-efficient fixtures) etc.	Older – increase Younger – decrease Future – neutral	Older – increase Younger – decrease Future – neutral	Older – increase Younger – decrease Future – neutral	Neutral	Older – increase Younger – decrease Future – neutral	Older – increase Younger – decrease Future – neutral

Variable	Discussion	Predicted influence (increase or decrease per connection demand in general and in future)					
		Residential	Commercial	Industrial	Municipal – public parks	Other municipal	Rural
House/ building size	Larger properties tend to have larger outdoor areas and gardens and a resulting increase in demand. House sizes are expected to decrease in future with higher density housing and an ageing population.	Larger – increase Smaller – decrease Future - decrease	Larger – increase Smaller – decrease Future - decrease	Larger – increase Smaller – decrease Future - decrease	Neutral	Larger – increase Smaller – decrease Future - decrease	Larger – increase Smaller – decrease Future - decrease
Outdoor/ garden area	Larger outdoor areas and gardens would have a higher demand for outdoor water use (particularly during a drought). Education programs are predicted to reduce discretionary uses of potable water.	Larger – increase Smaller – decrease Future - decrease	Larger – increase Smaller – decrease Future - decrease	Neutral	Larger – increase Smaller – decrease Future - decrease	Neutral	Larger – increase Smaller – decrease Future - decrease
Low socio-economic index ¹	Lower socio-economic conditions may result in reduced disposable income available to upgrade appliances and fixtures and repair leaks. Over the long-term, all fixtures and appliances would be efficient (beyond the life of existing fixtures and appliances) due to regulation of the market.	Lower – increase Higher – decrease Future – neutral	Neutral	Neutral	Neutral	Neutral	Lower – increase Higher – decrease Future – neutral

Assessment of impacts of 2019/20 drought on demand

Variable	Discussion	Predicted influence (increase or decrease per connection demand in general and in future)					
		Residential	Commercial	Industrial	Municipal – public parks	Other municipal	Rural
Usage price	Higher usage prices provide economic incentives to conserve water. A significant decrease in residential consumption was observed in Tweed LGA with the increases in usage charge in 2007 and 2008. Between 2006 and 2016, an 11% p.a. increase in usage charge resulted in a 2% p.a. reduction in demand (on average) ⁴ . Future reductions in demand with increasing pricing are expected to be less significant.	High – decrease Low – increase Future - neutral	High – decrease Low – increase Future - neutral	High – decrease Low – increase Future - neutral	High – decrease Low – increase Future - neutral	High – decrease Low – increase Future - neutral	High – decrease Low – increase Future - neutral

Variable	Discussion	Predicted influence (increase or decrease per connection demand in general and in future)					
		Residential	Commercial	Industrial	Municipal – public parks	Other municipal	Rural
Take-up of demand management measures e.g. rebates/incentives	Rebates and incentives are expected to reduce demand where there is adequate take-up. With increasing regulation and market share of water efficient appliances/fixtures, the take-up is predicted to reduce over time.	High – decrease Low – neutral Future - neutral	High – decrease Low – neutral Future - neutral	High – decrease Low – neutral Future - neutral	High – decrease Low – neutral Future - neutral	High – decrease Low – neutral Future - neutral	High – decrease Low – neutral Future - neutral
Potable water substitution	Substituting potable water with recycled water or rain/stormwater will reduce demand on the town water supply. Future effectiveness will depend on the availability of non-potable sources but this is expected to increase in future.	High – decrease Low – increase Future - decrease	High – decrease Low – increase Future - decrease	High – decrease Low – increase Future - decrease	High – decrease Low – increase Future - decrease	High – decrease Low – increase Future - decrease	High – decrease Low – increase Future - decrease

Variable	Discussion	Predicted influence (increase or decrease per connection demand in general and in future)					
		Residential	Commercial	Industrial	Municipal – public parks	Other municipal	Rural
Household water efficiency	The average consumption (2012 – 2019) for BASIX efficient single residential properties was 151 kL/a (414 L/day) and non-efficient single residential properties was 259 kL/a (710 L/day). The BASIX target for Tweed LGA is 40% reduction in mains-supplied potable water consumption, compared to the average 'pre-BASIX' home benchmark. The efficiencies in BASIX compliant and modern efficient households are mainly achieved through rainwater tanks and water efficient fixtures and appliances (washing machines, showerheads, dishwashers, taps etc.). The proportion of efficient houses is expected to increase in future.	Higher efficiency – decrease Lower efficiency – increase Future - decrease	Neutral	Neutral	Neutral	Neutral	Higher efficiency – decrease Lower efficiency – increase Future - decrease
Productivity or market influences	Increased demand for products and services is expected to increase workforce size, hours of work and water demand (particularly for water-intensive industries). This is highly dependent on the industry.	Neutral	High – increase Low – decrease Future - unknown	High – increase Low – decrease Future - unknown	Neutral	High – increase Low – decrease Future - unknown	Neutral

1. 2016 Census – Statistical Area Level 2
2. At the target metered consumption of 160 L/person/day.
3. Measure of socio-economic advantage/disadvantage.
4. Source: Hydrosphere Consulting (2017).

5. CONCLUSION

This report has concluded that the assumptions relating to current average and dry year demand in the 2020 demand forecast remain appropriate for strategic planning purposes despite a drought period experienced in 2019/20 (after the forecast was undertaken). While high demand was experienced in the Spring of the drought period, the high demand was not sustained into Summer or beyond due to the high rainfall in January and February 2020.

In addition, non-climate factors appear to be influencing demand in periods of highest demand as these did not coincide with particularly hot or dry weather. In any one year, the demand may be higher than the last year, but there are no factors that would suggest that an upward trend in demand is likely to occur. In future, it is more likely that per connection demand will decrease due to non-climate factors rather than increase.

As there are insufficient data to predict any future changes in demand due to climate and non-climate variables with any certainty, the key assumptions used in the 2020 demand forecast (static demand per connection and the dry year increase in demand) are considered to remain appropriate. While these are conservative assumptions, this is also considered to be appropriate given the risks of under-estimating demand and potentially increasing the frequency, duration or impact of restrictions. Therefore no change to the 2020 demand forecast is recommended at this time.

As discussed in the 2020 demand forecast, demand forecasting is inherently difficult as it relies on assumptions regarding development and growth, customer usage patterns as well as climate and their influence on water usage. It is important that the appropriateness of the assumptions is monitored and reviewed regularly so that the demand profiles can be updated. Improved data collection and analysis of all components of the water balance should be undertaken to enable increased certainty in future demand forecasts.

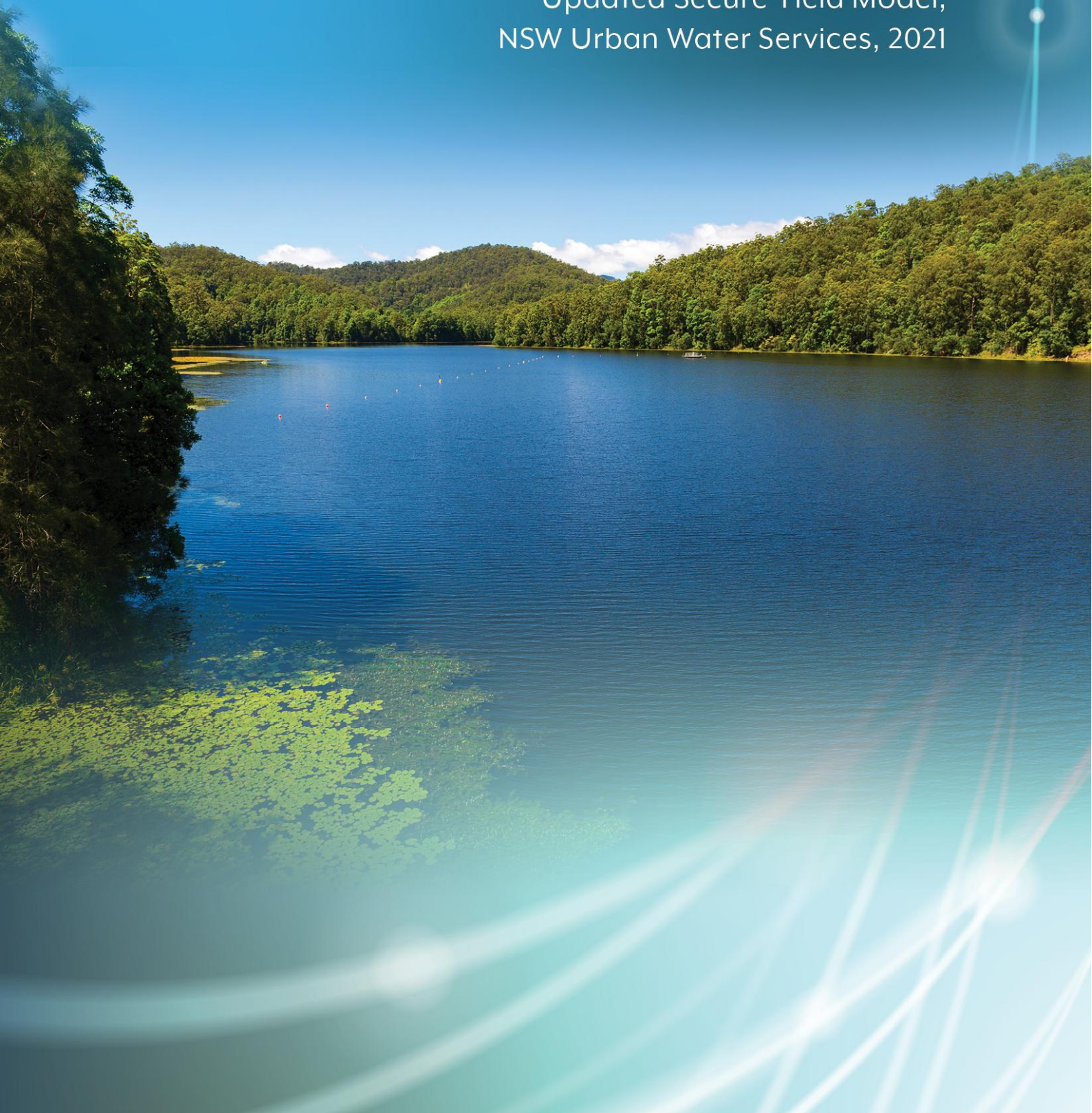
REFERENCES

Hydrosphere Consulting (2017) *Tweed Shire Council Water Efficiency and Demand Management Review: Part 1: Review of Efficacy of Demand Management Strategy and Implementation Plan*

Hydrosphere Consulting (2020) *Tweed District, Uki and Tyalgum Water Supplies - Demand Forecast: 2020 Update*

APPENDIX C

Updated Secure Yield Model,
NSW Urban Water Services, 2021





CLARRIE HALL DAM

Yield Study Report

Prepared for Tweed Shire Council

Report No. 20029

November 2021

NSW Urban Water Services Pty Ltd

Summary

Introduction

Clarrie Hall Dam is located within the Tweed Shire Local Government Area (LGA), 15 kilometres (km) south-west of Murwillumbah on the north coast of New South Wales (NSW). It is operated by Council to provide a drinking water supply to the Tweed Shire. Estimates undertaken in 2014 for both Secure Yield and Demand forecast a need to augment the Tweed District Water Supply by 2026.

Council in its meeting of 10 Dec 2015 resolved, in part, that

Based on the information currently available, Council adopts the raising of the wall of the Clarrie Hall Dam as the preferred option for future water security and proceeds with the planning approval and land acquisitions phase for the project.

The Proposal is to increase the dam wall height by 8.5 metres (m) to provide a Full Supply Level (FSL) height of 70 m Australian Height Datum (AHD) (RL70 m), thereby increasing the capacity of the dam from 16,000 megalitres (ML) to approximately 42,300 ML. Council is progressing with the preparation of an Environmental Impact Statement for the proposal.

Analysis of Secure Yield and its comparison to demand is required to:

- *Demonstrate the strategic need for a water supply augmentation, and*
- *Determine the “longevity” of the Proposal, that is how long it will provide a secure water supply to the Tweed.*

It is noted during the millennium drought (2001-2003) Clarrie Hall Dam observed storage level fell to about 30% full and the annual demand was less than about 10,000 ML/a. Future droughts particularly with Climate Warming are expected to be more severe. Future town water supply demands are projected to be much higher than 10,000 ML/a.

Methodology

The secure yield analysis was undertaken in accordance with DPIE Water/NSW Office of Water's¹ guidelines “Assuring future urban water security, Assessment and Adaption guidelines for NSW local water utilities” (Ref 1).

It is noted ‘secure yield’ is a defined term (see section 1.7) based on accepted methodology.

The method involves computer simulation modelling of the water supply headworks system using daily hydrometeorological (*rainfall, evaporation, evapotranspiration and stream flows*) time series data of historical climate and, in this case two (2) sets of climate change data to assess the performance of the system to meet water supply demands subject to specified constraints during past and future projected severe droughts.

The method ensures demands are met through all the droughts projected in the time series data (*with 10% restrictions*) and also allows for the restricted demand to be met through more severe droughts than in the simulated time series data.

The key input in the system modelling is the daily flow time series data. These were obtained from calibrated rainfall runoff models set up for the catchments of interest. The AWBM rainfall

1. NSW Office of Water roles migrated to NSW Department of Planning, Industry and Environment (DPIE) over 2017-2019.

runoff model was used. Once the models are calibrated using observed historical flow data, the longer available daily rainfall and daily evapotranspiration data were used to obtain historical climate flow series (1890-2021). Similarly daily rainfall and daily evapotranspiration data provided from climate change modelling were input to obtain daily flow time series data for assessing the water supply system performance under different scenarios.

The modelling steps are summarised in Figure S1.

Data

The SEARs for the Proposal require:

- *The EIS to include a summary of the strategic need for the Proposal and that*
- *The Proposal is designed constructed and operated to be resilient to future impacts of climate change*

Further the SEARs requires that in addressing these items

- *The Proponent must assess the risk and vulnerability of the proposal to climate change in accordance with the current guidelines.*
- *The Proponent must quantify specific climate change risks with reference to the NSW Government's climate projections and incorporate specific adaptation actions in the design.*

The Secure Yield Analysis for the changed climate scenarios was undertaken:

- using NARClIM1.5 data supplied by the NSW Government, consistent with the requirements of the SEARs issued and also,
- using the climate change data specified to be used in the DPIE Water Guidelines "Assuring future urban water security, Assessment and Adaption guidelines for NSW local water utilities" (Ref 1).

The first was done to satisfy the apparent requirements of SEARS and the latter done to satisfy the apparent requirements for facilitating obtaining if required Section 60 approval.

Results

Depending on the climate change model used to inform the time series data different secure yield estimates were obtained. Table S1 provides the two results from the two approaches that are judged using the precautionary principal to be the *best estimates* for decision making. All the modelled results are provided in the main body of the report.

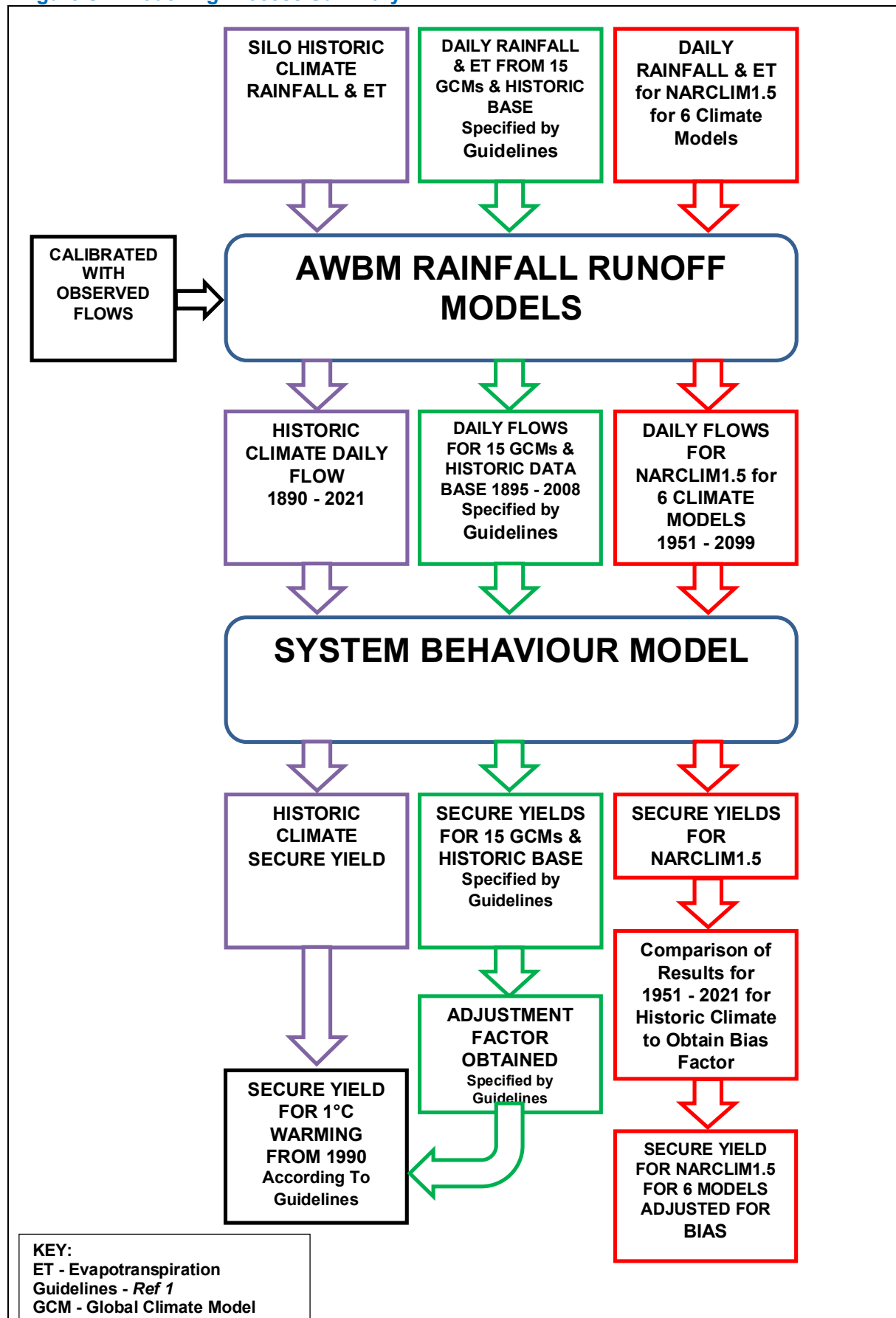
Table 1: Secure Yield Estimates

Case ²	Climate Change Data Basis	Secure Yield ¹ ML/a
2	NARClIM1.5 data : CanESM2_R2 Climate Model	19500
9	Climate Change Data Specified to be used in DPIE Water Guidelines "Assuring future urban water security, Assessment and Adaption guidelines for NSW local water utilities" (Ref 1).	22500

1. The Secure Yield is for the complete system to Bray Park Weir where the water is extracted for Town Water Supply including the proposed raising of Clarrie Hall Dam (42300 ML storage). Rounded down to nearest 500 ML/a

2. See Table 4.10

Figure S1: Modelling Process Summary

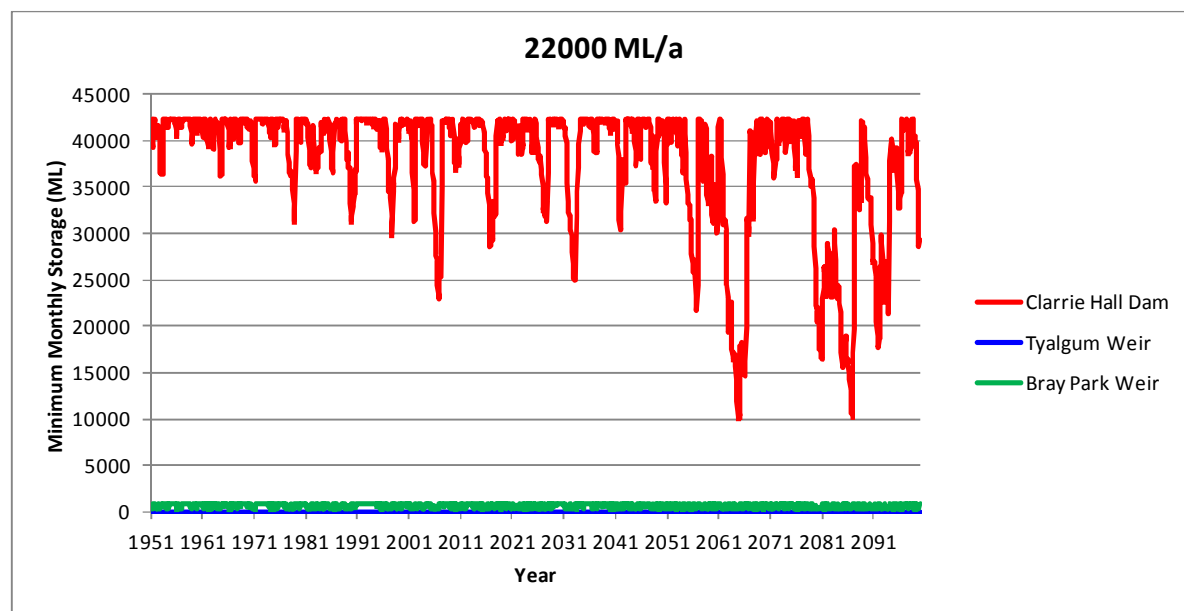


Conclusions

Both approaches to estimating secure yield allowing for climate warming show raising Clarrie Hall to provide storage of 42300 ML will provide a *safe* water supply well into the future based on projected water supply demands.

Figure S2 shows the raised Clarrie Hall modelled storage behaviour for a *bias corrected* future annual demand of 22,000 ML/a for 1951-2099 for the conservative (CanESM2-R2) future projected climate data series. While it shows the storage drawdowns get longer and lower into the future as droughts get worse from climate warming, the storage never empties and the demand is met in terms of the service criteria (*10% restrictions do not occur in more than 10% of the years and their duration is not more than 5% over the projected period based on applying them when the storage is 50% or less full*).

Figure S2: Modelled Storage Behaviour



CanESM2_R2 Flow Series

Acknowledgement

This work used data derived from the NSW and ACT Regional Climate Modelling (NARClIM) (1.5) project and provided by the Government of New South Wales, Australia.

Citation: Nishant N, Evans JP, Di Virgilio G, Downes S, Cheung KW, Tam E, Miller J, Beyer K and Riley M 2021, Introducing NARClIM 1.5: evaluating the performance of regional climate projections for southeast Australia for 1950-2100, *Earth's Future*, DOI: 10.1029/2020EF001833. Data accessed via the NSW Climate Data Portal on 16/8/2021.

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1. Introduction

1.1 Background

Clarrie Hall Dam is located within the Tweed Shire Local Government Area (LGA), 15 kilometres (km) south-west of Murwillumbah on the north coast of New South Wales (NSW). It is operated by Tweed Shire Council to provide a drinking water supply to the Tweed Shire. Estimates undertaken in 2014 for both Secure Yield and Demand forecast a need to augment the Tweed District Water Supply by 2026.

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Analysis of Secure Yield and its comparison to demand is required to:

- *Demonstrate the strategic need for a water supply augmentation, and*
- *Determine the “longevity” of the Proposal, that is how long it will provide a secure water supply to the Tweed.*

It is noted during the millennium drought (2001-2003) Clarrie Hall Dam observed storage level fell to about 30% full and the annual demand was less than about 10,000 ML/a. Future droughts particularly with Climate Warming are expected to be more severe. Future town water supply demands are projected to be much higher than 10,000 ML/a.

1.2 Scope of Work

Tweed Shire Council (TSC) engaged NSW Urban Water Services (NUWS) to:

- Update the 2016 Yield Study (Ref 2) *Secure Yield* estimates prepared by NUWS for TSC to include the recent 2019-2020 drought.
- Use the previously calibrated rainfall runoff models and the system behaviour model with NARCLim1.5 provided daily rainfall and daily evapotranspiration data from 6 models to obtain equivalent *Secure Yield* estimates.

The secure yields were to be estimated in accordance with DPIE Water² guidelines *Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities* (Ref 1).

It is noted *Secure Yield* is a defined term as provided by NSW Office of Water (NOW) *Best-Practice Management of Water Supply and Sewerage Guidelines* (Ref 3) and the *NSW Water Supply Investigation Manual* (Ref 4) and more recently by NOW's Draft *“Assuring future urban water security, Assessment and Adaption guidelines for NSW local water utilities”* (Ref 1).

2. NSW Office of Water roles migrated to NSW Department of Planning, Industry and Environment (DPIE) over 2017-2019.

Use of Secure Yield provides a practical consistent basis for assessing the yield of a system on a security of supply basis. Details of Secure Yield are provided in Section 1.7.

1.3 Objectives

This report contains a summary of the modelling undertaken to provide secure yield estimates for Tweed district water supply scheme whose main storage is Clarrie Hall Dam.

The outcomes from this modelling were required to provide the required secure yield analysis to support planning to meet future water demand.

1.4 Methodology

Estimating the yield of a headworks system involves two important stages:

- Streamflow estimation:
Developing an appropriate sequence of streamflows
- System Behaviour Modelling:
Modelling the behaviour of the headworks system subject to operating constraints using the streamflows to assess what demand subject to reliability or security criteria can be satisfied.

For this study the required streamflows were obtained using the Australian Water Balance Model (AWBM) rainfall runoff models (Ref 5) set up and calibrated for the 5 gauging station catchments of interest for the 2016 Yield Study (Ref 2). In general the historic stream flow sequences were extended to 2021 from 2014 using the observed streamflow data where appropriate. Other streamflow sequences were extended by inputting daily rainfalls and daily evapotranspirations to the AWBM models to obtain resulting stream flows. Figure 3 provides a schematic of the rainfall runoff model and Figure 4 provides a schematic of the modelled catchment. There were 5 AWBM subcatchment models linked to provide flows into Clarrie Hall Dam, Bray Park Weir, Uki Weir and Tyalgum Weir.

For the behaviour modelling the purposely developed system behaviour model to determine yield in terms of secure yield previously set up for the water supply headworks system for the 2016 Yield Study (Ref 2) was used. The underlying methodology used in the model arises from the definition of *Secure Yield* and has been successfully used on many other water supply headworks systems. The model logic has been developed and tested through many uses over the years.

1.5 Climate Change

While secure yield allows for meeting demand with restrictions through a much worse drought than has occurred since about 1890, consideration needs to be given to possible changes from Climate Change.

For this study additional consideration was given by using the general approach proposed in NSW Office of Water's (NOW) Draft Guidelines (Ref 1). In addition to using the climate change data specified to be used in Guidelines, climate change data based on NARClm1.5 required to satisfy the SEARS process was also used.

1.6 Qualifications

The work contained in this Report is considered valid within the context of the study purposes, but caution should be exercised if aspects of this report, including data and estimates, are abstracted out of context or are to be used for some other purpose. Hydrology is not an exact science and necessarily involves some uncertainty and the results should be regarded as estimates within the limitations of the study and available data to be used as indications in a much larger decision making process.

The yield of a headworks system is dependent on the assumed streamflows and operating constraints. For this study observed streamflows were provided by others or derived from data provided by others and the operating constraints are as specified. While the yield estimates are based on established methodology, NSW Urban Water Services Pty Ltd does not warrant or accept any liability in relation to the quality or accuracy of the yield estimates which are reliant on the provided information and no responsibility is accepted by NSW Urban Water Services Pty Ltd for the accuracy, currency, reliability and correctness of any information in this publication provided by the client or third parties.

1.7 Yield Model

Secure Yield

For the past 25 years or so most urban water supply headworks in country NSW have been sized on a robust Security of Supply basis. This methodology was developed to allow a water utility to plan for the cost effective provision of sufficient dam storage capacity to allow the water utility to effectively manage its water supply in future droughts of greater severity than experienced over the past 100 or more years. *Secure Yield* as determined by this methodology is the highest annual water demand that can be expected to be met with only moderate restrictions during a significantly more severe drought than has been experienced since about 1895 (from when generally reliable rainfall records are available). The water restrictions must not be too severe, not too frequent, nor of excessive duration. It has been argued that the definition of *Secure Yield* in effect allows meeting demand with moderate restrictions through a severe drought akin to a 1 in 1000 year drought³.

Under the NSW Security of Supply basis (commonly referred to as the 5/10/20 rule), water supply headworks system were normally sized so that:

- a) Duration of restrictions does not exceed 5% of the time; and
- b) Frequency of restrictions does not exceed 10% of years (ie 1 year in 10 on average)
- c) Severity of restrictions does not exceed 20%. Systems must be able to meet 80% of the unrestricted water demand (ie 20% average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy a) and b) above.

Secure Yield was therefore defined as the highest annual water demand that can be supplied from a water supply headworks system while meeting the above 5/10/20 rule.

Over the last 20 years there has been a significant reduction in residential water consumption per property and thus it is considered it will be difficult to achieve a 20% reduction in consumption as implied by the earlier 5/10/20 rule. Consequently DPIE Water/NSW Office of Water (NOW) recommends that future planning should be based on a 10% reduction in

3. It is noted that '1 in 1000 year drought' does not mean it only occurs once every thousand years but means it has a 0.1% probability of occurring any year.

consumption through a repetition of the worst drought commencing with the storage already drawn down to satisfy the 5% duration and 10% frequency criteria. Thus the 5/10/20 rule has now become a 5/10/10 rule.

It is also noted that more recently the 10% frequency rule has been slightly refined by NOW from frequency of restrictions occurring 1 in 10 years on average to only being applied in 10% of years. For a sample of test cases this was of little consequence, and was desired to fit in with NOWs requirements for Performance Reporting of restrictions and thus was also based on the financial year.

The current procedures to determine secure yield are illustrated in Figures 1 and 2 which have been taken from material provided by NOW.

Model

Essentially the model is a computer program that balances on a daily basis continuity equations between all the water sources and demands while incorporating the procedures (as illustrated in Figures 1 and 2) to determine secure yield. The model simulates the behaviour of the system by accounting for and balancing the available water. The hydrological cycle is modelled external to the model and the required hydrometeorological data is provided as input to the system behaviour model. In essence the system model is driven by operating conditions such as the need to meet a particular demand while satisfying constraints and available flow. Figure 5 provides a schematic of the storage behaviour water balance model.

2. Hydrometeorological Data

2.1 Introduction

In general estimates of daily rainfalls, streamflows and daily evaporation and evapotranspiration for as long a historical period as possible is desirable.

Satisfying the 5,10,10 rule for determining the historic climate secure yield requires more than 130 years of daily streamflows to be a sufficiently long data sample for testing the rules and so as to include the significant Federation drought (1895-1903) and other known significant droughts.

The daily rainfalls are also required as input to the rainfall runoff models as well as daily evapotranspiration to obtain streamflows when no observed streamflows are available.

In addition to daily streamflows, accompanying daily rainfalls and evaporation are required for input to the system behaviour model for determining the net loss or gain from or to the storage's water surface area due to evaporation or rainfall.

For this study three (3) broad data sets were applied to the system behaviour model:

- Stream flows and operating practices used to calibrate and bias correct results from the simulated data sets as well as identifying critical drought periods. For this study the historic climate data series developed covered the period 1890 to 2021.
- South Eastern Australia Climate Initiative data set (SEACI). This is a historic data set adjusted after consideration of 15 global climate models (GCMs) to allow for 1 °C climate warming using the methodology from the Guidelines (Ref 1).
- NARCLiM Data. This is data generated from three (3) Global Climate Models and used in conjunction with operating practices to estimate future secure yields.

Figure S1 shows how the various data sets were used and their interaction with the models.

2.2 Historical Meteorological Data

The daily rainfall and daily evapotranspiration data were obtained from the SILO Data Drill for the grid points as given in Table 2.1 and shown in Figure 6 to cover the relevant catchments. The SILO Data Drill is a service provided by the Science Delivery Division of Queensland Department of Science, Information Technology, Innovation and the Arts (DSITIA). The Data Drill accesses grids of data at 0.05° intervals derived from interpolation of point Bureau of Meteorology station records. Interpolations are calculated by Splinning and Kriging techniques. Further details of the processes are given in Ref 6.

The daily evaporation and rainfall data to represent losses from the storages was also obtained from the SILO Data Drill.

Morton's shallow lake evaporation data and Morton's wet-environment areal potential evapotranspiration overland data were used.

The 2016 Yield study input data sets were extended by adding the 2014 to 2021 data from the relevant SILO data grid points to the daily data time series.

Table 2.1: SILO Grid Points

Grid Point	Latitude °	Longitude °
1	28.25	153.15
2	28.25	153.20
3	28.30	153.15
4	28.30	153.20
5	28.30	153.25
6	28.35	153.10
7	28.35	153.15
8	28.35	153.20
9	28.35	153.25
10	28.35	153.30
11	28.40	153.10
12	28.40	153.15
13	28.40	153.20
14	28.40	153.25
15	28.40	153.30
16	28.45	153.15
17	28.45	153.20
18	28.45	153.25
19	28.45	153.30
20	28.50	153.15
21	28.50	153.20
22	28.50	153.25
23	28.50	153.30
24	28.50	153.35
25	28.55	153.30
26	28.55	153.35
B1	28.35	153.35
U1	28.40	153.35
U2	28.45	153.35
U3	28.45	153.40
U4	28.50	153.40
<i>Point 19 & B1 were used to represent evaporation losses from Clarrie Hall Dam & Bray Park Weir storages respectively</i>		

The daily rainfalls and daily evapotranspiration were provided from the climate change data bases for the same SILO Data Grid Points

2.3 Historical Flow Data

The key input for determining *secure yield* is a historic daily flows sequence going back to about 1890 to cover all observed significant droughts particularly the Federation drought.

From the 2016 Yield study the required daily historic climate flow series (*and rainfall and evaporation for the storages*) were available to May 2014 and as part of this study they were extended to May 2021.

The previous input data sets (*rainfall, evaporation and streamflow*) were extended by adding the 2014 to 2021 data from the relevant SILO data grid points and observed flows to the input flows at the gauging stations that were still in operation.

For the gauging station Tweed River at Uki Weir (201900) which in the system model is downstream of Clarrie Hall Dam the observed flows were reduced (*to prevent double accounting*) by the releases as advised by Council that were made from Clarrie Hall Dam from 2014.

For the two stations previously closed (201010 and 201015) the flows were obtained by running the previously calibrated rainfall runoff models for those gauging stations to generate modelled flows (using the extended period of rainfall and evapotranspiration data from the SILO data drill) at those two gauging stations.

Release Data from Clarrie Hall Dam

The release data provided by Council went back to January 2000. The data included releases and storage levels for Clarrie Hall Dam. Data from 2006 was daily and was understood to be more consistently recorded. The early data was based on irregular visits and was understood to be taken from manual log sheets. The data covered the critical 2001/2003 drought. To make use of the data the releases between visits were interpolated generally assuming if the valve was open on a visit it stayed at that value until the next recorded visit and if no value was given then the valve was closed. The provided data spreadsheet had inbuilt formulas to calculate the release based on the % opening of the valves. It was not possible to confirm these formula so they were assumed to be correct.

Expected Inflows

Utilising the provided operational data (ie the interpolated releases and daily storage levels) (and SILO data grill rainfall and evaporation) a water balance was undertaken to determine the *expected inflows* for the period 2000 to 2021.

The *expected inflows* (assuming the interpolated release data etc was reliable) suggested the previous modelled inflows for the 2001/2003 drought were underestimated (*this would be expected to be conservative for Secure Yield purposes; it would be preferable to underestimate rather than overestimate inflows*).

The operational data were not available for the 2016 Yield Study. It would be expected that the *expected inflows* in effect determined from observed data (ie recorded operational data) would be more reliable than the modelled inflows.

To test the sensitivity of the expected inflows they were used in preference to the previous modelled inflows for the two cases (Runs 512 and 513 i see Table 4.1) and resulted in a increase of secure yield of about 20% for the historic climate.

2.4 SEACI Data

Climate research is ongoing and dynamic and is being continually updated and improved. As part of this work the South Eastern Australia Climate Initiative (SEACI) published a synthesis of findings from Phase 2 of its research.

SEACI Theme 2 of Phase 2 provided the NSW Office of Water historic climate data adjusted for 1.0 °C global warming from 1990. The SEACI Theme 2 of Phase 2 projections use improved seasonal scaling factors derived from the period 2001-2100, rather than the period 1896-2100 previously used for the SEACI Phase 1 projections. The SEACI Phase 1 projections involve 0.9°C warming and were used in the pilot study and for the Murray Darling Sustainable Yields project.

The *Guidelines on Assuring Future Urban Water Security* (Ref 1) require use of the SEACI Theme 2 of Phase 2 data for 1.0°C warming for any new urban water security studies as it was considered the best available data set from this source. This data was made available by the NSW Office of Water.

The SEAC1 Data set provided daily rainfalls and evapotranspiration which were input into the calibrated AWBM rainfall runoff models to obtain resulting inflows for input to the system behaviour model.

2.5 NARClIM Data

NARClIM (NSW and ACT Regional Climate Modelling) is modelling used by NSW Government that provides high resolution climate change projections across NSW. Initially in 2014 NARClIM projections were generated from four global climate models (GCMs) dynamically downscaled by three regional climate models (RCMs).

The four GCMs (MIROC, ECHAM, CCCMA and CSIRO Mk3.0) form part of the World Climate Research Program's (WCRP) Coupled Model Inter-comparison Project phase 3 (CMIP3) models, which were used by the Intergovernmental Panel on Climate Change (IPCC) for its Fourth Assessment Report.

The latest update of NARClIM, NARClIM 1.5, uses three GCMs (ACCESS 1.0 ACCESS 1.3 and CanESM2) as well as two dynamic downscaling regional climate models (RCMs), R1 and R2, applied to each of the GCMs resulting in six (6) data sets within NARClIM 1.5 to be considered.

The differences between NARClIM 1.0 and NARClIM 1.5 can be seen in Figure 7. The figure suggests NARClIM 1.5 generally resulted in a larger reduction in rainfall and a higher increase in temperature than NARClIM 1.0 for the period 2060-2079 compared to 1990-2009.

Daily rainfall and evapotranspiration were provided for each of the SILO data grid points listed in Table 2.1 with the exception of three Grid points in Queensland however this was not an issue as there were still sufficient Grid points to determine the relevant subcatchment areal daily rainfall and daily evapotranspiration.

The provided daily rainfalls and daily evapotranspiration were input into the calibrated AWBM rainfall runoff models to obtain resulting inflows for input to the system behaviour model.

3. System Behaviour Modelling

3.1 Introduction

Modelling of the behaviour of the water supply headworks system is required to determine the *secure yield* of that system. The aim of the modelling is to determine the maximum annual demand that satisfies the 5/10/10 rules. This is done using a computer storage and system behaviour model using an iterative process to satisfy all the requirements implied by the rules and available water from the various sources.

A system behaviour model was set up for the Tweed District water supply headworks system using model logic developed and tested over many years and incorporating refinements to reflect current requirements.

The model is essentially driven by operating conditions such as the need to meet a specified demand whilst satisfying constraints such as available water from streamflows. Figure 5 shows a schematic of the general storage model.

In addition to the hydrometeorological data that has to be input into the computer simulation model, other data has to be incorporated into the model. The system behaviour modelling included the following assumptions that were agreed for the 2016 Yield Study (Ref 2) except the release rules were revised to reflect changes that have occurred.

3.2 Headworks System

Figure 4 provides a schematic of the water supply headworks system.

3.3 Other Demands

In addition to the Town Water Supply demand the other demands included in the model were:

- Demand allowed for Uki 50 ML/a with uniform daily demand.
- Demand allowed for Tyalgum 60 ML/a with uniform daily pattern.
- Irrigation demand allowed for from Bray Park weir, 730 ML/a, uniform demand pattern, only made when storage more than 405 ML

The above demands were required to be satisfied before Tweed town water supply and thus are not included in the reported *Secure Yield* estimates.

3.4 Demand Pattern

Whilst secure yield provides the system annual demand that can be met, the annual demand needs to be broken down into monthly patterns to reflect seasonality.

Table 3.1 provides the demand pattern used (excluding Uki and Tyalgum and irrigation which used a uniform pattern).

Table 3.1: Monthly Demand Pattern

Monthly Demand % of Total Annual Demand											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9.7%	7.7%	8.0%	7.7%	7.2%	7.0%	7.6%	8.3%	9.0%	9.5%	8.7%	9.6%

It is NUWS experience that generally the secure yield is not that sensitive to the monthly demand pattern as long as seasonality is shown by the differentials and that the storage can meet several months demand.

3.5 Release Requirements

The modelling allowed for several requirements for releases from the different storages to satisfy license requirements, environmental flow requirements or water sharing plans.

Bray Park Weir

Fish ladder releases from Bray Park weir were:

- 8 ML/d if Clarrie Hall Dam was greater or equal to 75% full
- 5 ML/d if Clarrie Hall Dam was less than 75% full and greater than 50% full.
- 3 ML/d if Clarrie Hall Dam was less than or equal to 50% full.

Clarrie Hall Dam

For the 2016 Yield Study the required (*as informed at the time*) releases made from Clarrie Hall Dam subject to flows at the Oxley River Eungella gauging station (201001) were:

- 2 ML/d when daily flow less than or equal to 95%ile flow
- 4 ML/d when daily flow is between 80%ile and 95%ile flow
- 6 ML/d when daily flow greater than or equal to 80% ile flow

The value of the 95%ile flow and the 80% ile flow used was 9.5 and 26.5 ML/d.

For the current study modelled cases reported herein the environmental flow release rule was updated as informed by the current license (30 SL 066195) to:

Releases (inclusive of any release for town water supply) were made from Clarrie Hall Dam subject to flows at the Oxley River Eungella Gauging station (201001):

- 1 ML/d when daily flow less than or equal 3 ML/d
- 2 ML/d when daily flow is greater than 3 ML/d and less than 13 ML/d
- 4 ML/d when daily flow greater than 13 ML/d

4. Modelling Results

4.1 Introduction

The secure yield estimates determined from the historic climate behaviour modelling for the weir storages are presented in this chapter.

Secure Yield determination is based on a defined methodology (see Section 1.7) and initially uses historic climate data and allows for supply to be met through a much more severe drought than has occurred in the last 130 years or so. Results presented in this chapter are based on using:

1. Historic climate.
2. Adjustments using SEACI Data to historic climate to allow for climate warming using the methodology from the *Guidelines* (Ref 1).
3. Using NARClIM1.5 future climate projections to 2099.

While secure yield is reliant on the available streamflows, it is also dependent on transfer capacities, environmental flow conditions, annual demands and their monthly distribution, level of security expected and the schemes operating rules. The conditions used have been described in Chapter 3.

The expected level of security arises from the 5/10/10 rules which provides for 10% restrictions occurring in 10% of the years for 5% of the time.

4.2 Inclusion 2019/2020 Drought Results

Table 4.1 provides the secure yield results from extending the historic climate data to include the 2019/2020 drought. Depending on the case either the 1901/1903 drought or the 2001/2003 were the critical drought and not the 2019/2020. Inclusion of the 2019/2020 has not materially changed the historic climate secure yield results as obtained for the 2016 Yield Study. The changes that have occurred are a consequence of the changed release rule and from using Councils operational data that was not available for the 2016 Yield Study. *Run 511 result of 14626 ML/a compares to 15000 ML/a for the existing dam in the 2016 Yield Study report.*

Figures 8 to 11 provide for the 4 cases in Table 4.1 the modelled storage behaviour for a repeat of the historic climate supplying annual demands (*with restrictions applied in accordance with 5/10/10 rules*) that equate to the secure yields. The storage behaviour diagrams show the significant drawdowns during the 1901/1903 and 2001/2003 droughts.

Table 4.2 provides the historic climate change secure yield estimates for the cases in Table 4.1 adjusted for climate change using the DPIE Water Guidelines (Ref 1) and the climate change data specified to be used in the *Guidelines* and as provided by DPIE Water.

Table 4.1: Historic Climate Secure Yield Estimates

Run No	Case	Period of Flows	Historic Climate Secure Yield ML/a	Critical Drought	
				From	To
511	Existing Clarrie Hall Dam (16000 ML)	1/1/1890 ÷ 27/5/2021	14626	27/7/2001	1/2/2003
512	Existing Clarrie Hall Dam (16000 ML) <i>Utilising Interpolated New Council CHD Release Data¹</i>	1/1/1890 - 27/5/2021	17605	23/10/1901	18/2/1903
515	Proposed Raised Clarrie Hall Dam (42300 ML)	1/1/1890 ÷ 27/5/2021	26122	27/7/2001	1/2/2003
513	Proposed Raised Clarrie Hall Dam (42300 ML) <i>Utilising Interpolated New Council CHD Release Data¹</i>	1/1/1890 - 27/5/2021	30890	23/10/1901	25/2/1903

1. ie Using Expected Inflows

Table 4.2: SEACI Based 1°C Climate Warming Secure Yield Estimates

Run No	Basis	Case	1 °C Climate Warming ¹ Secure Yield ML/a	
			Based on using Lowest GCM for adjustment ratio	Based on using lower of Median GCM and lowest GCM with 10/15/25 rule for adjustment ratio
511CC	See Appendix A for individual results Applied to Run 511	Existing Clarrie Hall Dam (16000 ML)	10397	11820
511CC	See Appendix A for individual results Applied to Run 512	Existing Clarrie Hall Dam (16000 ML) <i>Utilising Interpolated New Council CHD Release Data</i>	12515	13791
515CC	See Appendix A for individual results Also Applicable & Applied to Run 515	Proposed Raised Clarrie Hall Dam (42300 ML)	19228	21240
515 CC	See Appendix A for individual results Also Applicable & Applied to Run 513	Proposed Raised Clarrie Hall Dam (42300 ML) <i>Utilising Interpolated New Council CHD Release Data</i>	22738	25116

1. See Chapter 5 for details of determination

4.3 NARCIIM 1.5 Results

Daily rainfall and daily evapotranspiration was provided by DPIE for the SILO Data Grid points used for the AWBM rainfall runoff modelling. Data were provided from 6 models for NARCIIM1.5:

1. ACCESS1.0R1
2. ACCESS1.0R2
3. ACCESS1.3R1
4. ACCESS1.3R2
5. CanESM2 R1
6. CanESM2 R2

The daily data covered the period 1951 and 2099 and included the climate change projections that were modelled to occur to 2099 from the above 6 climate change models.

These data were input into the previously calibrated AWBM rainfall runoff models to obtain resulting stream flows. The system behaviour model was then used to determine secure yield estimates resulting from the resulting inflow series. Additional simulations were undertaken based on different periods and combination of the previously modelled inflow series to enable comparison of secure yield estimates on an informed basis. Tables 4.3 to 4.8 provide the secure yield results.

Table 4.3: Secure Yield Results for ACCESS1.0R1 Model

Run No.	Modelled Period	Data Basis	Secure Yield ML/a	Critical Drought
<i>Existing Clarrie Hall Dam:</i>				
523	1951-2099	ACCESS1.0R1	10718	17/9/2064-13/9/2066
<i>Raised Clarrie Hall Dam (42300 ML):</i>				
580	1951-2099	ACCESS 1.0R1	15498	13/3/2063-6/1/2070
581	1951-27/5/2021	ACCESS 1.0R1	20019	13/12/1964-6/2/1967
536	1951-27/5/2021	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data	26122	27/7/2001-1/2/2003
534	1951-27/5/2021	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data & <i>expected inflows 2000-2021</i>	30341	4/8/2001-1/2/2003
582	1890-2099	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data to 27/5/2021 and then extended to 2099 using ACCESS 1.0R1 data	15591	13/3/2063 - 6/1/2070
583	1890-2099	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data (& <i>expected inflows 2000-2021</i>) to 27/5/2021 and then extended to 2099 using ACCESS 1.0R1 data	15600	13/6/2063-6/1/2072

* See Table 4.1.

NOTE: NUWS Run Data does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

Table 4.4: Secure Yield Results for ACCESS1.0R2 Model

Run No.	Modelled Period	Data Basis	Secure Yield ML/a	Critical Drought
<i>Existing Clarrie Hall Dam:</i>				
554	1951-2099	ACCESS1.0R2	15173	2/8/2070-13/9/2066
<i>Raised Clarrie Hall Dam (42300 ML):</i>				
550	1951-2099	ACCESS 1.0R2	20594	17/2/2093-7/11/2097
551	1951-27/5/2021	ACCESS 1.0R2	27363	28/6/1975-21/3/1978
536	1951-27/5/2021	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data	26122	27/7/2001-1/2/2003
534	1951-27/5/2021	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data & <i>expected inflows 2000-2021</i>	30341	4/8/2001-1/2/2003
552	1890-2099	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data to 27/5/2021 and then extended to 2099 using ACCESS 1.0R2 data	21469	17/2/2093 - 7/11/2097
553	1890-2099	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data (& <i>expected inflows 2000-2021</i>) to 27/5/2021 and then extended to 2099 using ACCESS 1.0R2 data	21469	17/2/2093 - 7/11/2097

* See Table 4.1.

NOTE: NUWS Run Data does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

Table 4.5: Secure Yield Results for ACCESS1.3R1 Model

Run No.	Modelled Period	Data Basis	Secure Yield ML/a	Critical Drought
<i>Existing Clarrie Hall Dam:</i>				
544	1951-2099	ACCESS1.3R1	10766	28/9/2058-6/12/2061
<i>Raised Clarrie Hall Dam (42300 ML):</i>				
540	1951-2099	ACCESS 1.3R1	16985	27/4/2058-31/12/2061
541	1951-27/5/2021	ACCESS 1.3R1	20327	13/2/1986-18/4/1989
536	1951-27/5/2021	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data	26122	27/7/2001-1/2/2003
534	1951-27/5/2021	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data & <i>expected inflows 2000-2021</i>	30341	4/8/2001-1/2/2003
542	1890-2099	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data to 27/5/2021 and then extended to 2099 using ACCESS 1.3R1 data	18277	27/4/2058 - 31/12/2061
543	1890-2099	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data (& <i>expected inflows 2000-2021</i>) to 27/5/2021 and then extended to 2099 using ACCESS 1.3R1 data	18377	27/4/2058 - 31/12/2061

* See Table 4.1.

NOTE: NUWS Run Data does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

Table 4.6: Secure Yield Results for ACCESS1.3R2 Model

Run No.	Modelled Period	Data Basis	Secure Yield ML/a	Critical Drought
<i>Existing Clarrie Hall Dam:</i>				
531e	1951-2099	ACCESS1.3R2	16020	28/9/2058-6/12/2061
<i>Raised Clarrie Hall Dam (42300 ML):</i>				
531	1951-2099	ACCESS 1.3R2	21126	27/4/2058-31/12/2061
532	1951-27/5/2021	ACCESS 1.3R2	27457	13/2/1986-18/4/1989
536	1951-27/5/2021	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data	26122	27/7/2001-1/2/2003
534	1951-27/5/2021	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data & <i>expected inflows 2000-2021</i>	30341	4/8/2001-1/2/2003
533	1890-2099	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data to 27/5/2021 and then extended to 2099 using ACCESS 1.3R2 data	21835	24/8/2068 - 31/12/2061
535	1890-2099	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data (& <i>expected inflows 2000-2021</i>) to 27/5/2021 and then extended to 2099 using ACCESS 1.3R2 data	22008	24/8/2068 - 18/10/2074

* See Table 4.1

NOTE: NUWS Run Data does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021 .

Table 4.7: Secure Yield Results for CanESM2 R1 Model

Run No.	Modelled Period	Data Basis	Secure Yield ML/a	Critical Drought
<i>Existing Clarrie Hall Dam:</i>				
564	1951-2099	CanESM2 R1	12062	21/6/2061-18/11/2064
<i>Raised Clarrie Hall Dam (42300 ML):</i>				
560	1951-2099	CanESM2 R1	17454	11/6/2061-28/12/2065
561	1951-27/5/2021	CanESM2 R1	27196	20/9/2000-6/11/2002
536	1951-27/5/2021	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data	26122	27/7/2001-1/2/2003
534	1951-27/5/2021	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data & <i>expected inflows 2000-2021</i>	30341	4/8/2001-1/2/2003
562	1890-2099	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data to 27/5/2021 and then extended to 2099 using CanESM2 R1 data	18427	10/6/2061 - 28/12/2065
563	1890-2099	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data (& <i>expected inflows 2000-2021</i>) to 27/5/2021 and then extended to 2099 using CanESM2 R1 data	18427	10/6/2061 - 28/12/2065

* See Table 4.1.

NOTE: NUWS Run Data does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

Table 4.8: Secure Yield Results for CanESM2 R2 Model

Run No.	Modelled Period	Data Basis	Secure Yield ML/a	Critical Drought
<i>Existing Clarrie Hall Dam:</i>				
574	1951-2099	CanESM2 R2	9914	18/6/2061-3/11/2064
<i>Raised Clarrie Hall Dam (42300 ML):</i>				
570	1951-2099	CanESM2 R2	15694	31/5/2061-3/11/2064
571	1951-27/5/2021	CanESM2 R2	24072	18/3/2005-19/11/2006
536	1951-27/5/2021	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data	26122	27/7/2001-1/2/2003
534	1951-27/5/2021	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data & <i>expected inflows 2000-2021</i>	30341	4/8/2001-1/2/2003
572	1890-2099	From previous NUWS Run 515* data, utilises SILO Drill Data, uses observed data to 27/5/2021 and then extended to 2099 using CanESM2 R2 data	16299	31/5/2061 - 3/11/2064
563	1890-2099	From previous NUWS Run 513* data, utilises SILO Drill Data, uses observed data (& <i>expected inflows 2000-2021</i>) to 27/5/2021 and then extended to 2099 using CanESM2 R2 data	16360	31/5/2061 - 3/11/2064

* See Table 4.1.

NOTE: NUWS Run Data does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

4.4 Results Discussion

Table 4.9 summarises all the secure yield results and shows them varying with modelled period and the basis of the modelled flows.

Figures 12 to 43 provide the modelled storage behaviour for the various time series data supplying annual demands (with restrictions applied in accordance with 5/10/10 rules) that equate to the secure yields. The storage behaviour for the future period is quite varied for the different climate model data sets particularly the timing of the critical drought.

Of particular note is the large reserve storage that is available for all the cases for all the droughts. This is a consequence of the Secure Yield 5/10/10 rule allowing for the occurrence of more severe droughts.

Table 4.9: Summary Secure Yield Modelling Results

Case	Flows	Modelled Period	SECURE YIELD ML/a (Run No given in brackets)					
			ACCESS 1.0_R1	ACCESS 1.0_R2	ACCESS 1.3_R1	ACCESS 1.3_R2	CanESM2 _R1	CanESM2 _R2
Existing Dam:								
1	New	1951-2099	(523) 10718	(554) 15173	(544) 10766	(531e) 16020	(564) 12072	(574) 9914
Raised Dam:								
2	New	1951-2099	(580) 15498	(550) 20954	(540) 16985	(531) 21126	(560) 17454	(570) 15694
3	New	1951- 27/5/2021	(581) 20019	(551) 27363	(541) 20327	(532) 27457	(561) 27196	(571) 24072
4	NUWS without expected inflows	1951- 27/5/2021	(536) 26122					
5	NUWS with expected inflows	1951- 27/5/2021	(534) 30341					
6	NUWS &New without expected inflows	1890-2099	(582) 15591	(552) 21469	(542) 18277	(533) 21835	(562) 18427	(572) 16299
7	NUWS & New with expected inflows	1890-2099	(583) 15600	(553) 21469	(543) 18377	(535) 22008	(563) 18427	(573) 16360
Raised Dam Using DPIE Guidelines (Ref 1) including its specified Climate Warming data (see Table 4.2):								
8	Without expected Inflows	Based on using Lowest GCM for adjustment ratio						19228
		Based on using lower of Median GCM and lowest GCM with 10/15/25 rule for adjustment ratio						21420
9	With expected Inflows	Based on using Lowest GCM for adjustment ratio						22738
		Based on using lower of Median GCM and lowest GCM with 10/15/25 rule for adjustment ratio						25116

NOTE: NUWS Run Data in cases 4 to 7 does not include adjustment for climate change. Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

From comparing the Case 3 results with the Case 4 and Case 5 results, all essentially for historic climate for 1951-2021, it can be seen a range of results is obtained for the same climate period. The difference between Case 4 and Case 5 is explained by the use of the expected inflows for 2000-2021. The differences from Case 4 and Case 5 results to Case 3 results can be attributed to apparent *model bias*.

The flows come from the same AWBM rainfall runoff models however the daily rainfall and daily evapotranspiration data come from different sources or models. The Case 4 and 5 daily rainfall and daily evapotranspiration data comes from the SILO Data Base while the Case 3 daily rainfall and daily evapotranspiration is linked to the 6 climate models.

Figures 44 to 53 compare the daily rainfall and daily evapotranspiration from the provided 6 climate model data sets with those used from the SILO Drill data base used for the five calibrated AWBM rainfall runoff models for the *Reference Period* 1951- 2021. It is expected the differences in the daily rainfalls and daily evapotranspiration would be contributing to the differences in the yield estimates. It would seem there is an apparent bias in the 6 climate model data sets to be underestimating the rainfall and slightly overestimating the evapotranspiration. Both of these apparent biases would be expected to lead to lower secure yield estimates.

It was not feasible if not impossible to directly adjust the daily rainfalls and daily evapotranspiration for the relative bias. However to correct for the apparent model bias a similar approach to that used in DPIE Water *Guidelines* (Ref 1) was used. In the *Guidelines* the secure yield results from the 15 GCMs are compared to the results from the secure yield from the historic climate from the same data base. Thus an adjustment factor is obtained and this is applied to the secure yield result for the historic climate from using the best observed historic climate and flow data. This is different to that from the historic data base linked to the 15 GCMs.

Table 4.10 provides the unbiased secure yield results, historic results, bias adjustment figures and the bias adjusted secure yield results.. The secure yield results from use of the Guidelines and use of the climate change data specified in the Guidelines are also included for comparison. Both sets of results are within similar ranges.

Table 4.10: Bias Correction of Secure Yield Results

Case	Flows	Modelled Period	SECURE YIELD ML/a (Run No given in brackets)						
			ACCESS 1.0_R1	ACCESS 1.0_R2	ACCESS 1.3_R1	ACCESS 1.3_R2	CanESM2 _R1	CanESM2 _R2	
Raised Dam:									
2	New	1951-2099	(580) 15498	(550) 20954	(540) 16985	(531) 21126	(560) 17454	(570) 15694	
3	New	1951- 27/5/2021	(581) 20019	(551) 27363	(541) 20327	(532) 27457	(561) 27196	(571) 24072	
4	NUWS without expected inflows	1951- 27/5/2021	(536) 26122						
5	NUWS with expected inflows	1951- 27/5/2021	(534) 30341						
Bias Factor (Case 3/Case4) result Without expected inflows			0.7664	1.0475	0.7782	1.0511	1.0411	0.9215	
Case 2 results adjusted for bias Without expected inflows			20222	20003	21826	20098	16765	17030	
Bias Factor (Case 3/Case 5) result With expected inflows			0.6598	0.9018	0.6700	0.9049	0.8963	0.7934	
Case 2 results adjusted for bias With expected inflows			23489	23235	25352	23346	19473	19781	
Raised Dam Using DPIE Guidelines (Ref 3) which includes Climate Warming (results from Ref 4)									
8	Without expected Inflows		Based on using Lowest GCM for adjustment ratio						19228
			Based on using lower of Median GCM and lowest GCM with 10/15/25 rule for adjustment ratio						21420
9	With expected Inflows		Based on using Lowest GCM for adjustment ratio						22738
			Based on using lower of Median GCM and lowest GCM with 10/15/25 rule for adjustment ratio						25116

NOTE: Expected inflows were calculated from a water balance of Councils operational records for 2000 to 2021.

5. Discussion

5.1 Climate Change Guidelines Approach

The required Climate Change data to follow their *Guidelines* (Ref 1) were provided by DPIE Water (*Water Utility Group*). Daily values of rainfall and evapotranspiration were provided by DPIE Water using the methodology developed for their 2008 data sets (Vaze et al, 2008) (Ref 7) for the 15 GCMs and the corresponding historic data for the nominated representative SILO grid points for all the subcatchments and storages. The climate change data are for projected ~2030 and were obtained by Vaze et al (Ref 7) by scaling the historical 1894-2008 daily rainfall and evapotranspiration data using the methods detailed in Chiew et al, 2008 (Ref 8). The climate change data were based on the Years 2030 A1B warming scenarios, mid-range emissions scenarios and was based on SEACI Theme 2 data.

The daily data from the 15 GCMs and the corresponding historic base data were used to provide the necessary input to the headworks system model. Sixteen sets of data for the 15 GCMs and corresponding historic base were developed for assessing the 1°C warming scenario. The climate change data series developed were:

- Daily rainfall and daily evaporation for assessing water losses from Clarrie Hall Dam and Bray Park Weir.
(The required daily evaporation for the storage was obtained from relations developed between historic evapotranspiration and historic evaporation and then applied to the climate change evapotranspiration daily values).
- Daily inflows at the required points of interest from inputting the daily rainfall and daily evapotranspiration data into the AWBM rainfall runoff models.

The modelling essentially involved:

- The 16 series of daily data (*daily flows, daily rainfalls, daily evaporation*) were input into the headworks storage behaviour models to determine 16 corresponding secure yield estimates for nominated cases. It is noted the modelling period due to data availability was 1/1/1895 to 31/12/2008 which was shorter to that used for the secure yield modelling without climate change.

The results of the individual 16 secure yields for the 15 GCMs and corresponding historic base for the nominated cases are provided in Appendix A.

Table 5.1 summarises the key results for determining the factors to apply to the *adopted historic* secure yield estimates for the Tweed District water supply Dam system modelled to allow for Climate Change using the approach as provided by DPIE Water's *Guidelines* (Ref 1).

Table 5.1: Climate Change Factors

Case for 1°C Warming	Secure Yield Estimates ML/a				Relevant Case in terms of NOW Draft Policy (letters refer to previous columns)	Adopted Factor to be Applied for Climate Change
	Historic from Climate Change data Base	Median from GCMs (5/10/10)	Lowest from GCMs (5/10/10)	Lowest from GCMs rerun with (10/15/25)		
	A	B	C	D		
Existing Clarrie Hall Dam (16000 ML)	15831	14301	11254	12794	D/A	0.8082
Raised Clarrie Hall Dam (42300 ML)	26869	24231	19778	21848	D/A	0.8131

It is noted that the secure yields in column A are different than the *adopted* historic secure yields. This is a common finding and is due to differences in data sets including period of data and use of observed data. This is the reason for the adjustment factor in the last column of the table which also caters for if the critical drought occurs post 2008.

Table 5.2 provides the secure yield estimates adjusted for climate change in accordance with the *Guidelines* (Ref 1).

Table 5.2: Secure Yield Adjusted for Climate Change

Case	Secure Yield Estimates ML/a			
	Run No for Original Historic Case*	Original Historic* (Best Estimate) (5/10/10)	Adjustment factor for Climate Change	With Climate Change
Existing Clarrie Hall Dam (16000 ML)	511	14626	0.8082	11820
Existing Clarrie Hall Dam (16000 ML) (with expected inflows)	512	17065	0.8082	13791
Raised Clarrie Hall Dam (42300 ML)	515	26122	0.8131	21240
Raised Clarrie Hall Dam (42300 ML) (with expected inflows)	513	30890	0.8131	25116
* see Table 4.1				

Use of the DPIE Water Guidelines *Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities* (Ref 1) (which are understood still currently required to be used to satisfy DPIE Water Utility Group requirements) to assess Climate Change on Secure Yield allows for 1°C Climate warming. The 1°C Climate warming in the Guidelines relates to changes from 1990. It is noted often climate warming quoted elsewhere is referring to what has occurred since 1900 or post industrialisation rather than 1990. However it can be argued since climate warming has already been occurring, for example the 2001/2003 and 2019./2020 drought would have been influenced by whatever warming has

occurred since 1990, and how the adjustment factors are applied, that the 1 °C warming can be considered to be from 1990 or the critical drought whichever is more recent.

The results provided in Table 5.2 are regarded by the *Guidelines* as the *best estimate* of future secure yield however the Guidelines suggest alternative estimates should be considered based on affordability and capital works program (*refer to Guidelines for details*). They are based on using the lowest GCM and the median GCM in obtaining the ratio to the historic case from the climate change data base to obtain the factor to be applied for climate change.

The proposed raising of Clarrie Hall Dam involves major capital works to secure Tweed District Water Supply well into the future. Thus of the alternatives allowed to be considered according to the Guidelines then it would seem to be prudent to base the results on the adjustment factor from the lowest GCM (*ie Column numbered 3 in Table 5.3*).

Table 5.3: Capital Works Planning Alternative Estimates

Run No	System Case	Secure Yield ML/a			
		Historic Climate	1°C Climate Warming		
			1*	2*	3*
511	Existing Clarrie Hall Dam (16000 ML)	14626	11820	13212	10397
512	Existing Clarrie Hall Dam (16000 ML) (with expected inflows)	17065	13791	15415	12515
515	Raised Clarrie Hall Dam (42300 ML)	26122	21240	23557	19228
513	Raised Clarrie Hall Dam (42300 ML) (with expected inflows)	30890	25116	27857	22738
*1 : Best estimate according to Guidelines and as determined given in Tables 5.1 to 5.2 *2: Based on using median GCM (column B) to column A to obtain Factor in Tables 5.1 *3: Based on using lowest GCM (column C) to column A to obtain Factor in Tables 5.1					

5.2 Consideration

The determination of Secure Yield through the 5/10/10 rules allows for a more severe drought than has occurred in the past. The 5/10/10 rules with 1 °C climate warming adjustment aims to provide sufficient storage to allow the local water utility to manage its water supply with appropriate restrictions and bringing on contingency emergency sources through any drought that occurs in the planning horizon (about 40 years). This is achieved by in effect a buffer amount of storage being created through the 5/10/10 process. That is the supply has to be maintained with 10% restrictions through all droughts in the flow series with the storage already drawdown at the start of each drought to the level that does not occur more often than 10% of the years and for 5% of the time (see Figures 1 and 2).

Use of the 5/10/10 rule with the NARClIM1.5 data may be adding extra conservatism depending on the basis of the NARClIM1.5 data. If the data is forecasting what will happen for the period up to 2099 then it can be argued that it is also forecasting all the droughts that may occur and thus the buffer storage to allow for all droughts is double accounting and not required.

5.3 Expected Inflows

Secure Yield results were obtained from a consideration of using modelled inflows into Clarrie Hall Dam for 2000-2021 and also from using expected inflows into Clarrie Hall Dam. The expected inflows being the inflows calculated from a water balance of Councils operational records. Since the expected inflows are based on recorded data they are preferred to modelled data. The results in Table S1 are based on the use of the expected inflows. For comparable cases the Secure Yield results from using the expected inflows were higher.

If there are concerns about the reliability of the operational data then the results not based on the expected inflows should be adopted.

5.4 Stress Test

Figures 10 to 43 (*excluding Figures 12,19,24,29,34 & 39 which are for the existing Dam*) show that in the worst drought the proposed storage does not fall below 10,000 ML. This reflects the conservatism in the methodology used for determining the secure yield and demonstrates that in the worst case modelled there was still an availability of water.

To confirm the availability of water a stress test was conducted to determine if the water supply would fail. The test was undertaken on a bias corrected demand of 22,000 ML/a. Average demand was chosen as in the event of imminent failure water demand would be restricted. 22,000 ML/a was chosen by TSC as that average demand will not be exceeded until sometime after 2090.

The demand of 22,000 ML/a was adjusted using the bias correction factor from the expected inflows for the CanESM2 R2 modelled flows case. This demand was then tested in the model using the CanESM2 R2 flow series in the model. The results of the stress test are shown in Figure 54.

The results reflect the conservatism of the methodology and the data sets used. While it shows the storage drawdowns get longer and lower into the future as droughts get worse from climate warming, the storage never empties and the demand is met in terms of the service criteria (*10% restrictions do not occur in more than 10% of the years and their duration is not more than 5% over the projected period based on applying them when the storage is 50% or less full*).

6. Recommendations

The results presented in this report should be used keeping in mind the assumptions on which the estimates are based.

7. References

1. NSW Department of Primary Industries, Office of Water (2013), "Assuring future urban water security, Assessment and adaption guidelines for NSW local water utilities" Draft-December 2013.
2. NSW Urban Water Services (2016), "Secure Yield Assessment for Tweed District Water Supply, Summary Report" Report N0 16004, June 2016, prepared for Tweed Shire Council.
3. NSW Department of Water and Energy (2007), "Best-Practice Management of Water Supply and Sewerage, Guidelines" August 2007.
4. NSW Public Works (1986), "Water Supply Investigation Manual" (Amended 1990).
5. CRC for Catchment Hydrology (2004), "Rainfall Runoff Library V1.05, AWBM Catchment Water Balance Model"
6. Jeffrey, S.J., Carter, J.O., Moudie, K.M., and Beswick, A.R. (2001), "Using Spatial Interpolation to construct a Comprehensive archive of Australian Climatic data" Environmental Modelling and Software, Vol 16/4 pp309-330, 2001.
7. Vaze, J., Post D., Chiew F., Perraud J-M. and Kirono D. (2008), "Future climate and runoff projections (~2030) for New South Wales and Australian Capital Territory, NSW Department of Water and Energy, Sydney.
8. Chiew F., Teng J., Kirono D., Frost A.J., Bathols J.M., Vaze J., Viney N.R., Young W.J., Hennessy K.J., and Cai W.J., (2008), "Climate data for hydrologic scenario modelling across the Murray-Darling Basin" A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Sydney.
9. Nishant, N., Evans J.P., Di Virgilio G, Downes S. M., Ji F., Cheung K.K.W, Tam E., Miller J., Beyer K & Riley M.L. (2021), "Introducing NARClIM1.5: evaluating the performance of regional climate projections for southeast Australia for 1950-2100" Earths Future. 9, e2020EF001833. <https://doi.org/10.1029/2020EF001833>

8. Figures

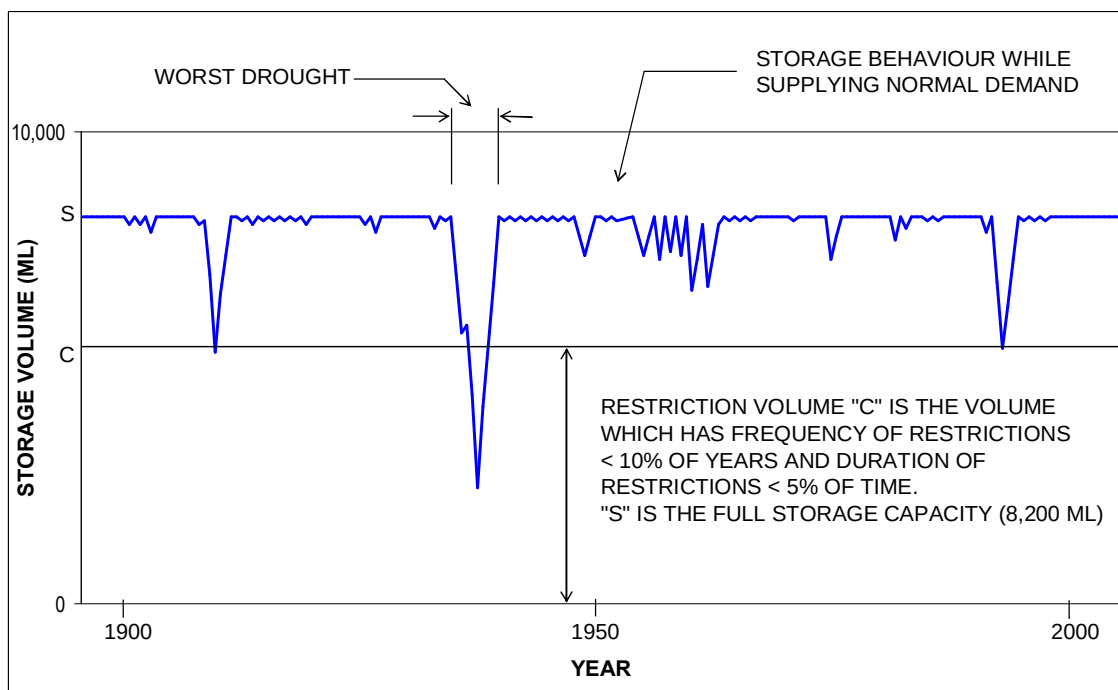


Figure 1: Duration and Frequency of Restrictions

Figure 1 shows the results of simulating an example utility's storage behavior for 120 years of daily streamflow, rainfall and evaporation data and shows that:

- Unrestricted water demand can be supplied for over 95% of the time and over 90% of years (ie. whenever the storage volume is above the **restriction volume C**). In order to satisfy the 5/10/10 rule, restrictions must be imposed whenever the volume of water in storage falls below the **restriction volume C**.
- A 10% reduction in demand is applied when the storage falls below **restriction volume C**
- The worst drought shown in Figure 1 is for approximately the 5-year period January 1939 to December 1943
- The minimum simulated storage volume is approximately 30% of the full storage capacity.

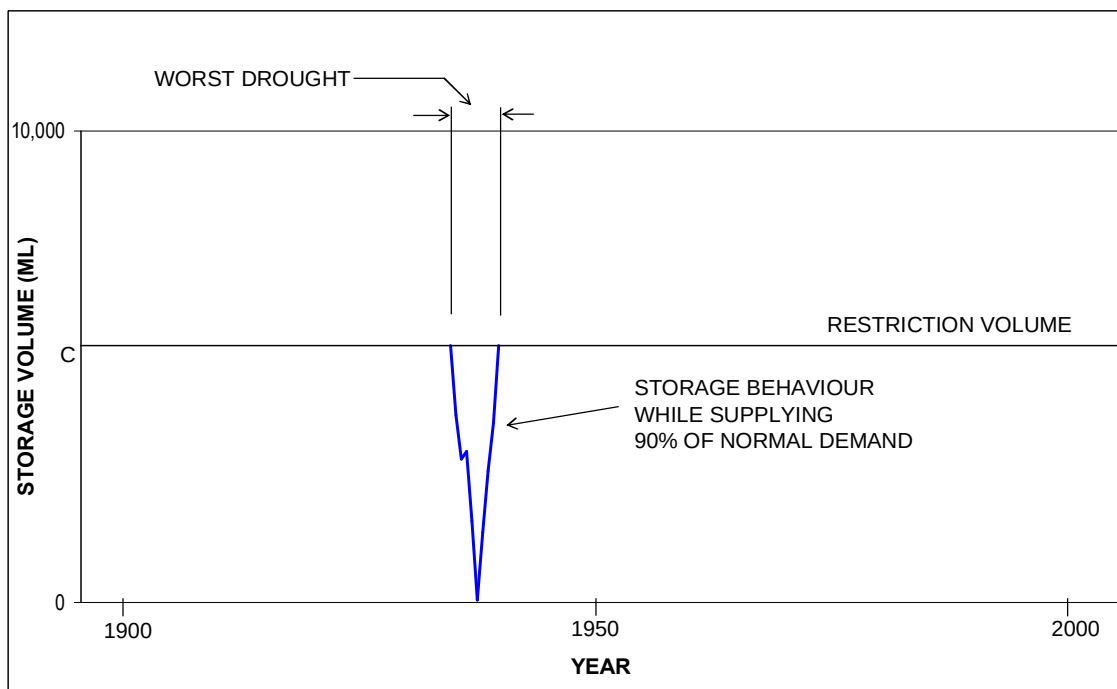


Figure 2: Severity of Restrictions

Figure 2 shows the results of simulating storage behaviour for the worst drought identified in Figure 1 (5-year drought from January 1939 to December 1943) on the following basis:

- A 10% reduction in demand for the full 5-year drought as the storage volume is below the Restriction volume C
- The commencing storage volume for this simulation is the **restriction volume C** and the resulting minimum simulated storage volume is approximately 2% of the full storage capacity.

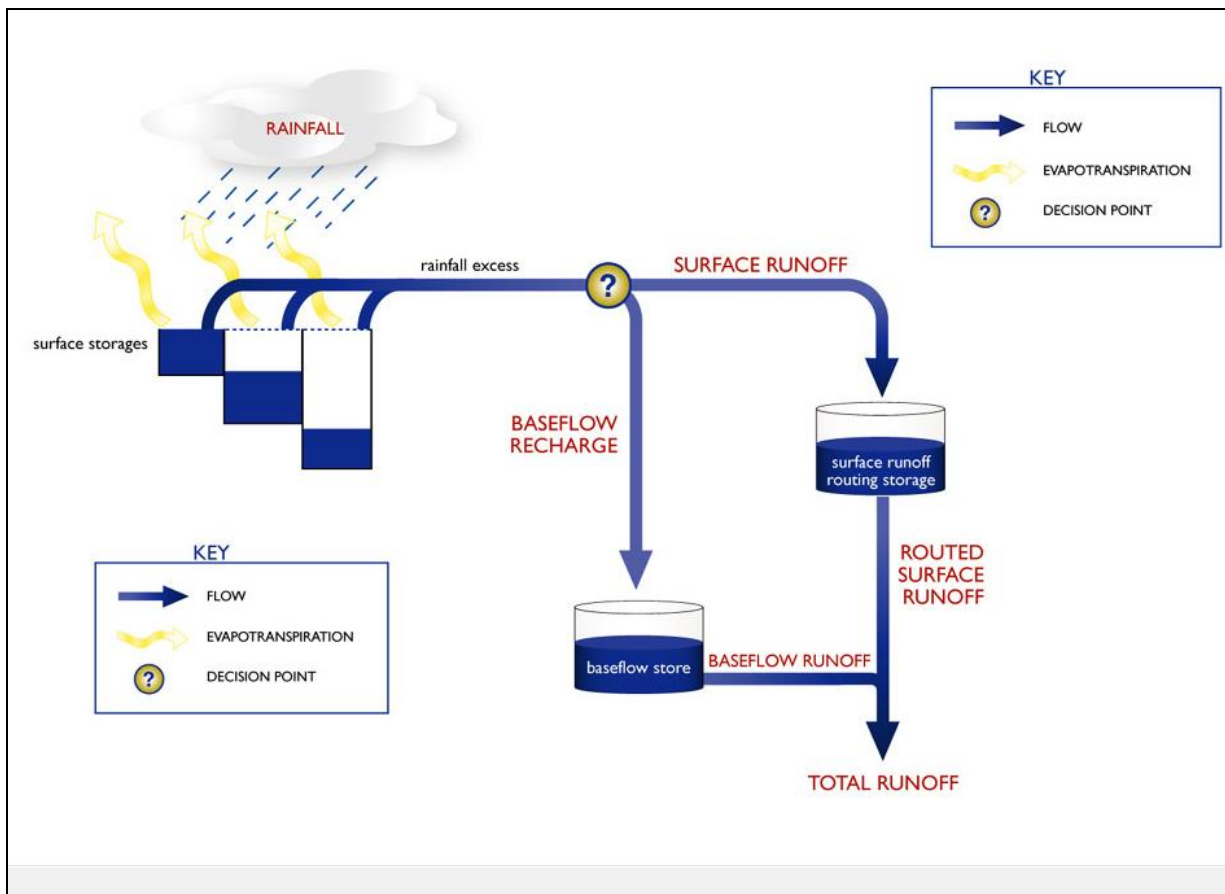
Comment

Imposition of the requirements of the 5/10/10 rule approximates the severity of a 1 in 1000 year drought and is necessary in order to enable a utility to manage its system in a drought more severe than the worst drought in the 120 year historical record, with only moderate drought water restrictions.

As the first year of the worst drought for this example utility is simulated in **both Figure 1 and Figure 2**, the water supply system must be able to cope with effectively a 6-year drought, rather than the 5-year worst drought in Figure 1 as it takes about 1-year to drawdown to **restriction volume C**.

It is important to note that the analytical process for the 5/10/10 rule is iterative and that a solution is identified only when all 3 requirements have been met.

A refinement that the NUWS model undertakes and as practiced by NSW Public Works Hydrology Group is to test all droughts for criticality when testing the critical drought with the storage already drawdown at the start of the drought. This is done as it was occasionally found in previous studies that the drought that is critical for the full storage was not necessarily the drought that was critical for in effect a smaller (ie drawdown) storage. This is achieved by modelling the full flow series with the reduced storage size and the restricted demand. This also arises from the "1 in 1000 year" security concept.



Source Ref 5

Figure 3: AWBM Model

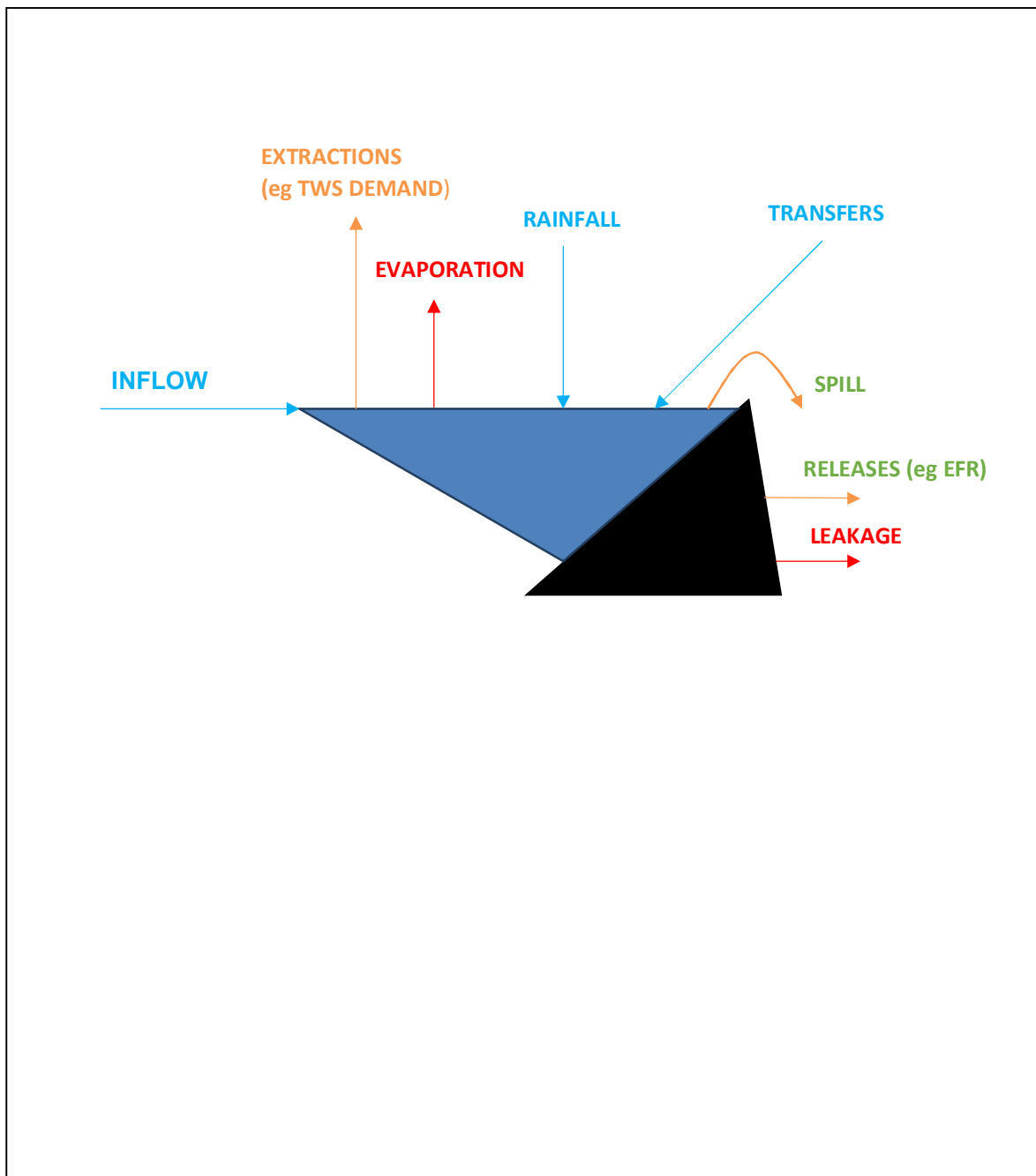


Figure 4: Storage Behaviour Model Schematic

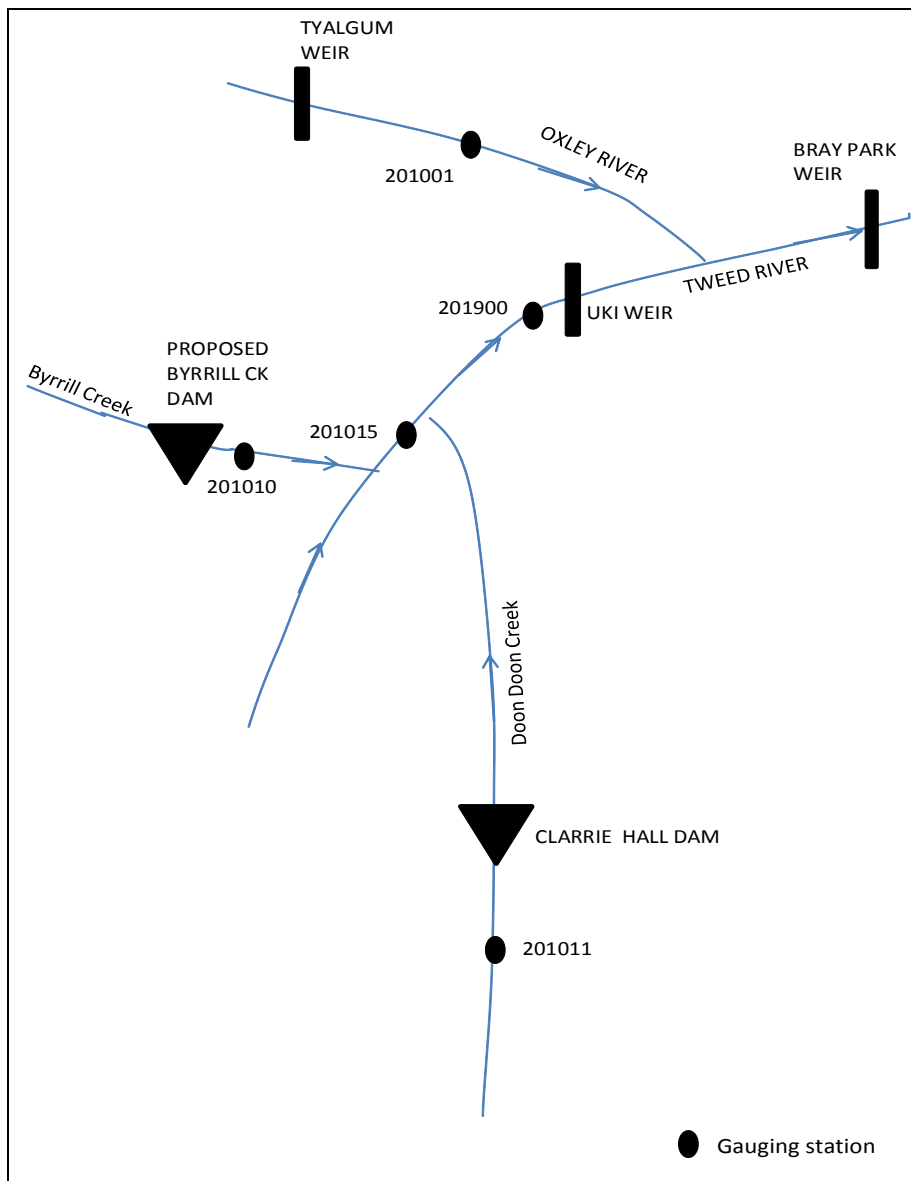


Figure 5: Tweed District Water Supply Headworks Schematic

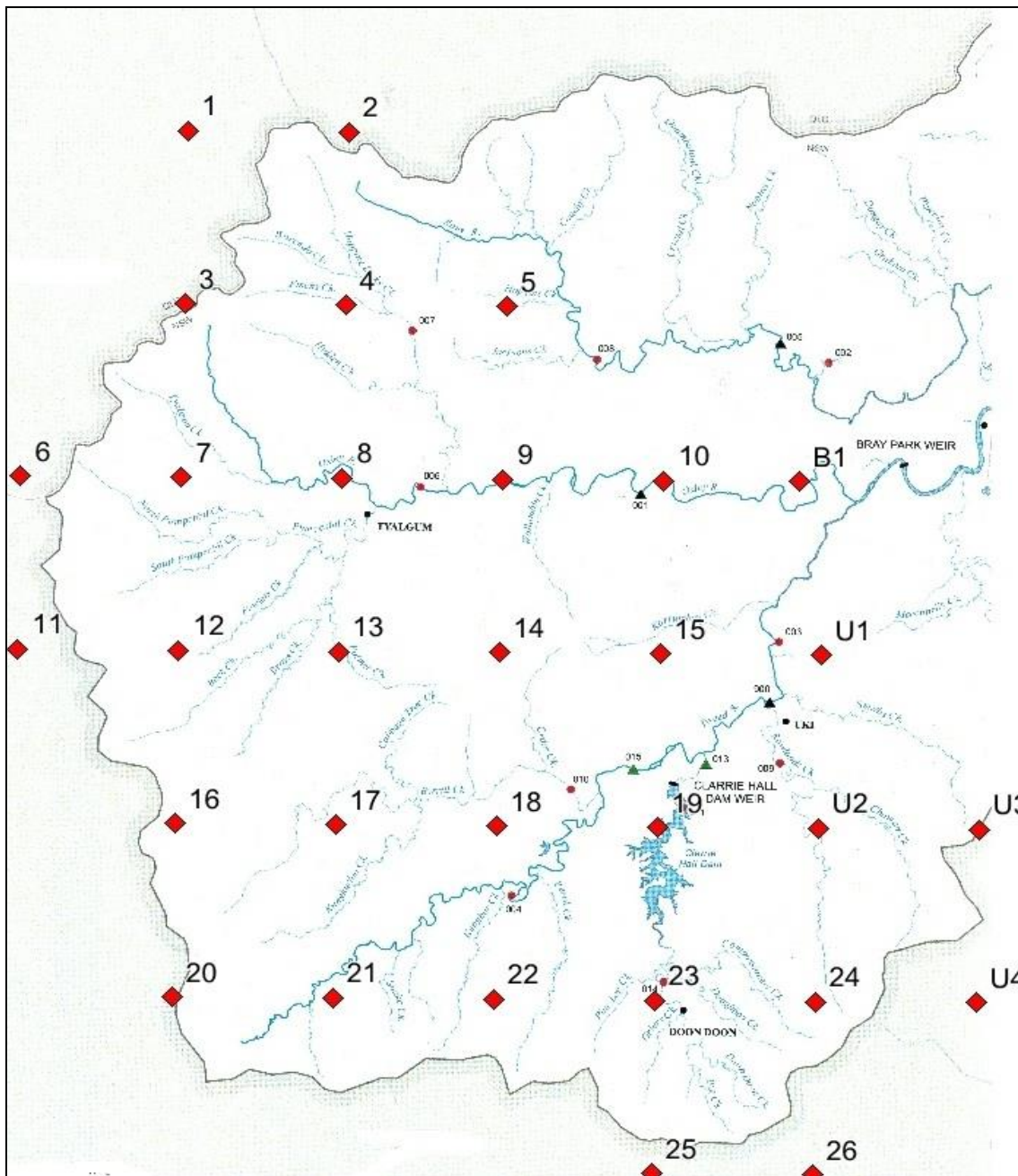
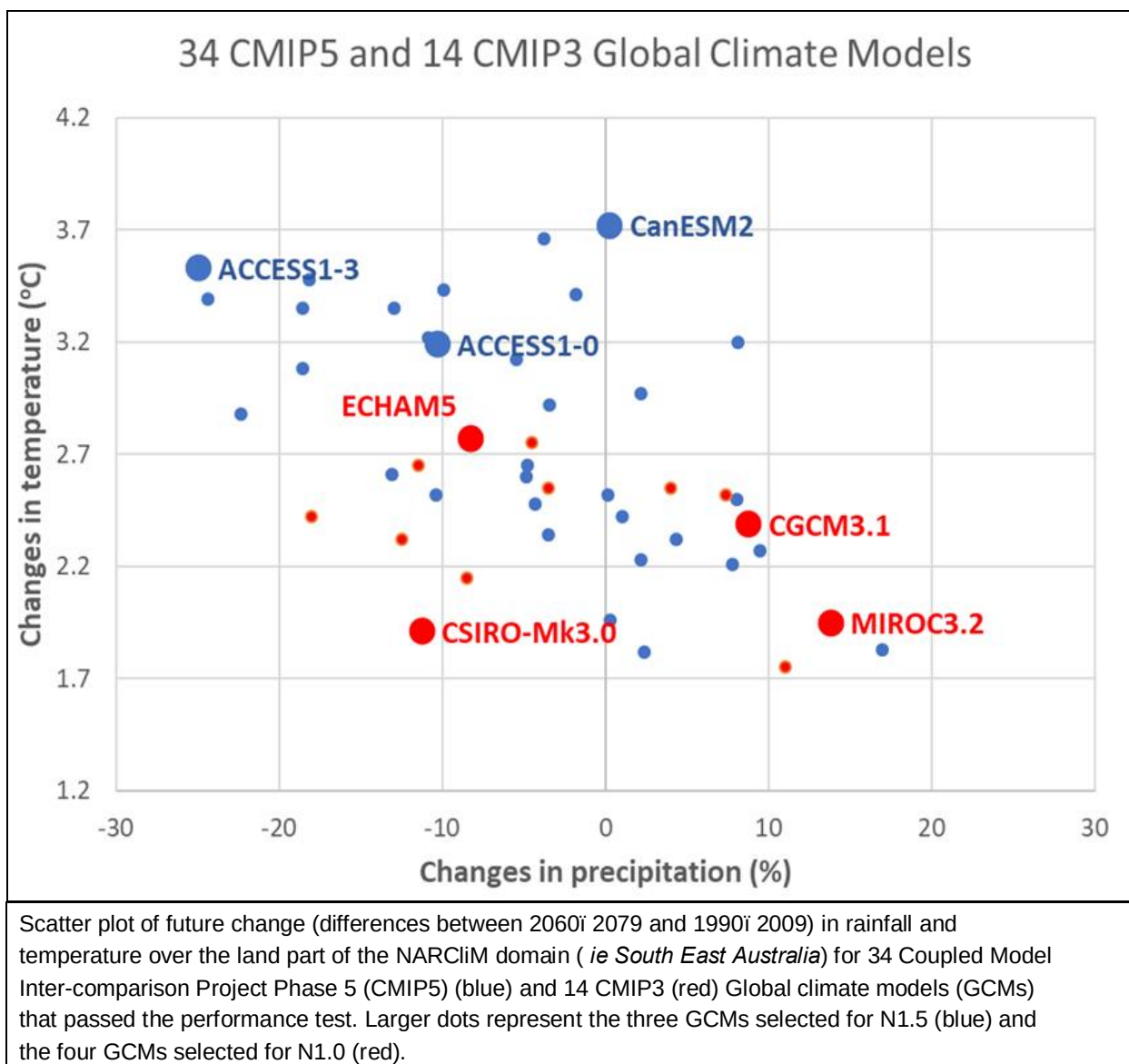


Figure 6: SILO Data Grid Points



Source Ref 9

Figure 7: GCM Comparison

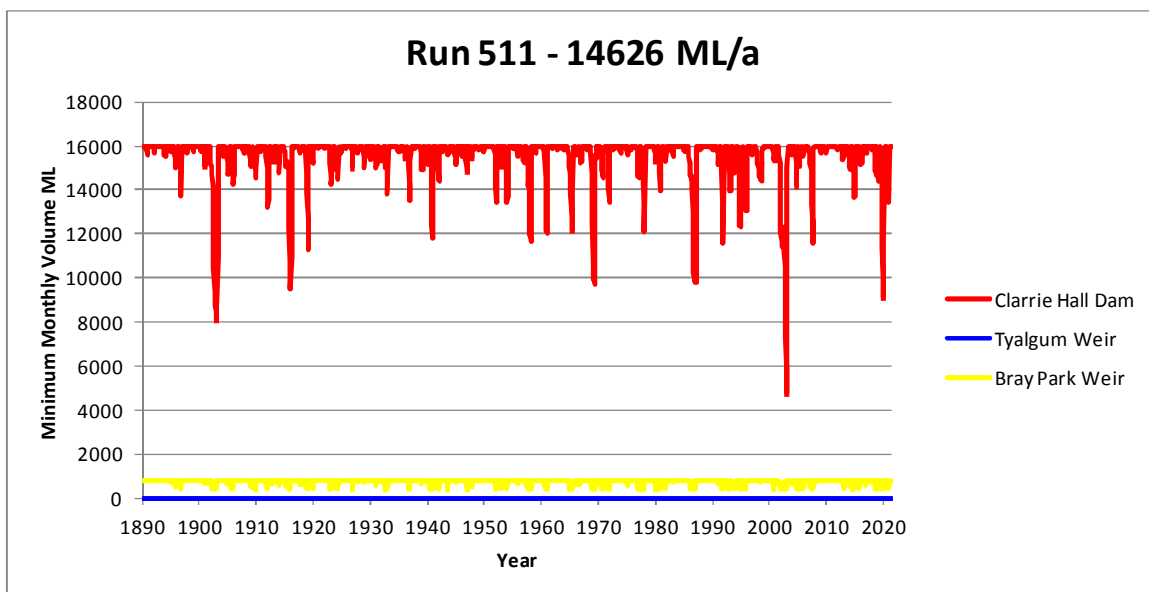
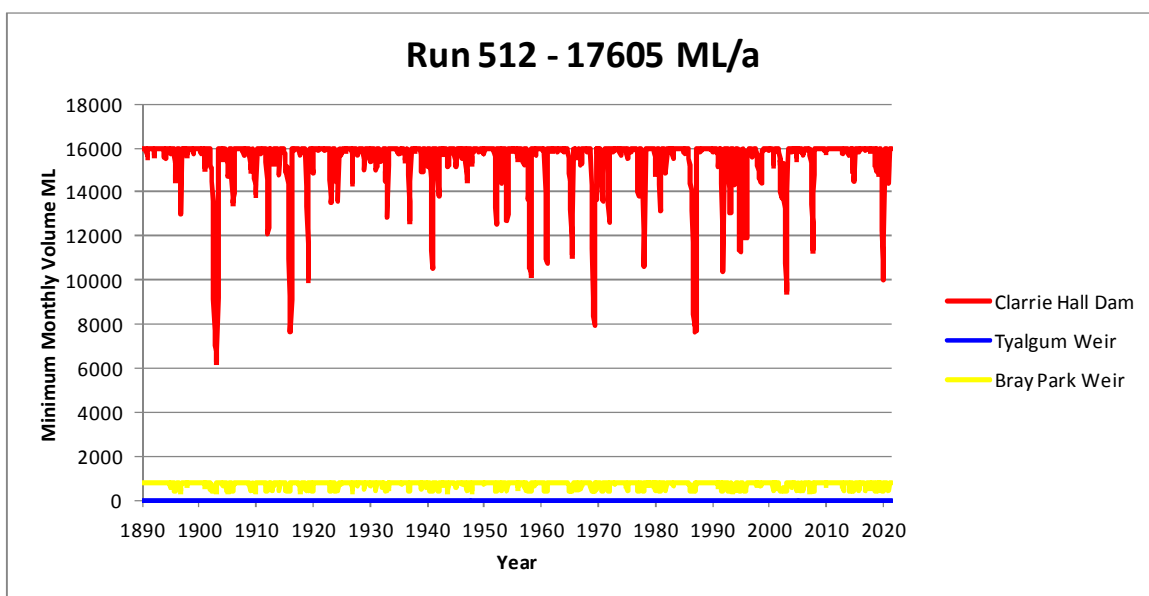


Figure 8: Storage Behaviour Run 511



2000 to 2021 CHD expected inflows

Figure 9: Storage Behaviour Run 512

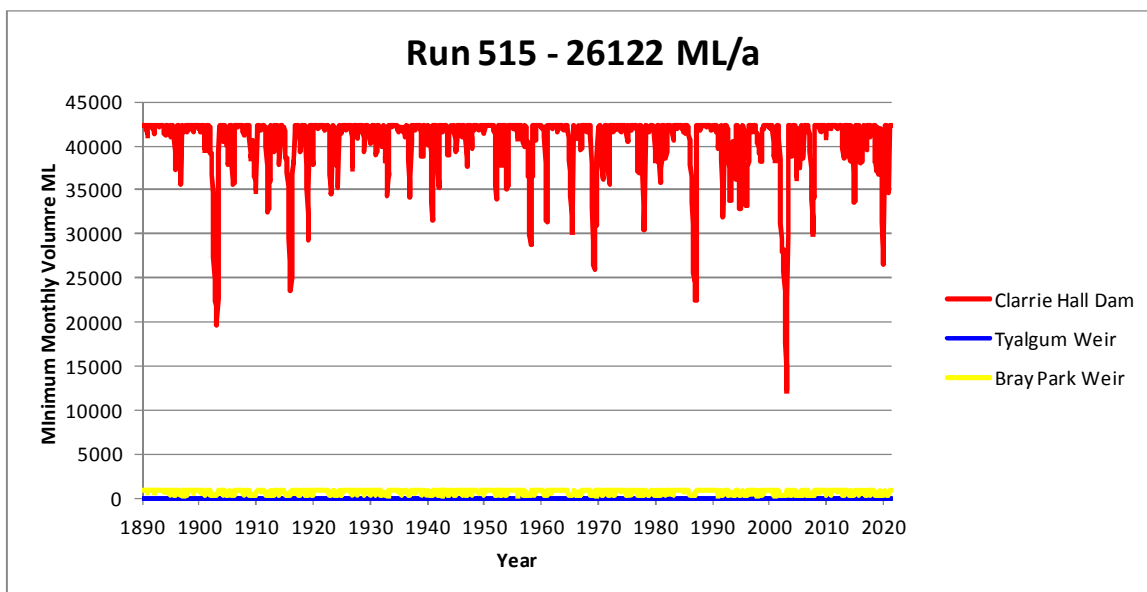
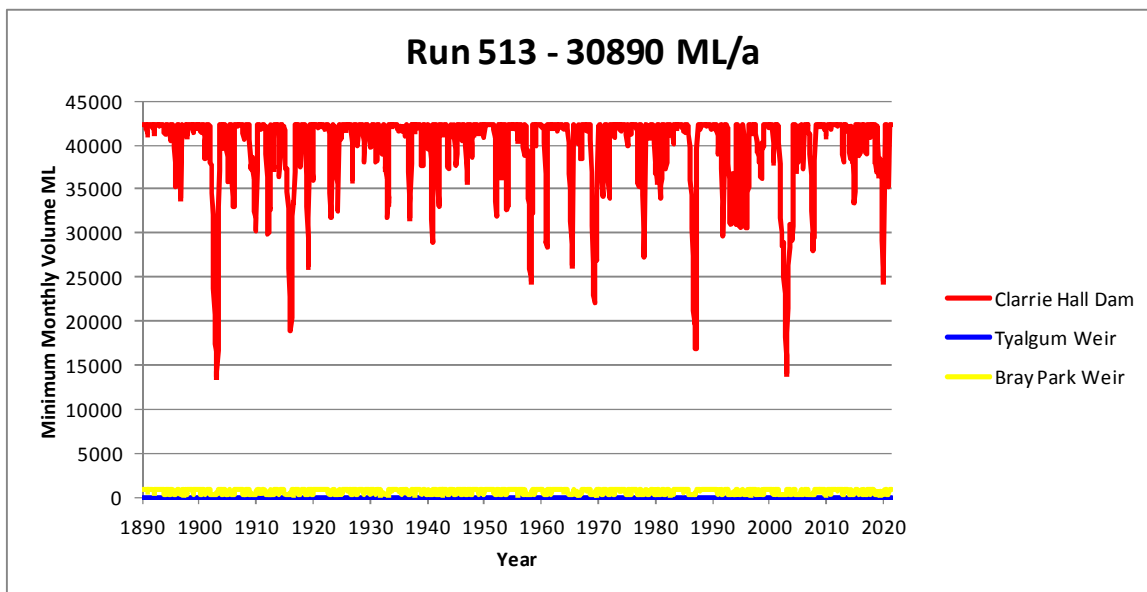


Figure 10: Storage Behaviour Run 515



2000 to 2021 CHD expected inflows

Figure 11: Storage Behaviour Run 513

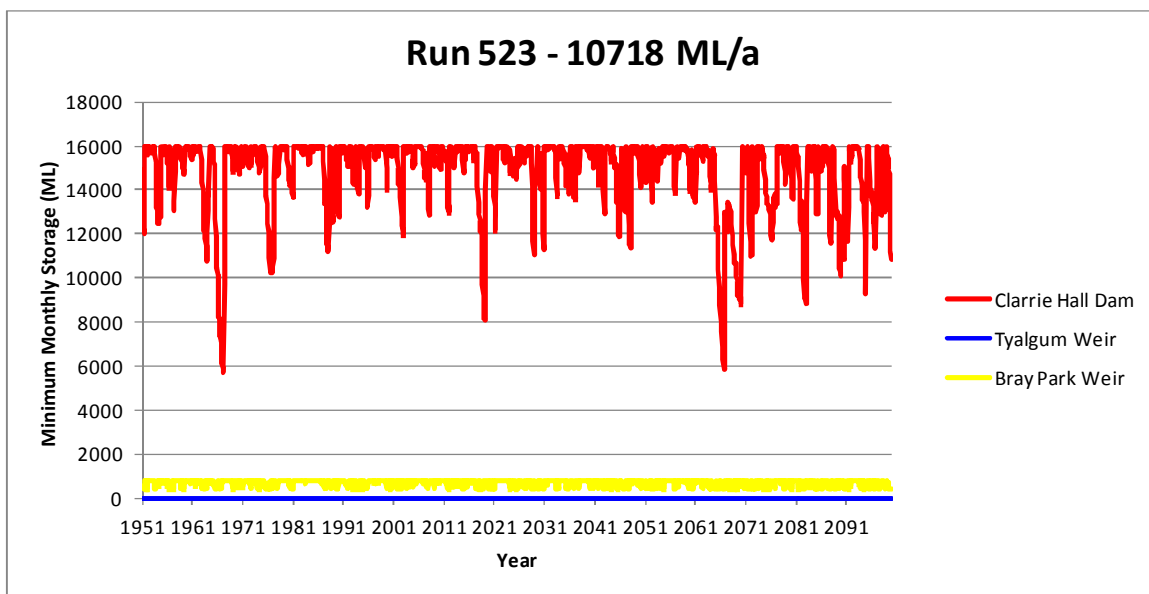


Figure 12: Storage Behaviour Run 523

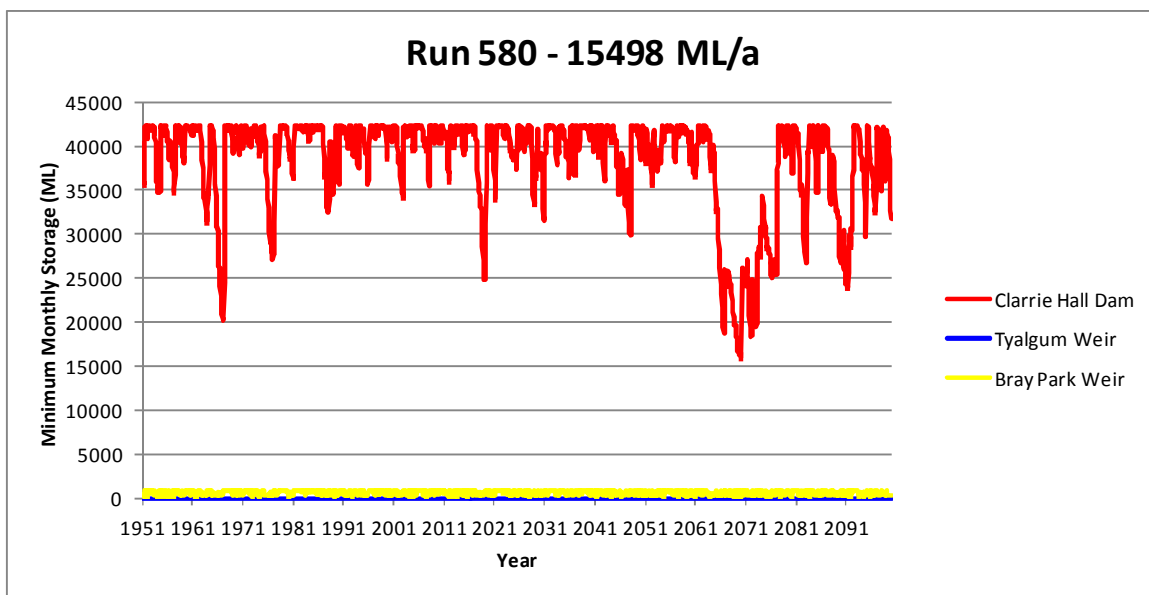


Figure 13: Storage Behaviour Run 580

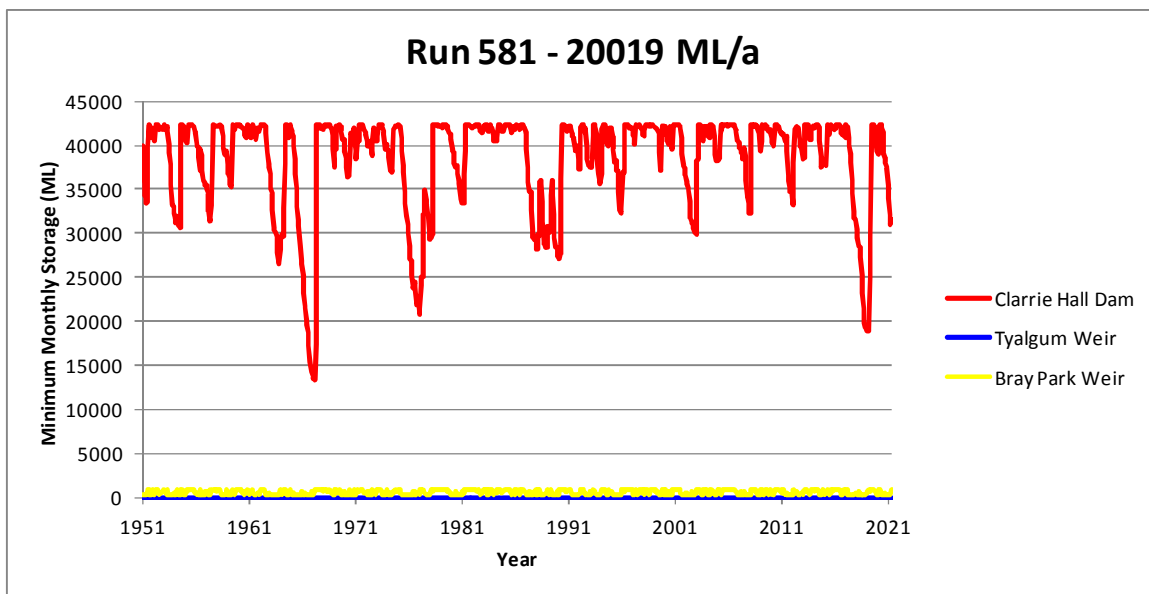


Figure 14: Storage Behaviour Run 581

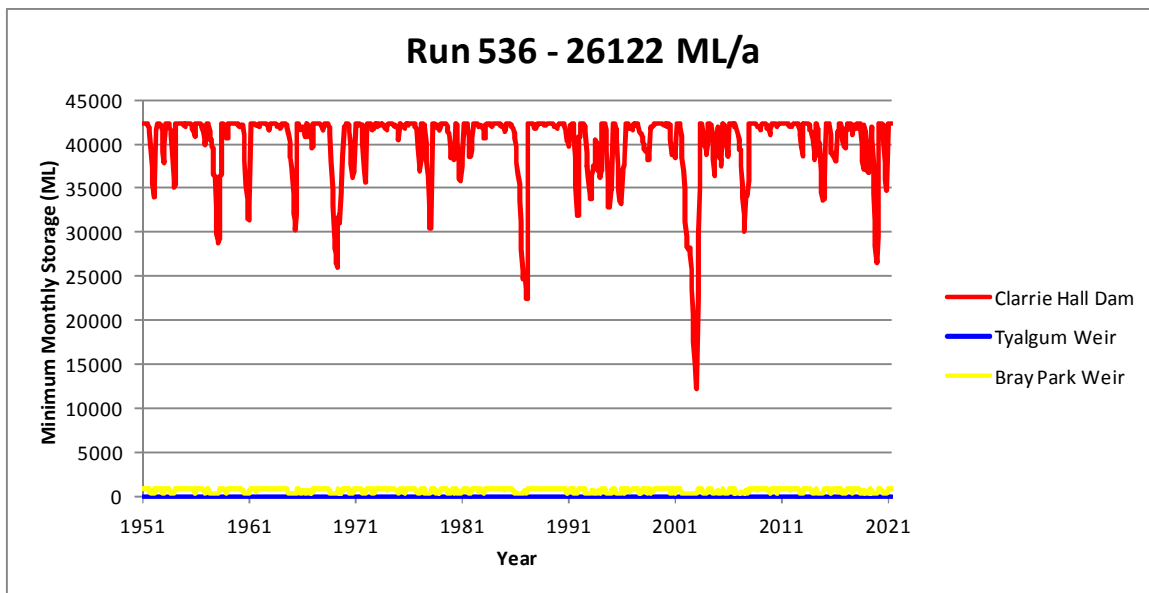


Figure 15: Storage Behaviour Run 536

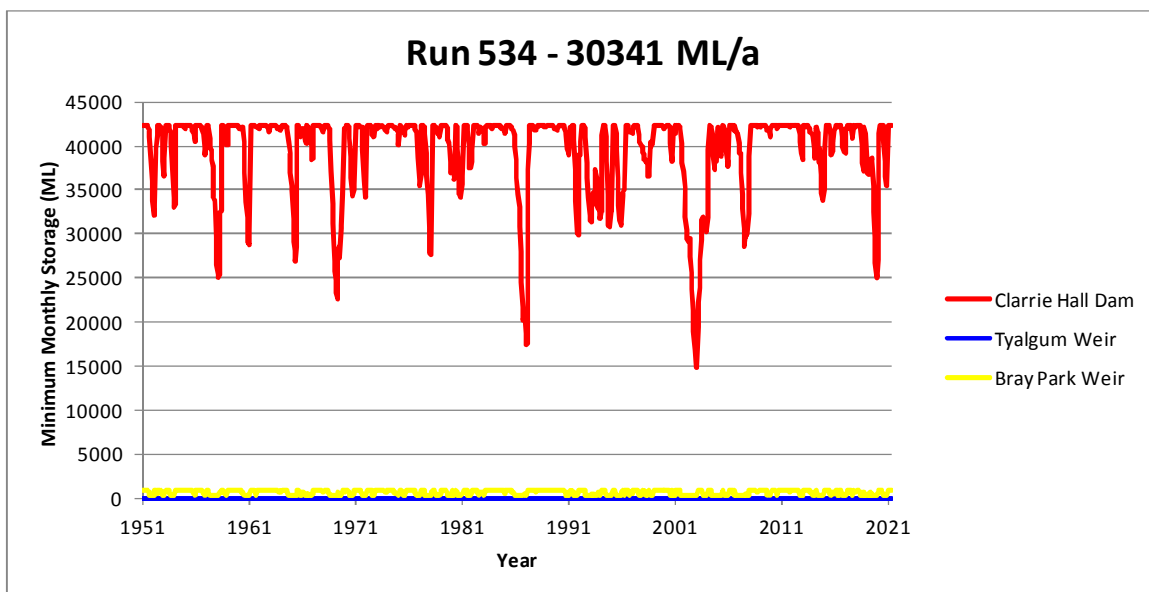


Figure 16: Storage Behaviour Run 534

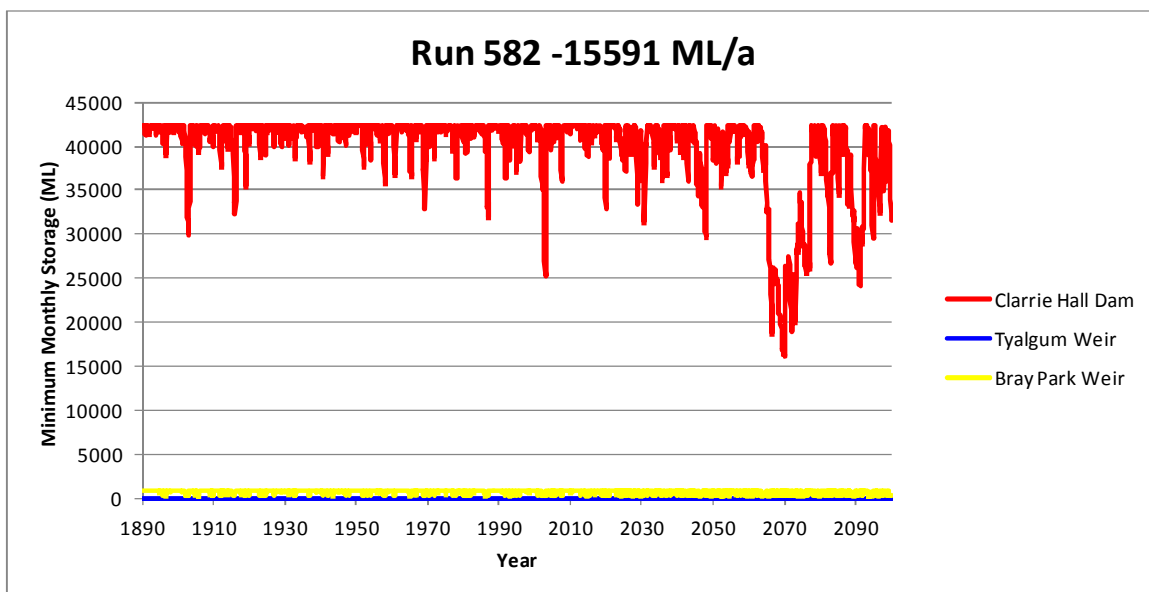


Figure 17: Storage Behaviour Run 582

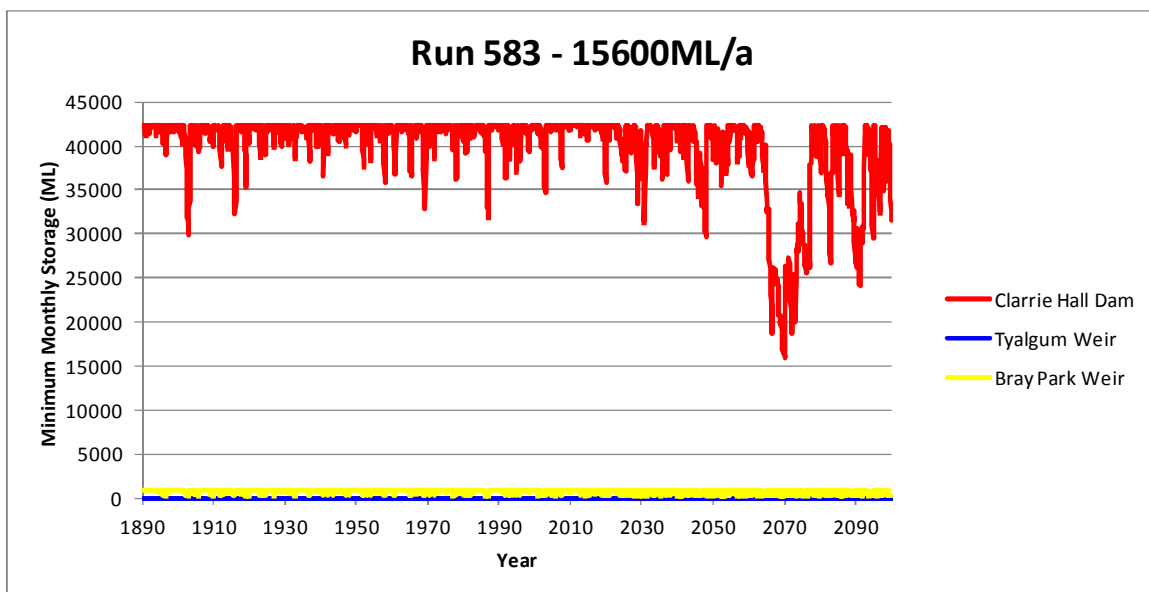


Figure 18: Storage Behaviour Run 583

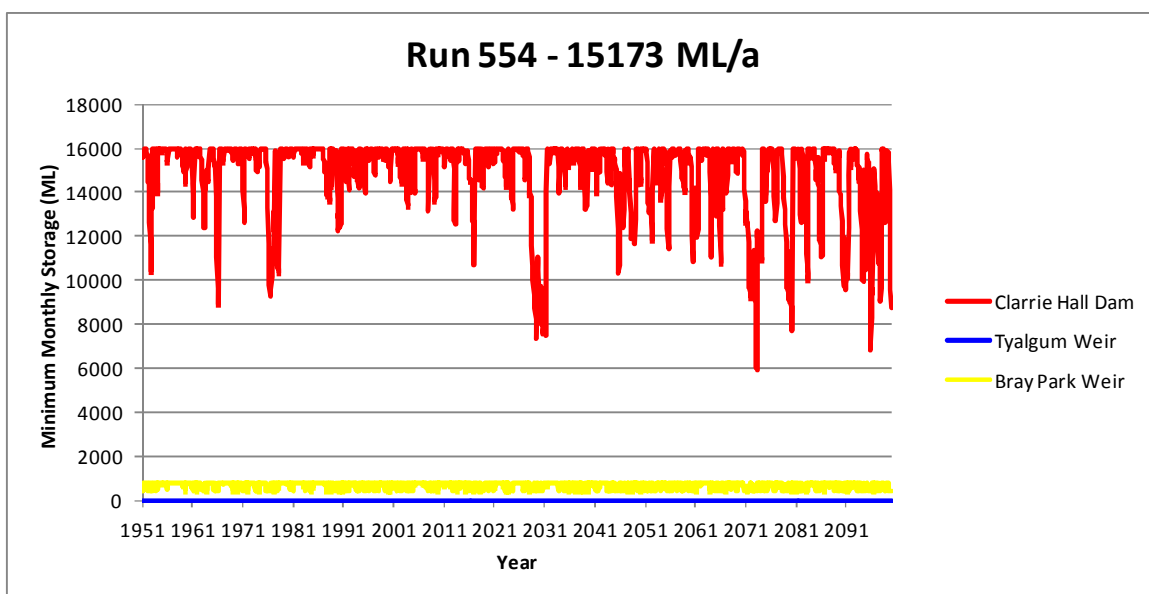


Figure 19: Storage Behaviour Run 554

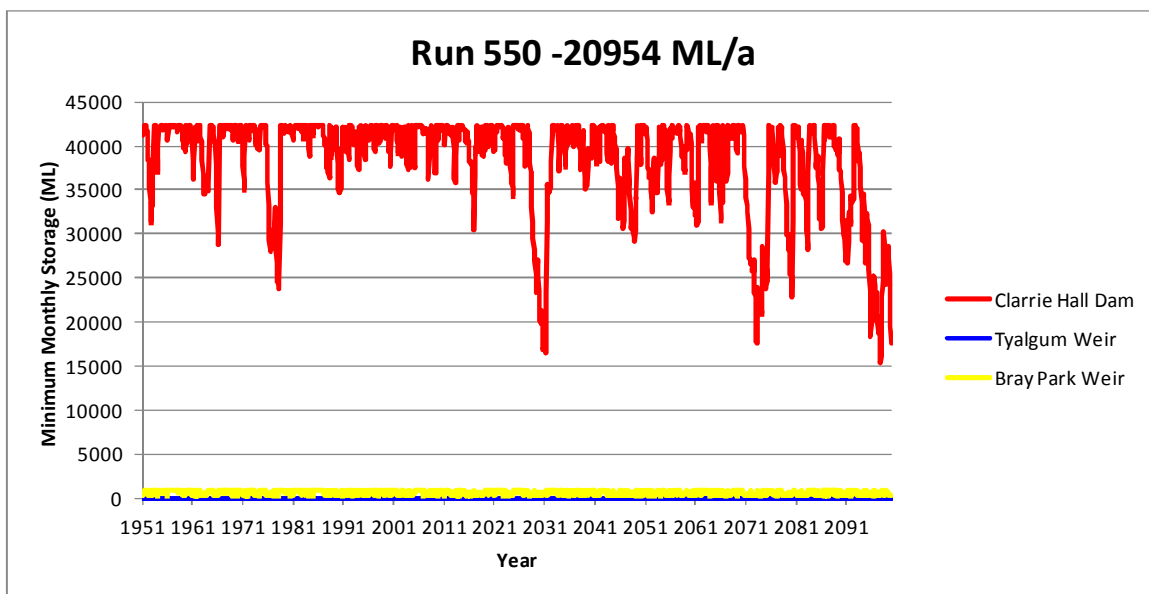


Figure 20: Storage Behaviour Run 550

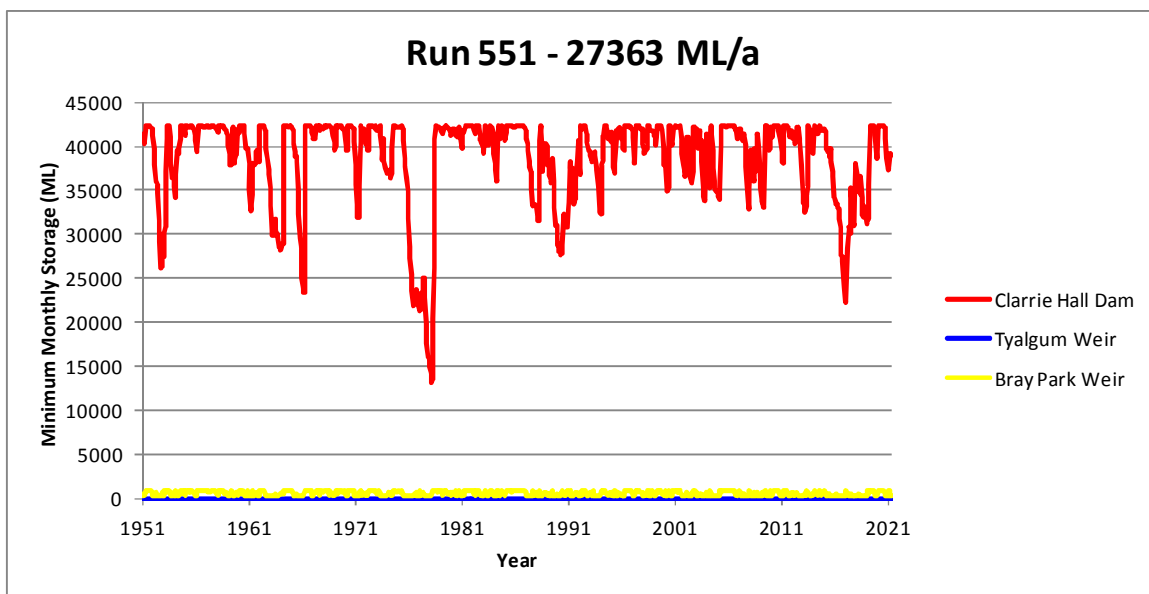


Figure 21: Storage Behaviour Run 551

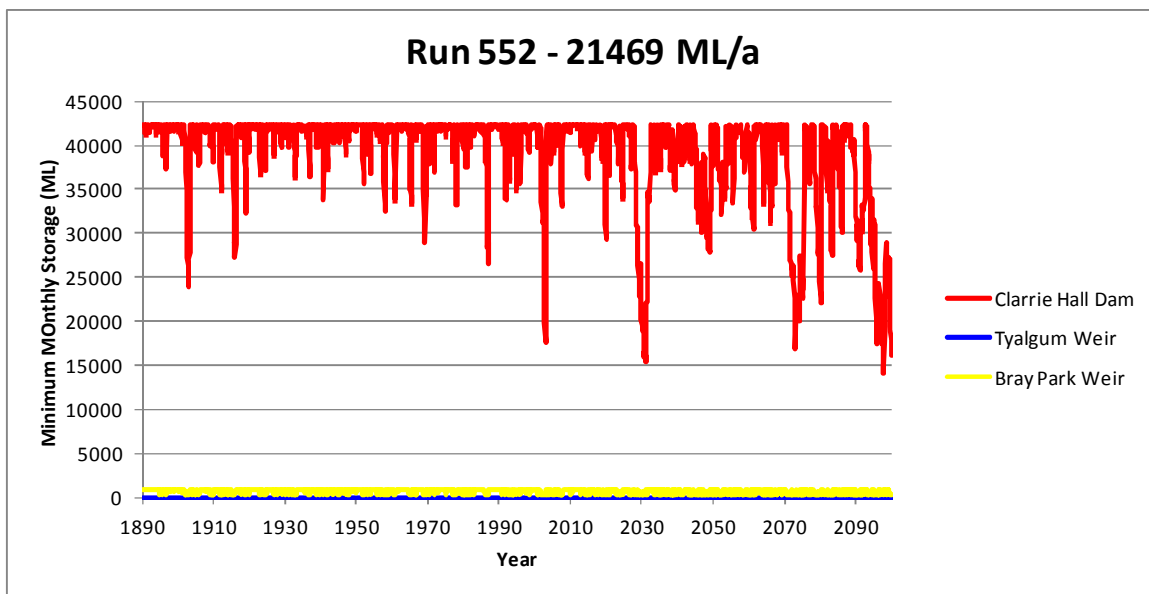


Figure 22: Storage Behaviour Run 552

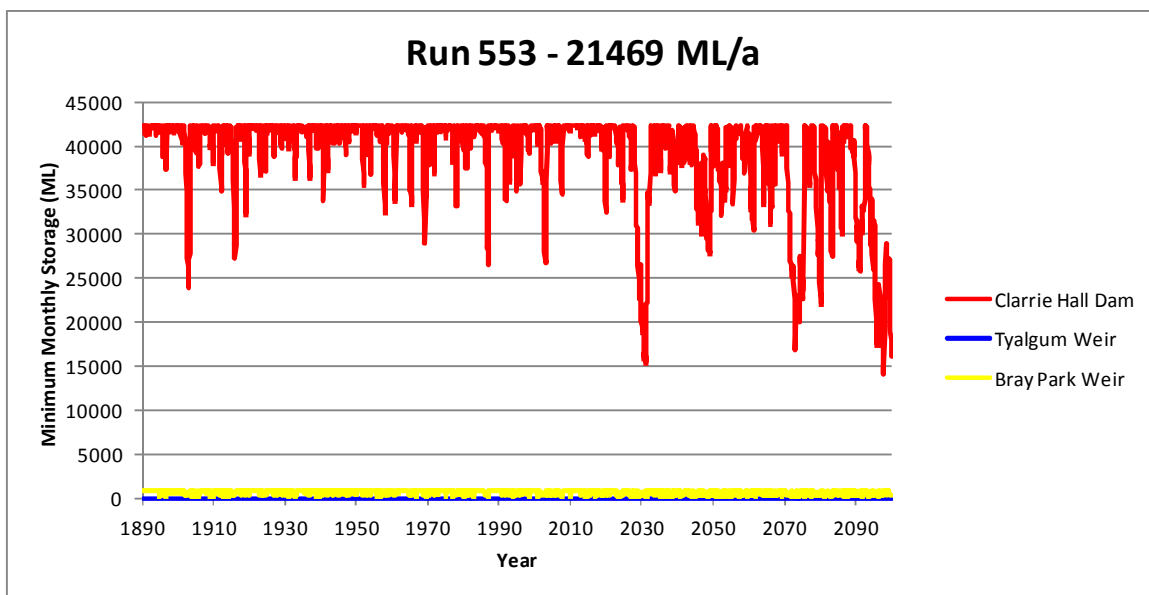


Figure 23: Storage Behaviour Run 553

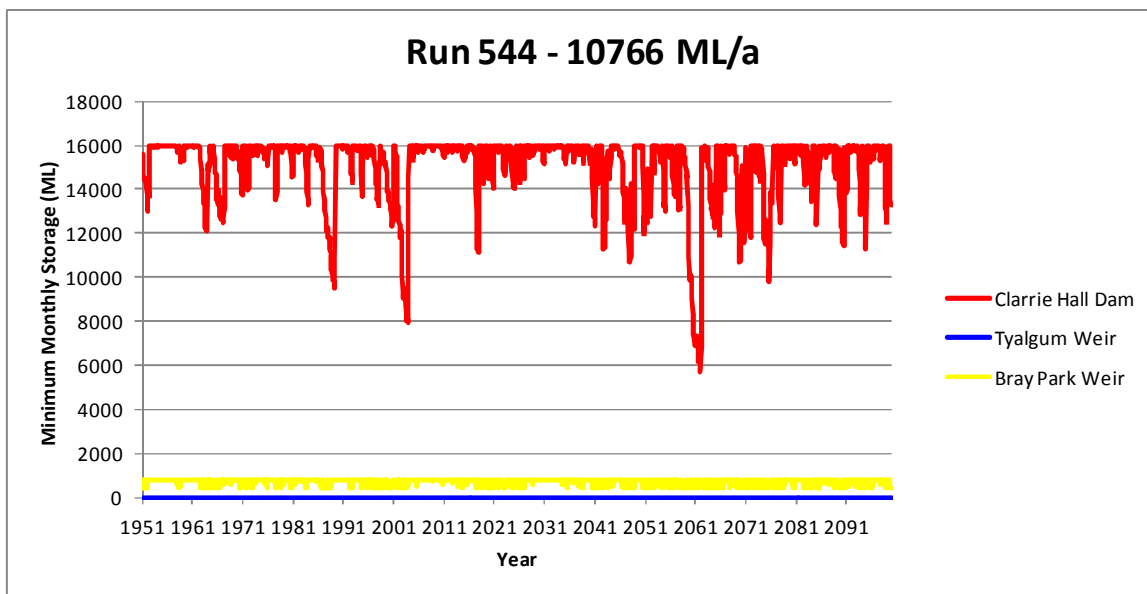


Figure 24: Storage Behaviour Run 544

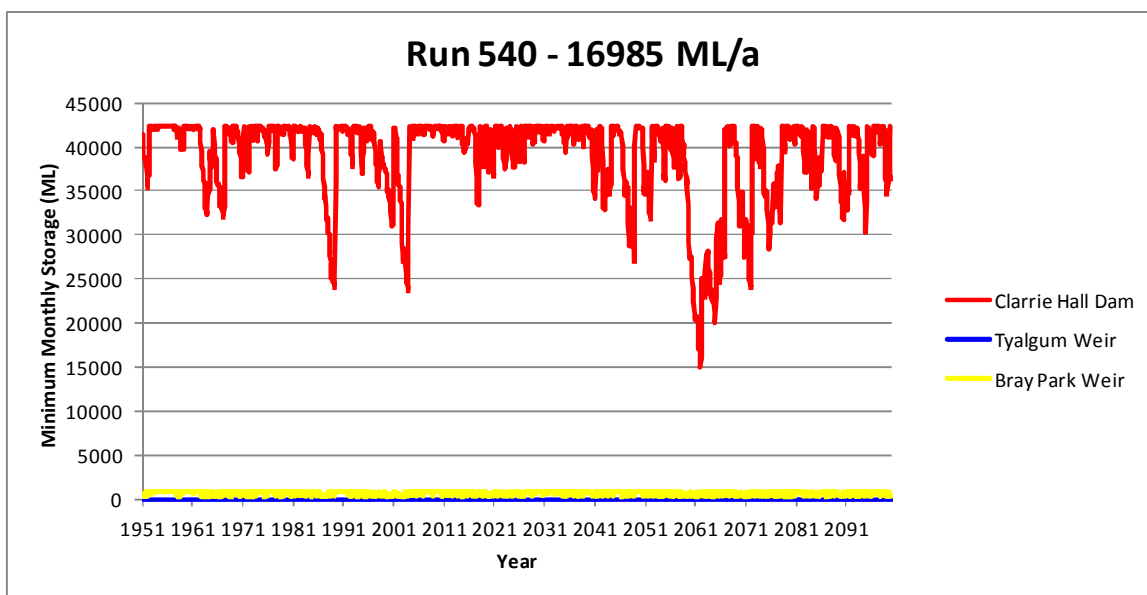


Figure 25: Storage Behaviour Run 540

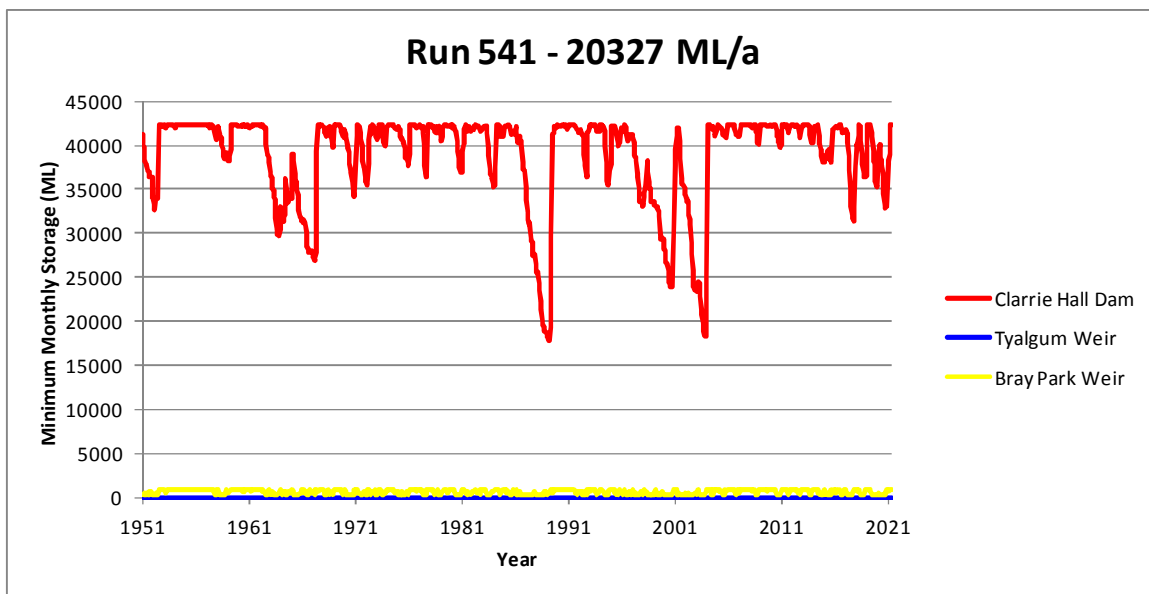


Figure 26: Storage Behaviour Run 541

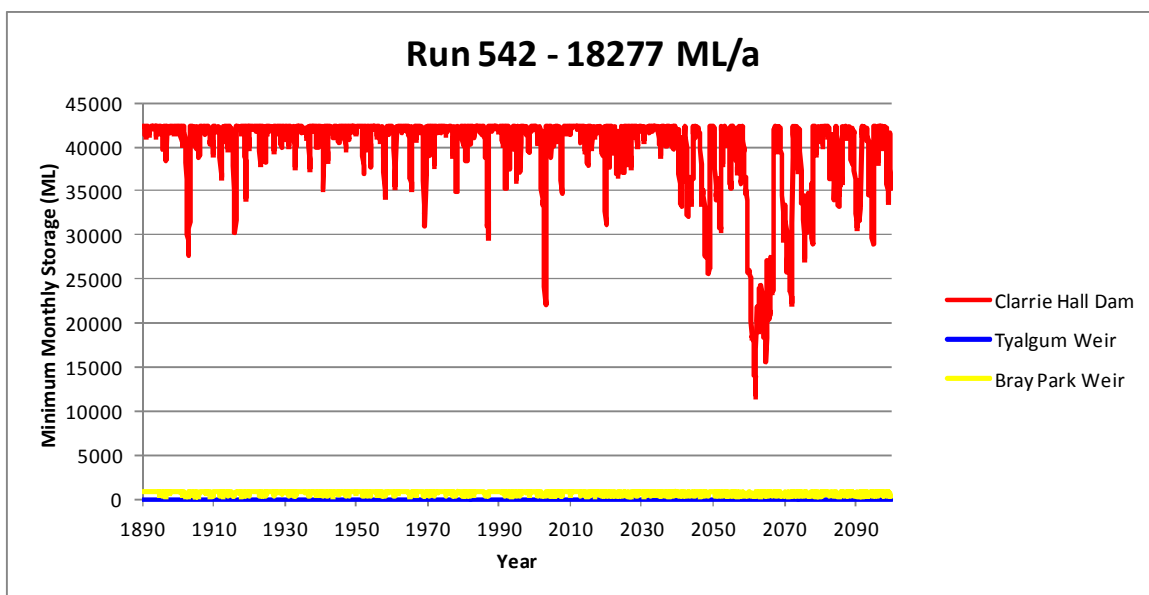


Figure 27: Storage Behaviour Run 542

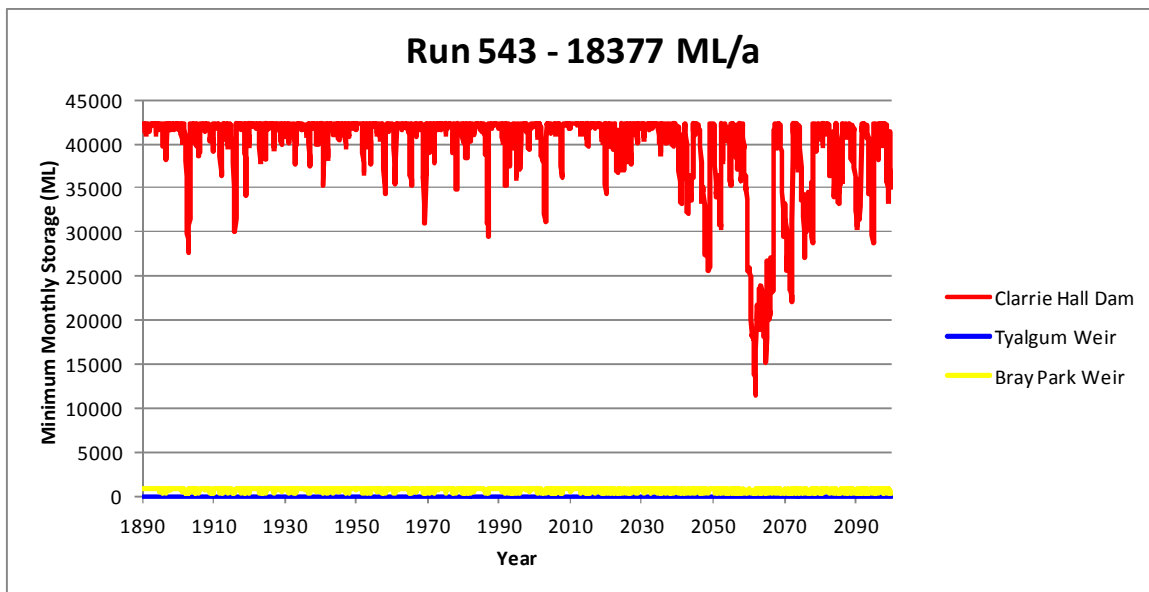


Figure 28: Storage Behaviour Run 543

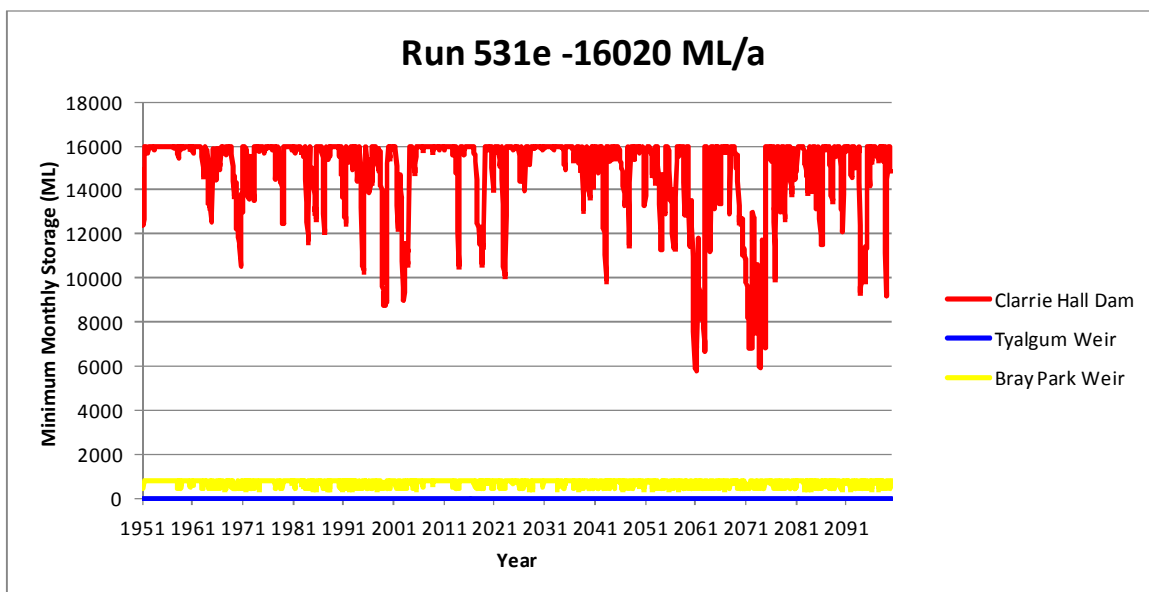


Figure 29: Storage Behaviour Run 531e

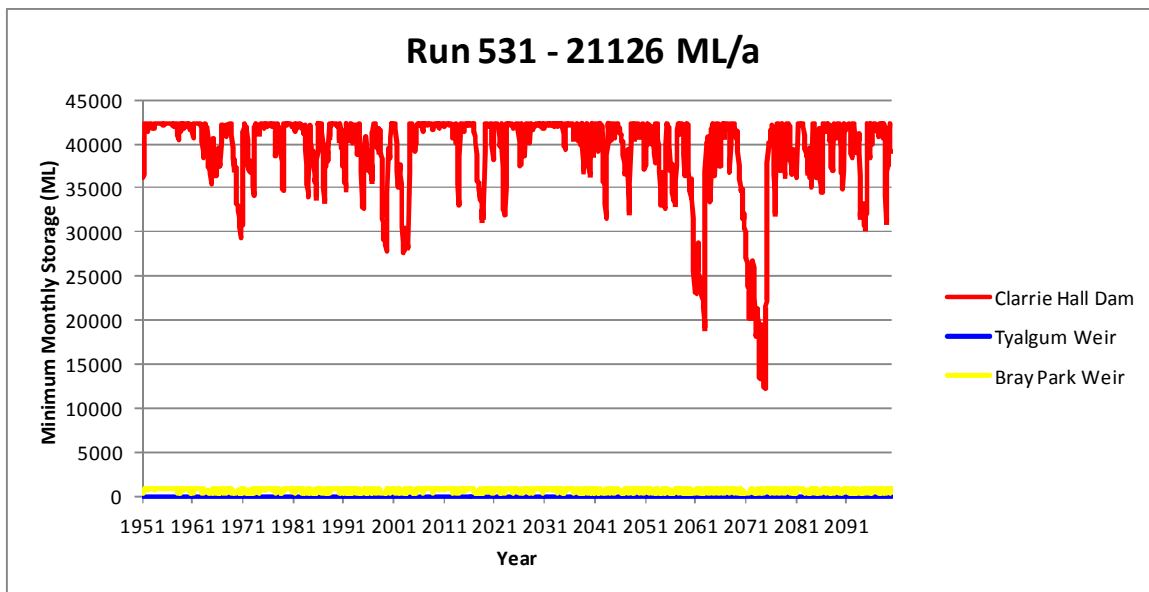


Figure 30: Storage Behaviour Run 531

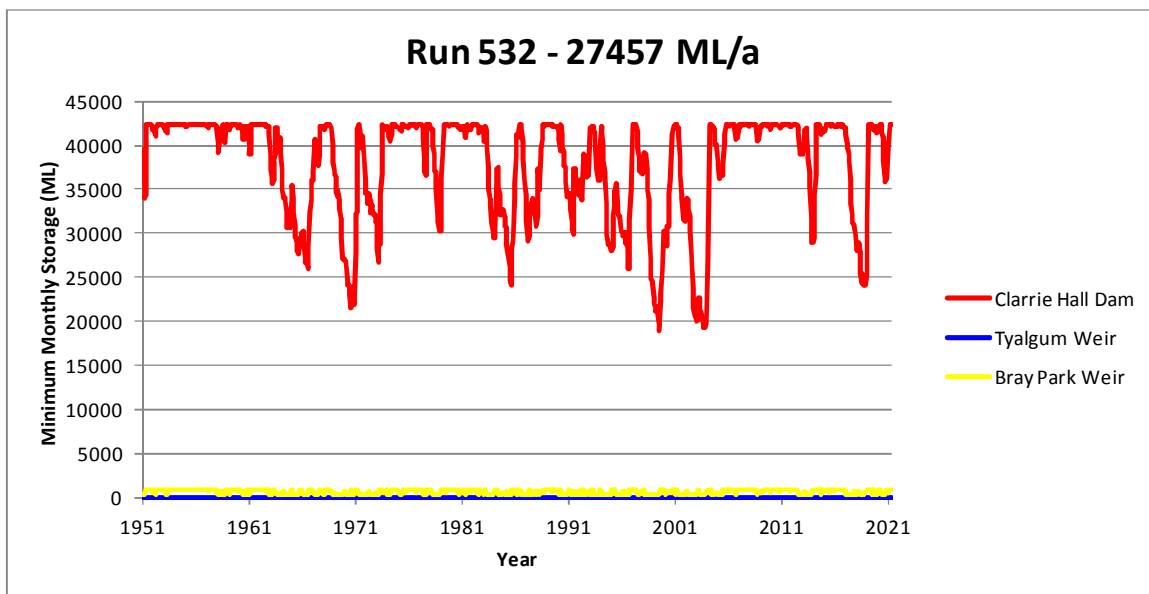


Figure 31: Storage Behaviour Run 532

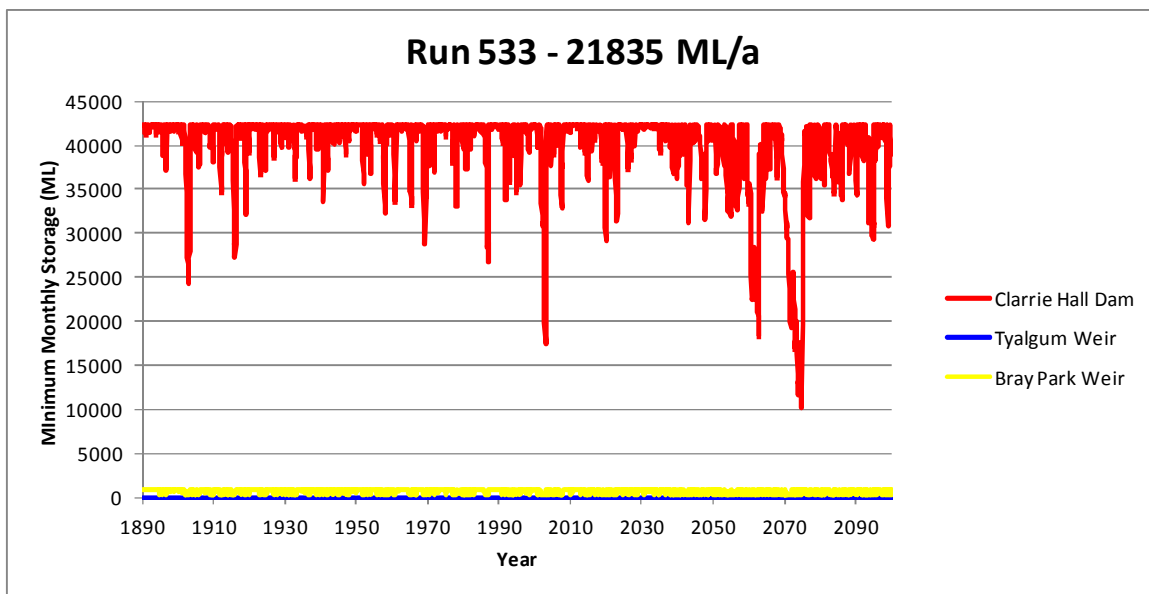


Figure 32: Storage Behaviour Run 533

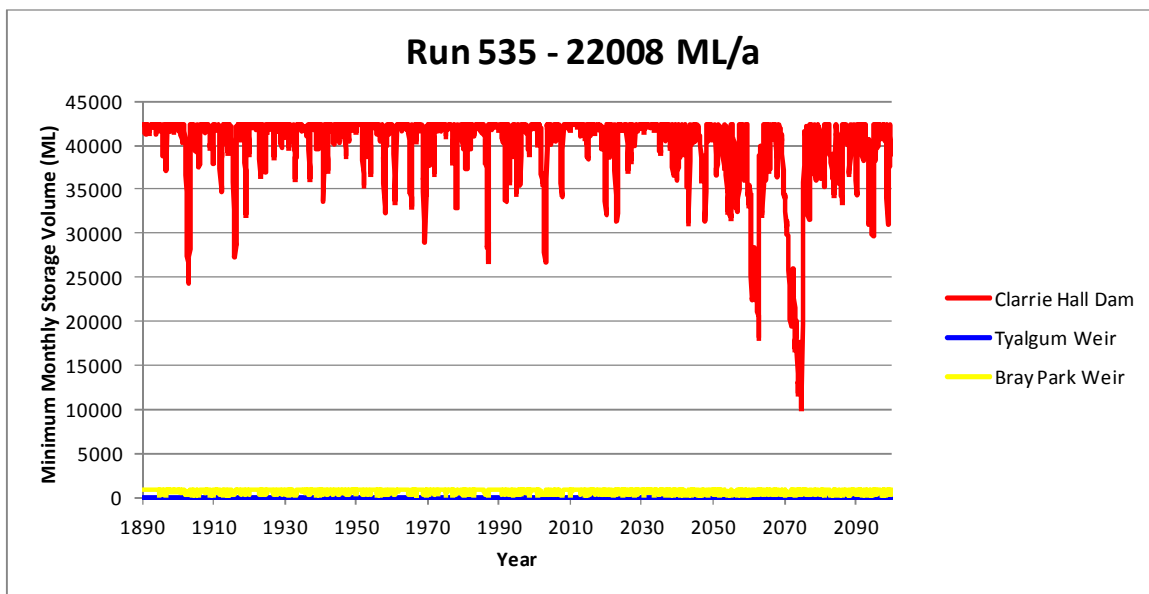


Figure 33: Storage Behaviour Run 535

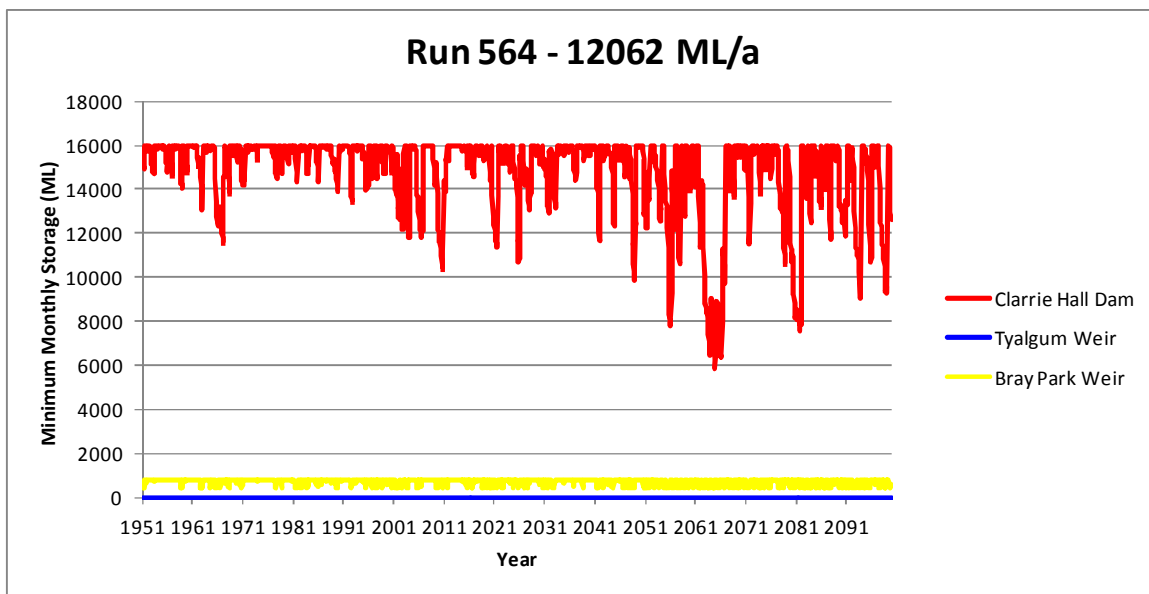


Figure 34: Storage Behaviour Run 564

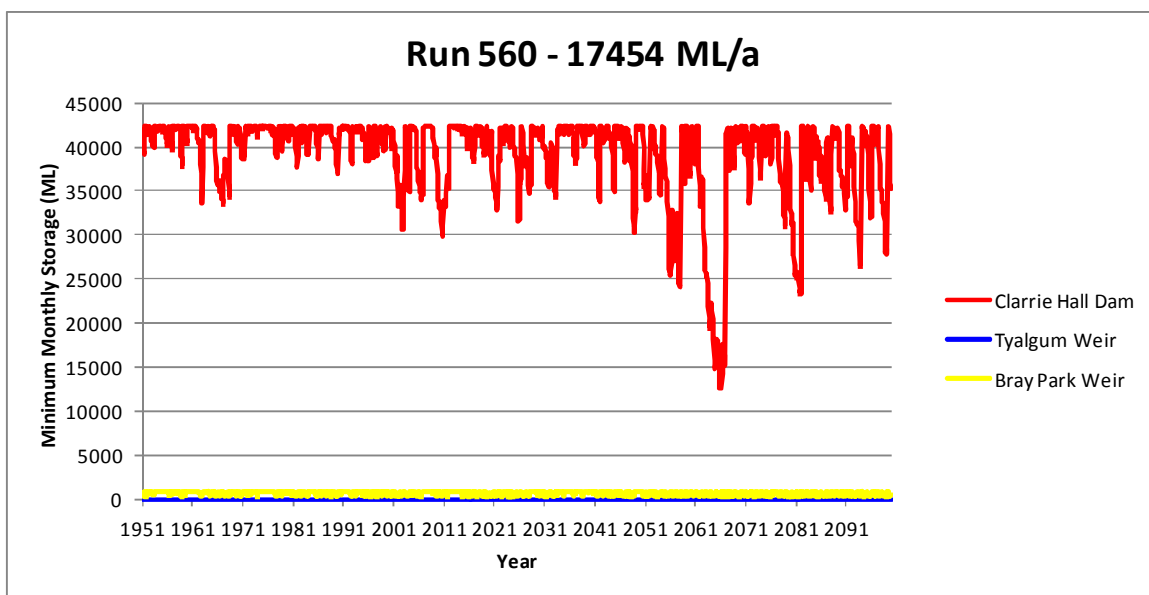


Figure 35: Storage Behaviour Run 560

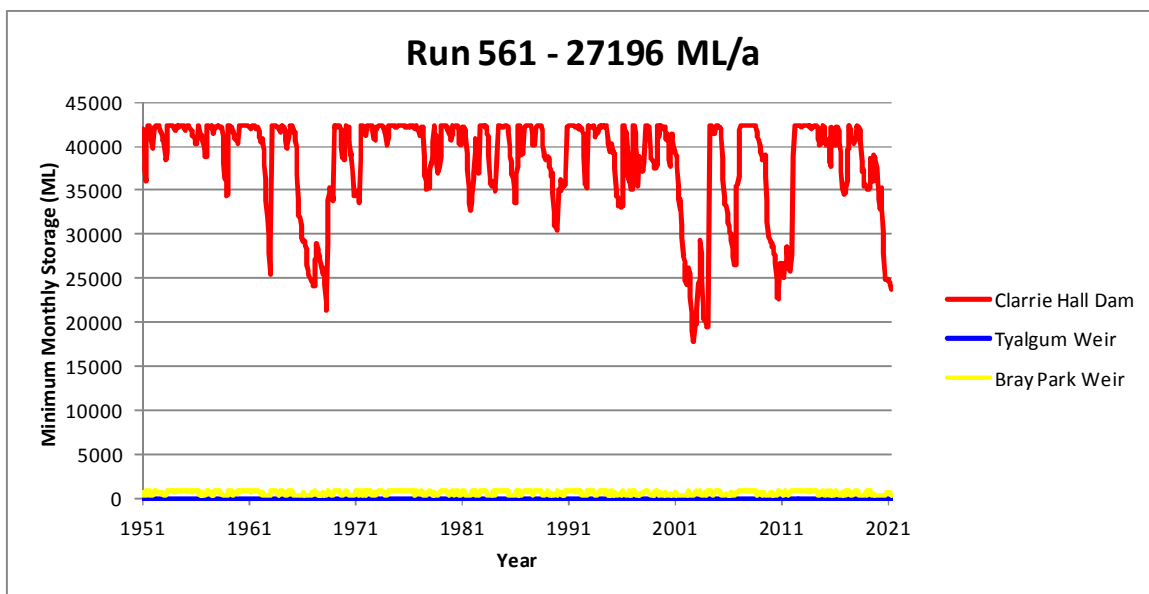


Figure 36: Storage Behaviour Run 561

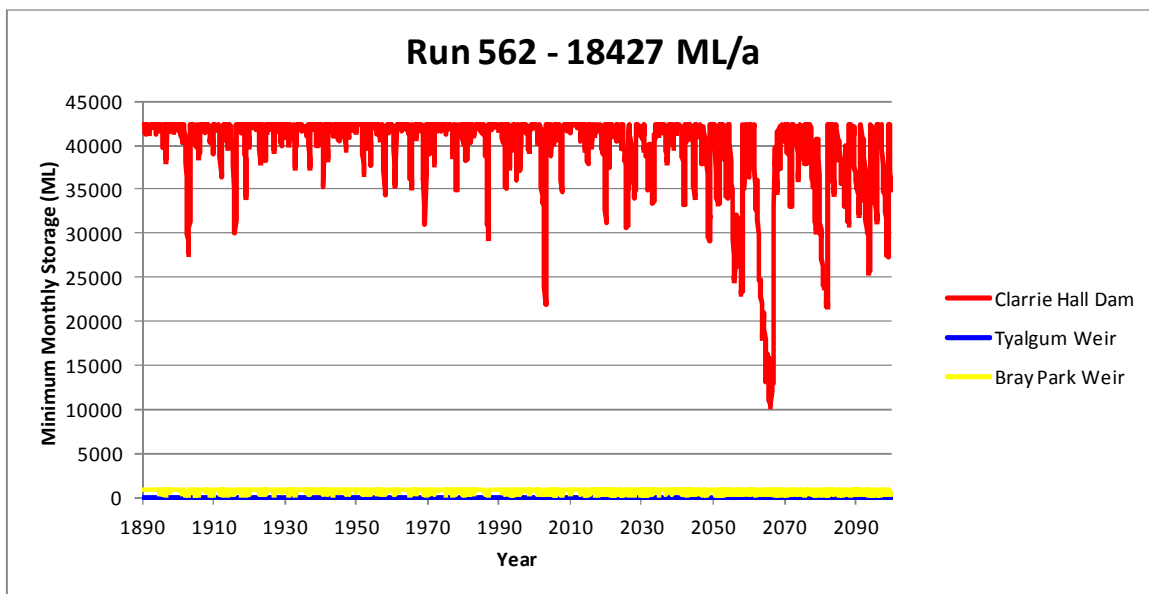


Figure 37: Storage Behaviour Run 562

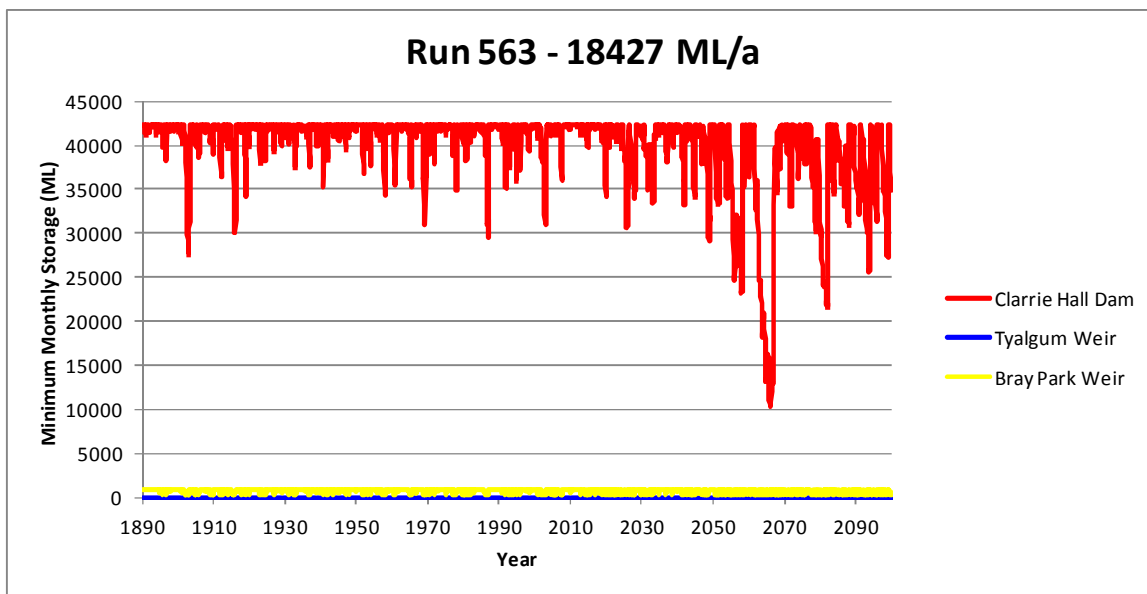


Figure 38: Storage Behaviour Run 563

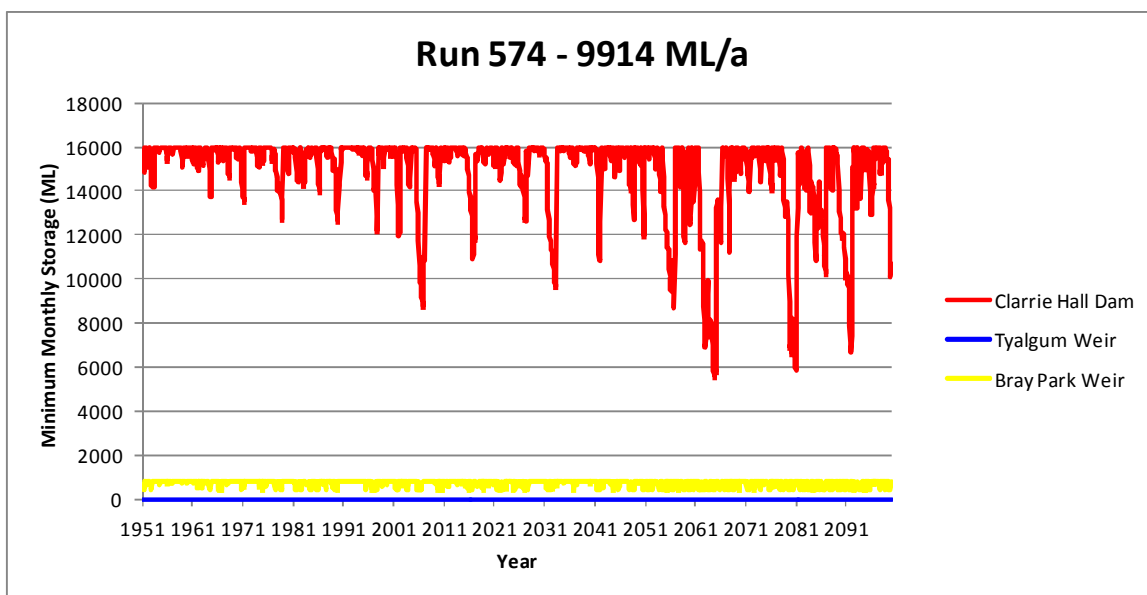


Figure 39: Storage Behaviour Run 574

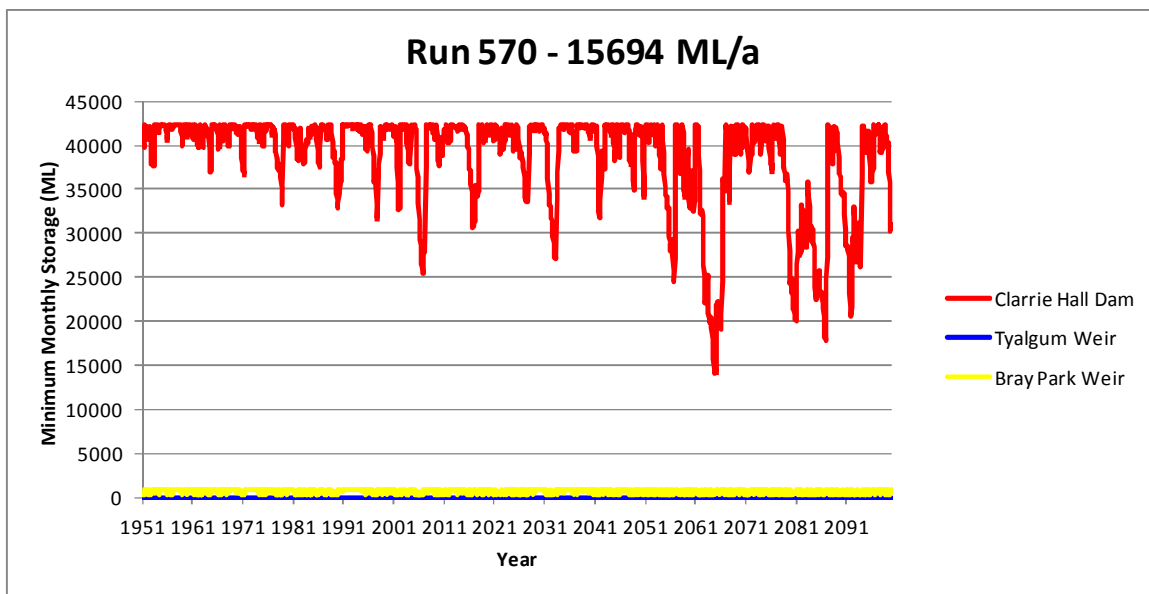


Figure 40: Storage Behaviour Run 570

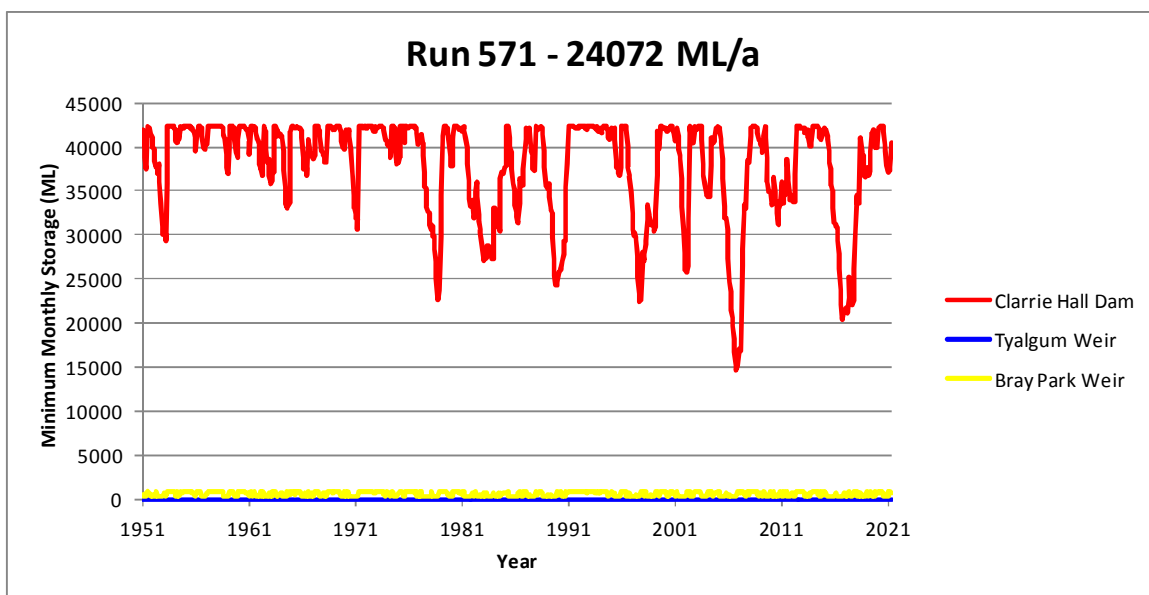


Figure 41: Storage Behaviour Run 571

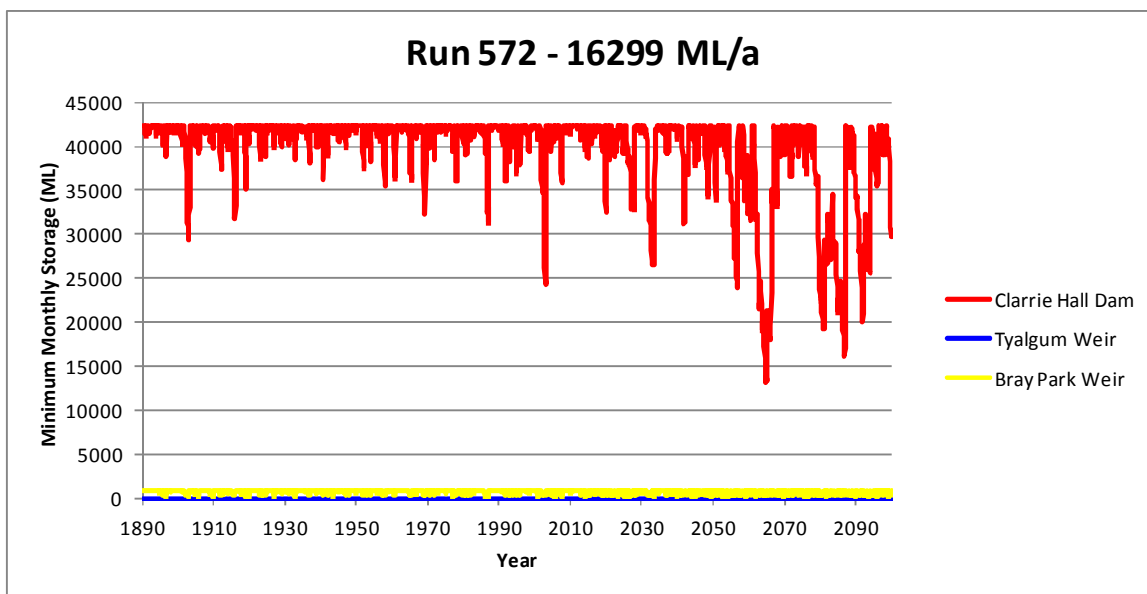


Figure 42: Storage Behaviour Run 572

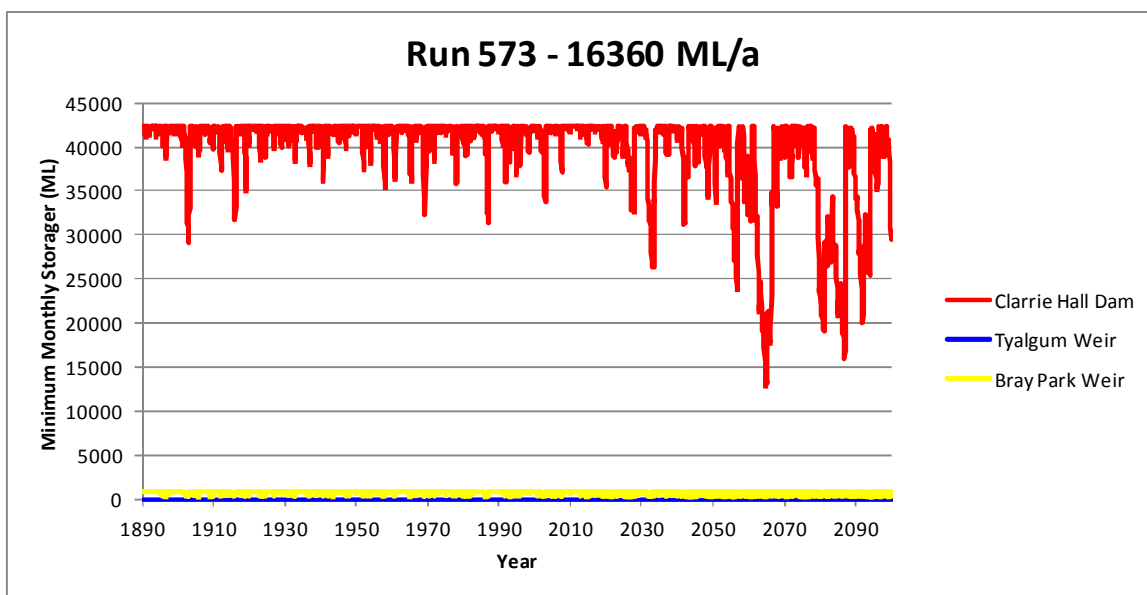
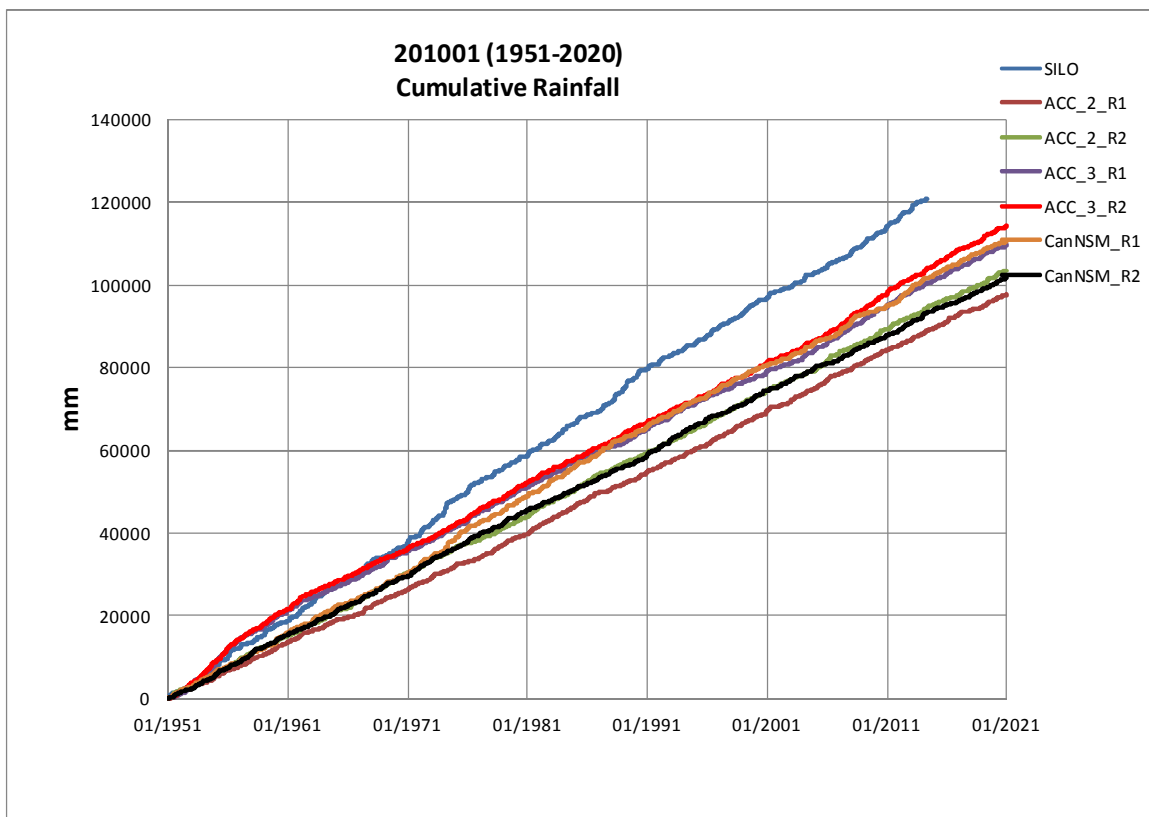
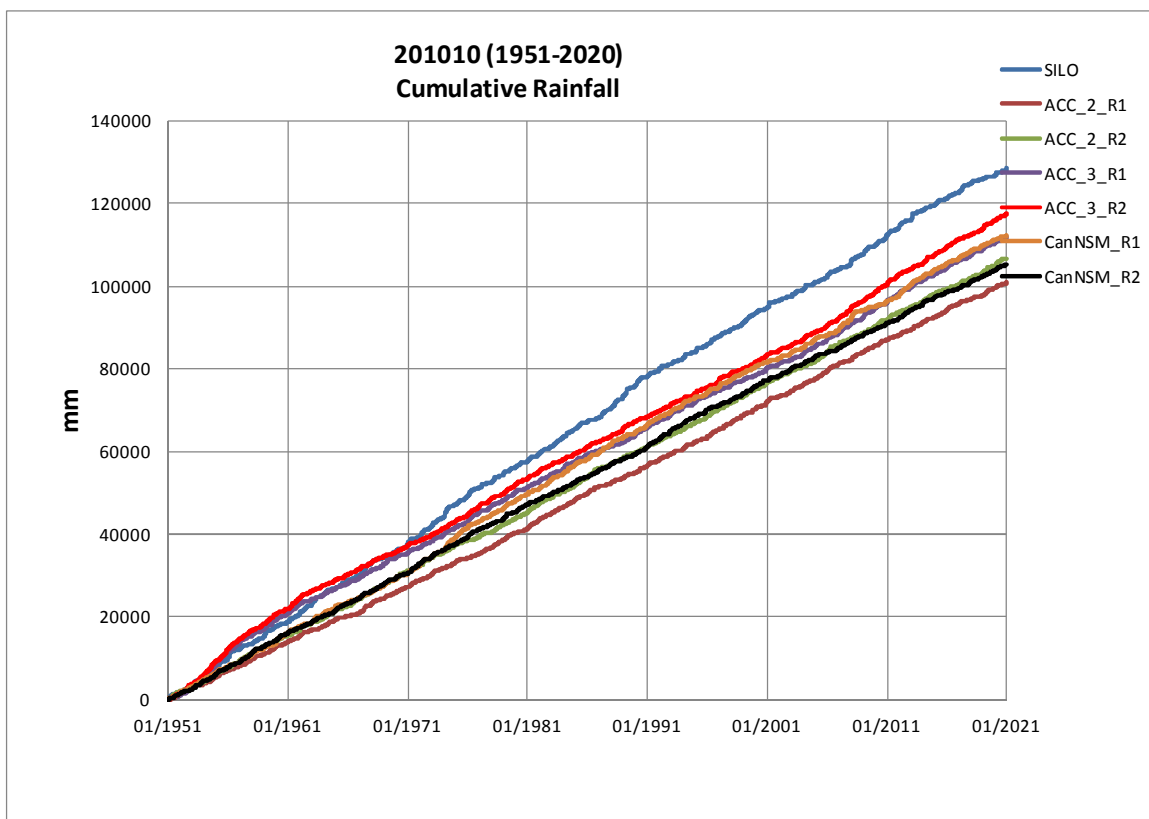


Figure 43: Storage Behaviour Run 573

**Figure 44: Gauging Station 201001 Subcatchment Rainfall****Figure 45: Gauging Station 201010 Subcatchment Rainfall**

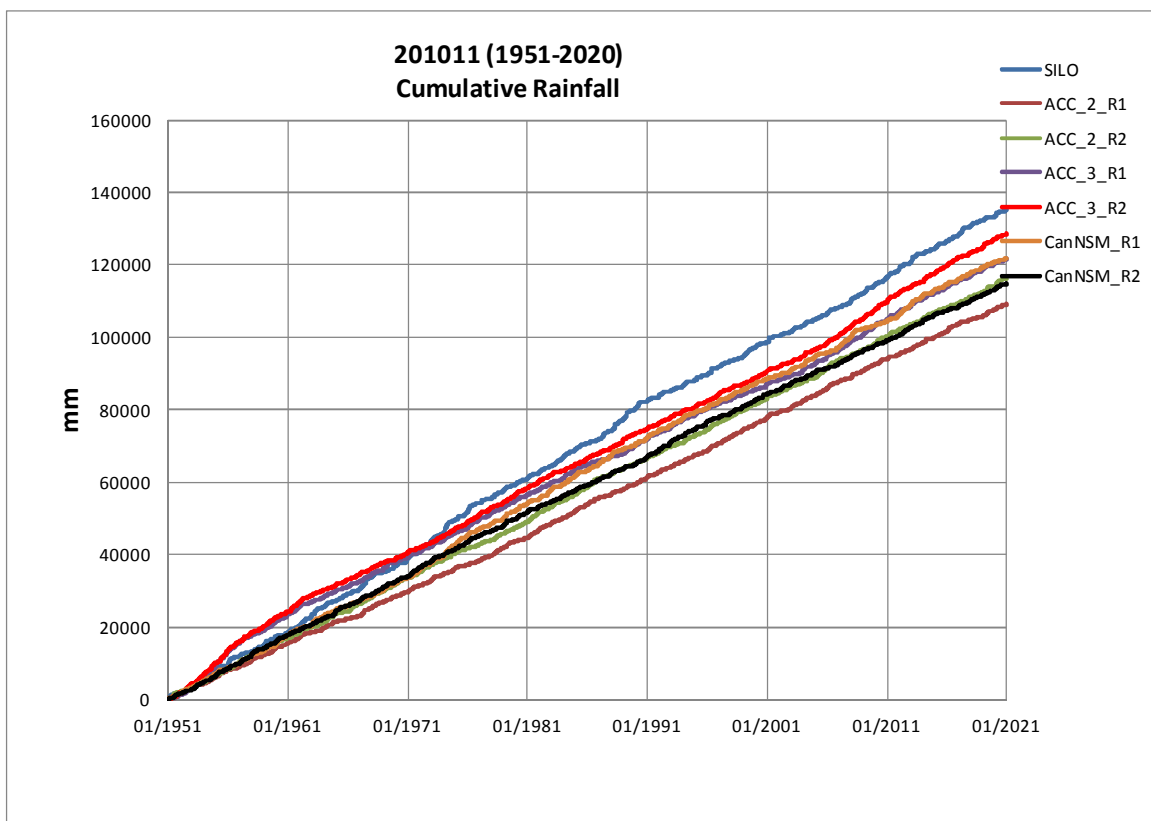


Figure 46: Gauging Station 201011 Subcatchment Rainfall

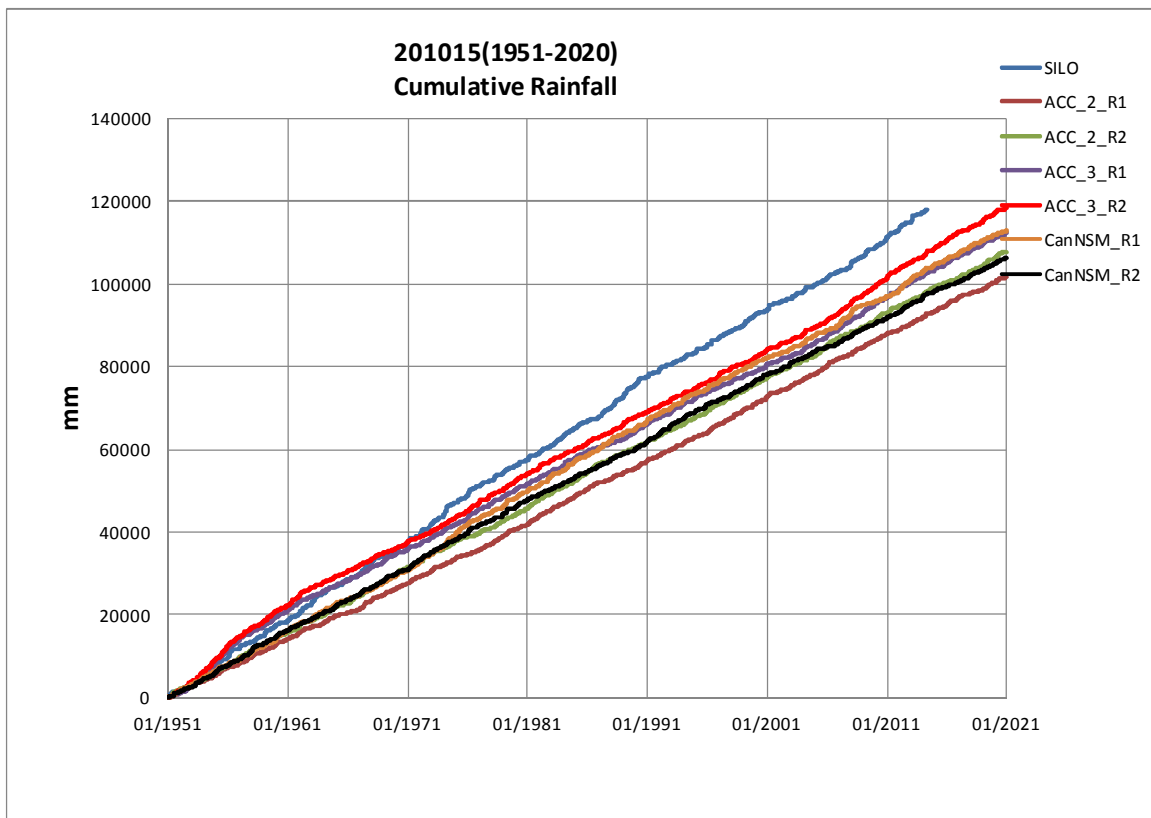


Figure 47: Gauging Station 201015 Subcatchment Rainfall

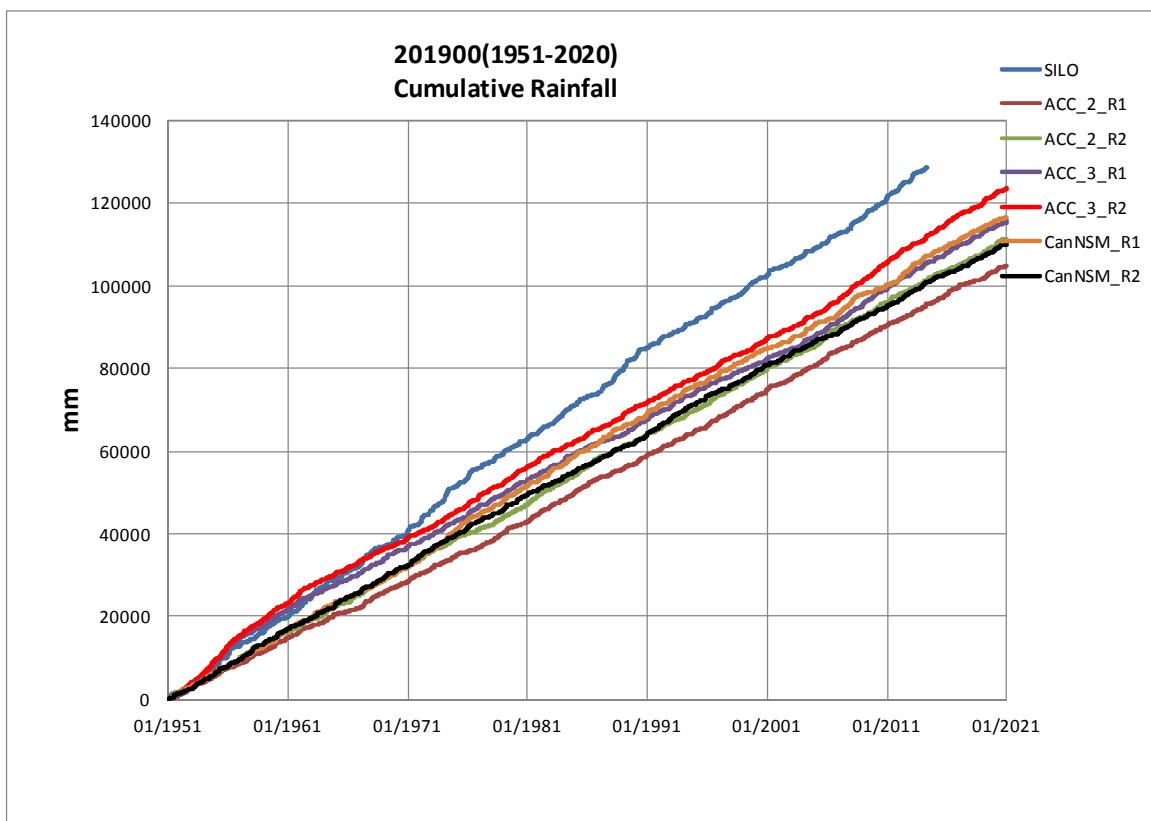
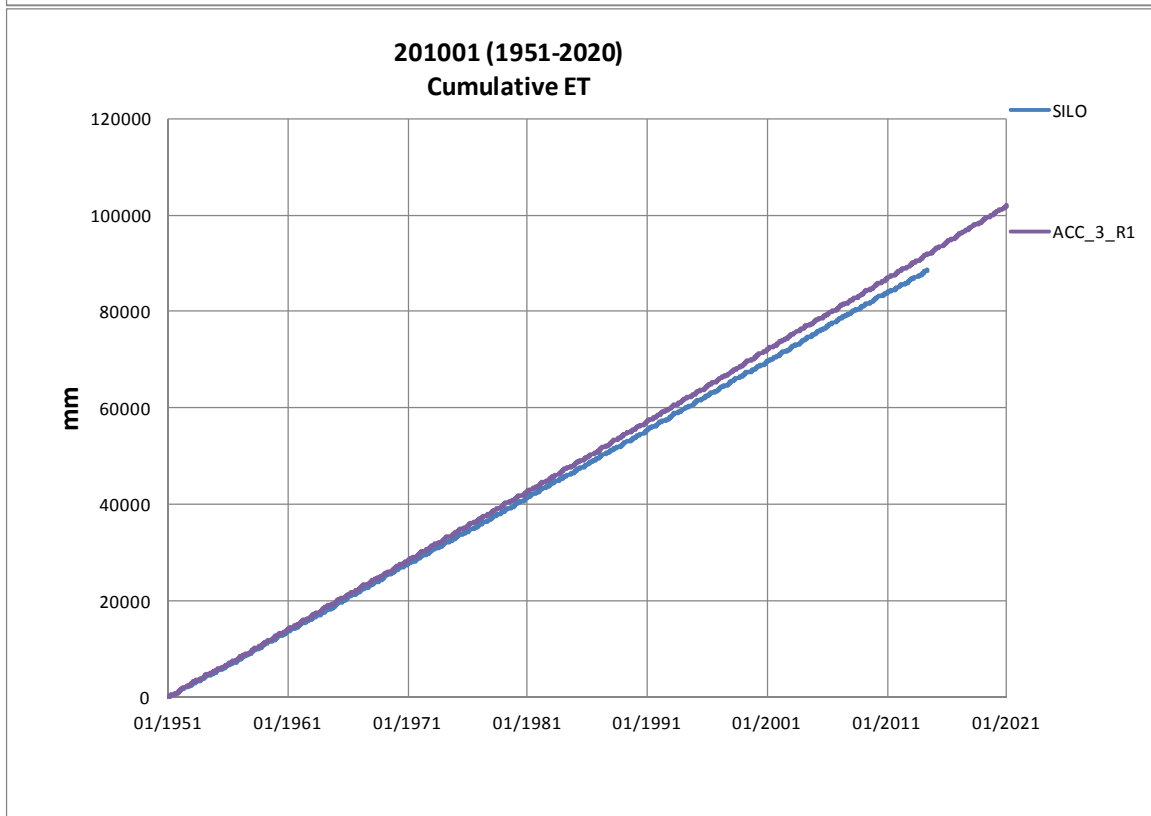
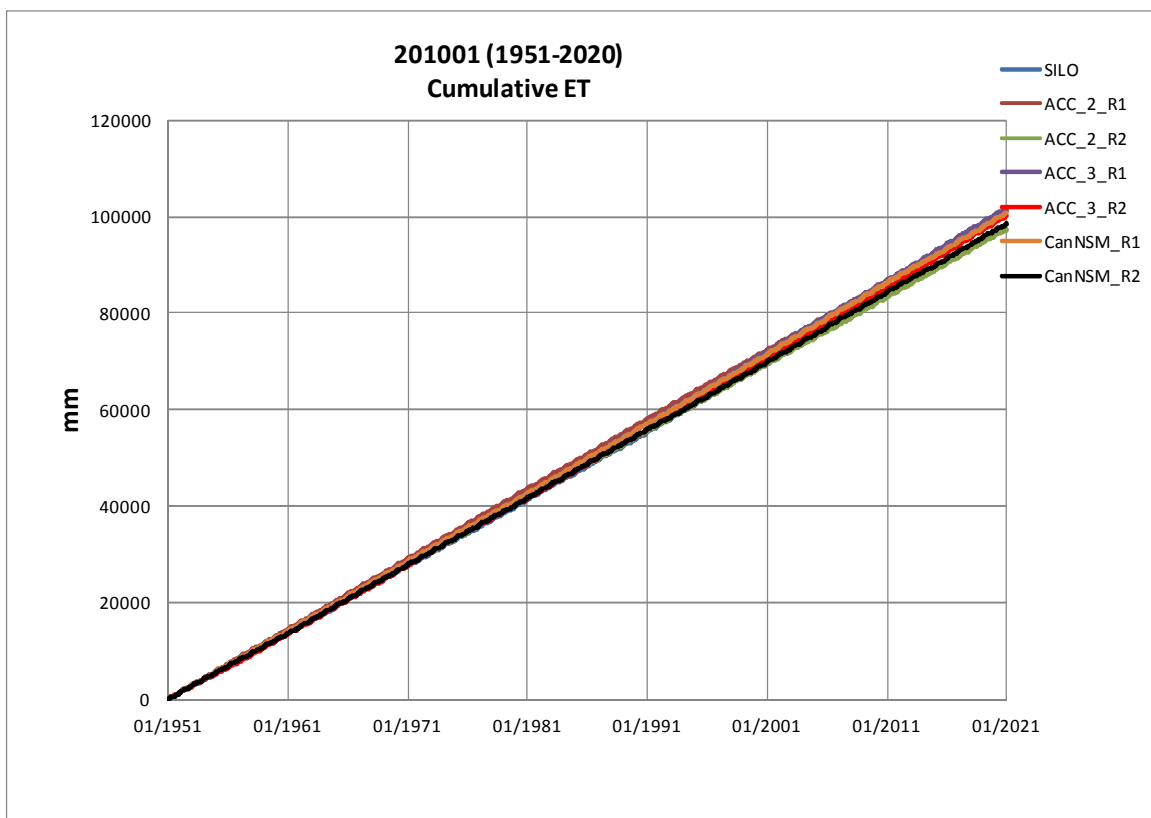
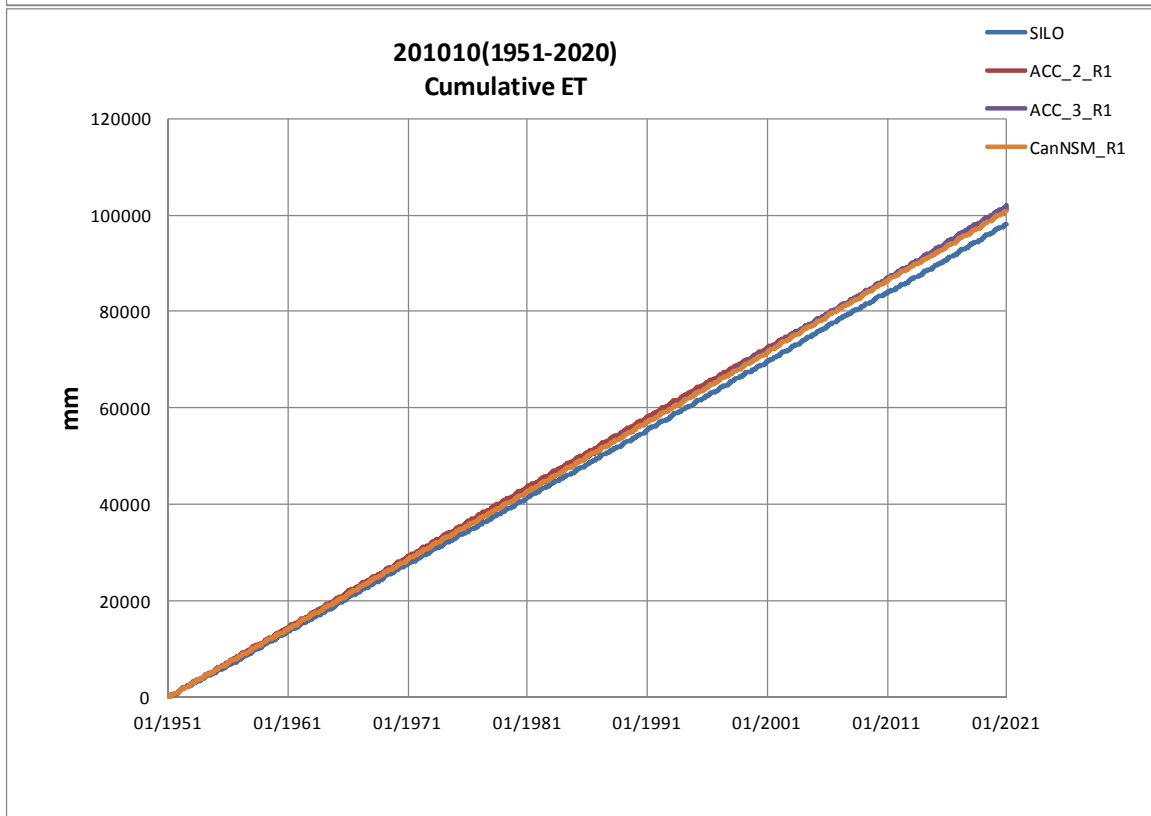
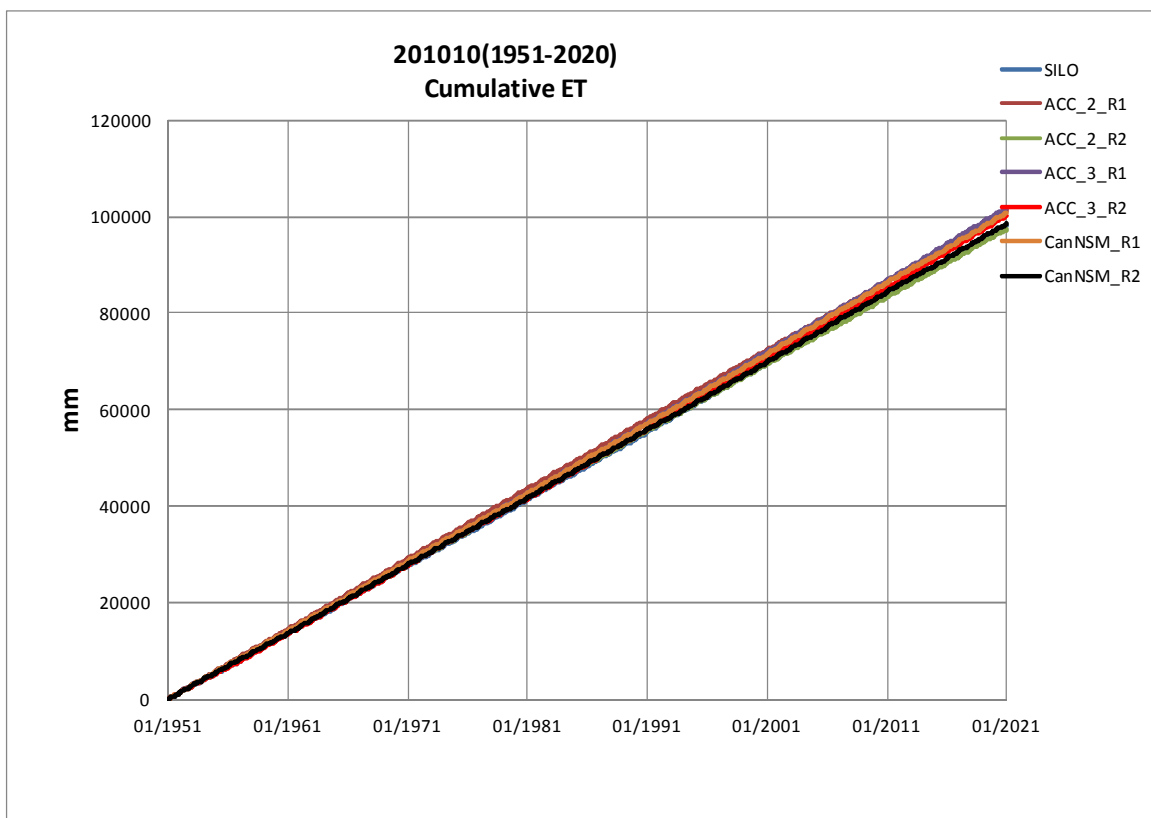


Figure 48: Gauging Station 201900 Subcatchment Rainfall



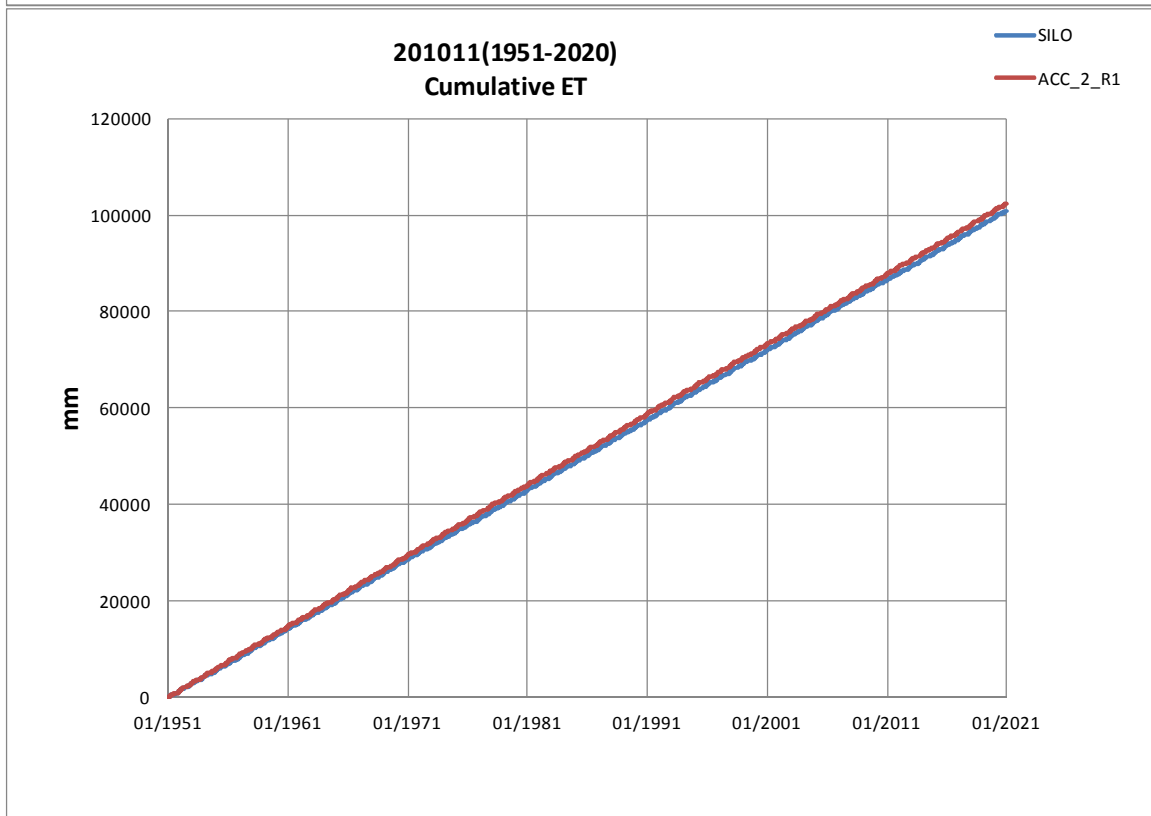
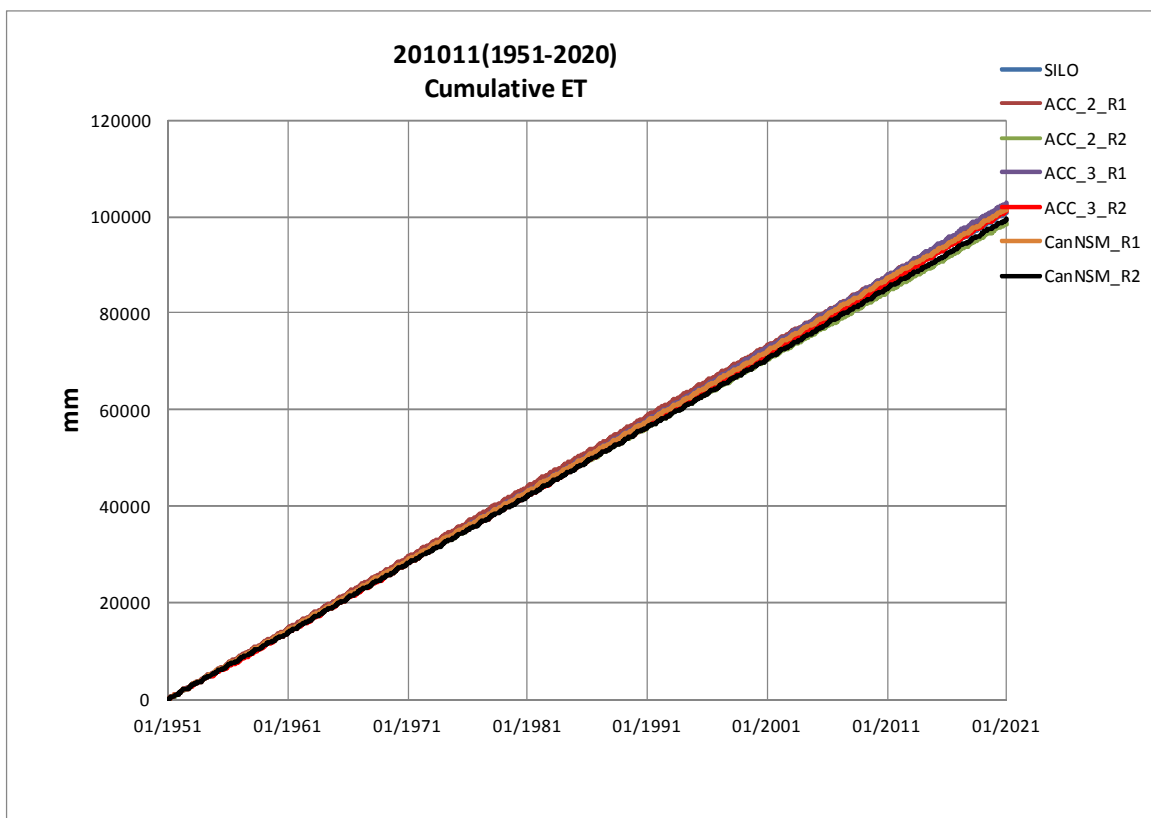
The lower plot provided to better show example separation from SILO Data

Figure 49: Gauging Station 201001 Subcatchment Evapotranspiration



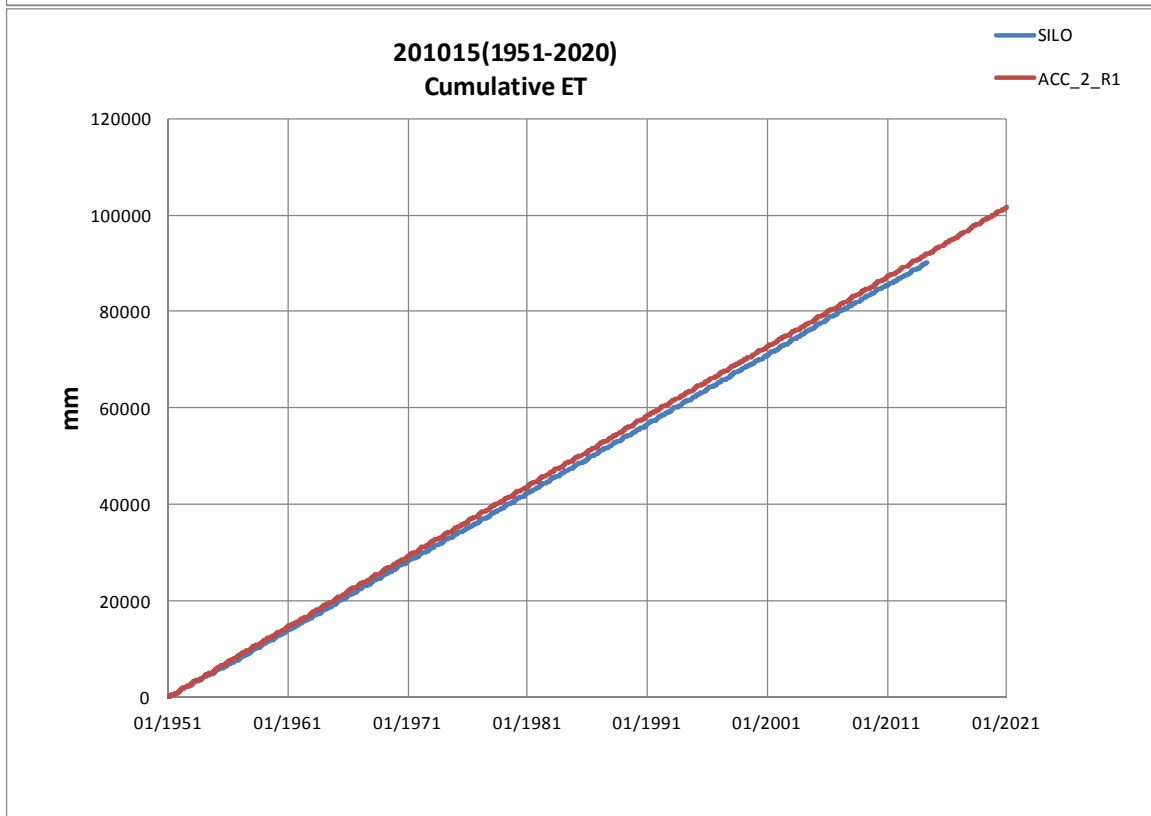
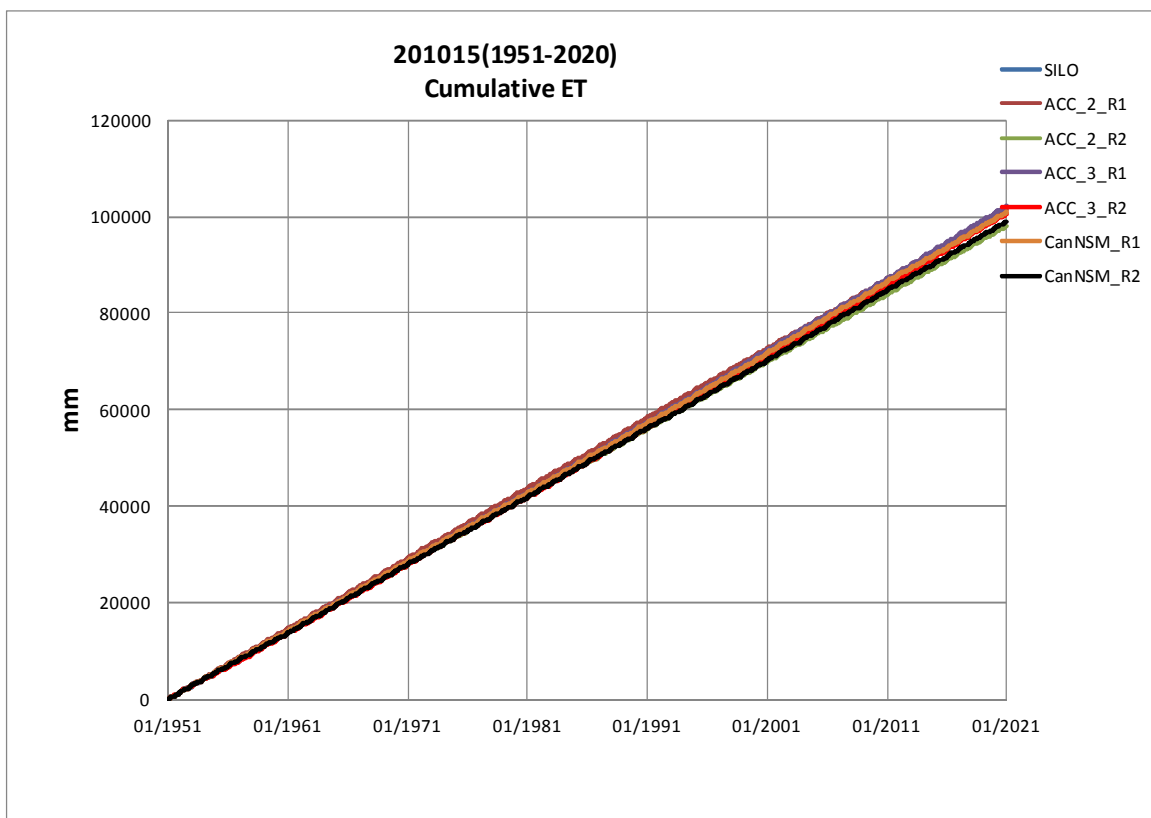
The lower plot provided to better show example separation from SILO Data

Figure 50: Gauging Station 201010 Subcatchment Evapotranspiration



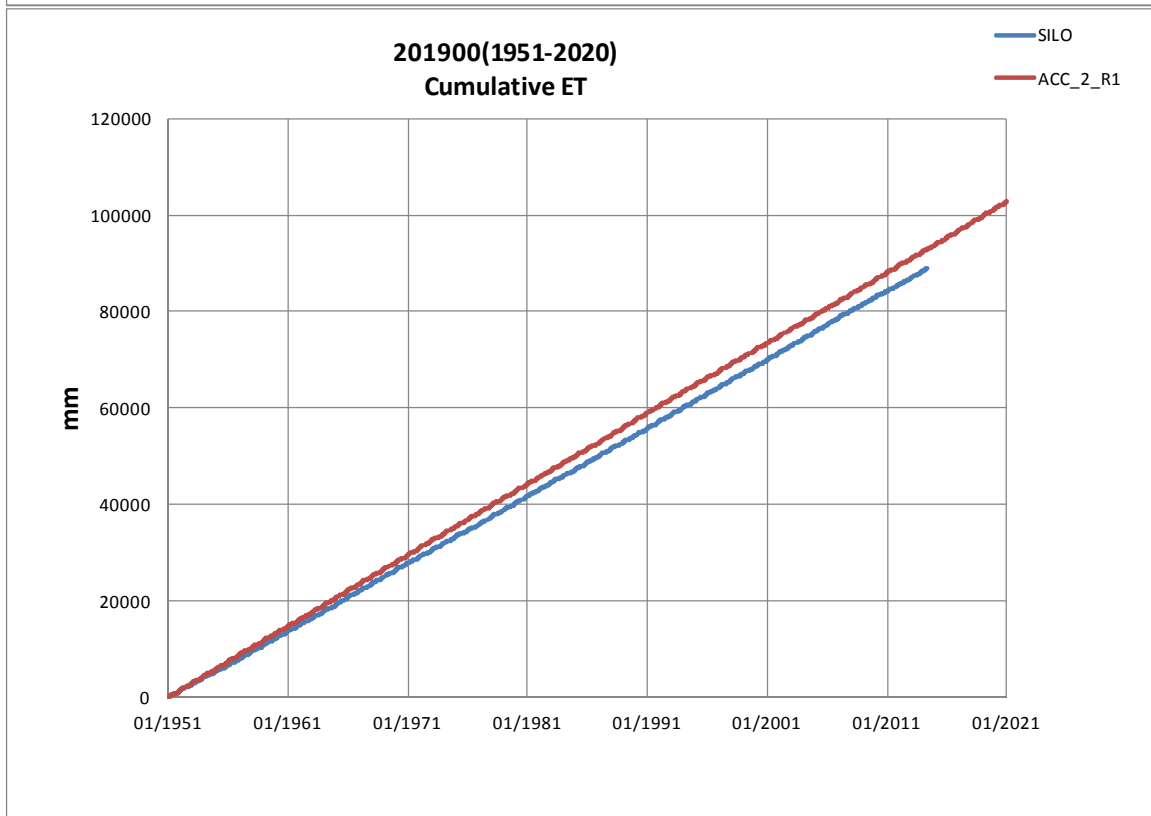
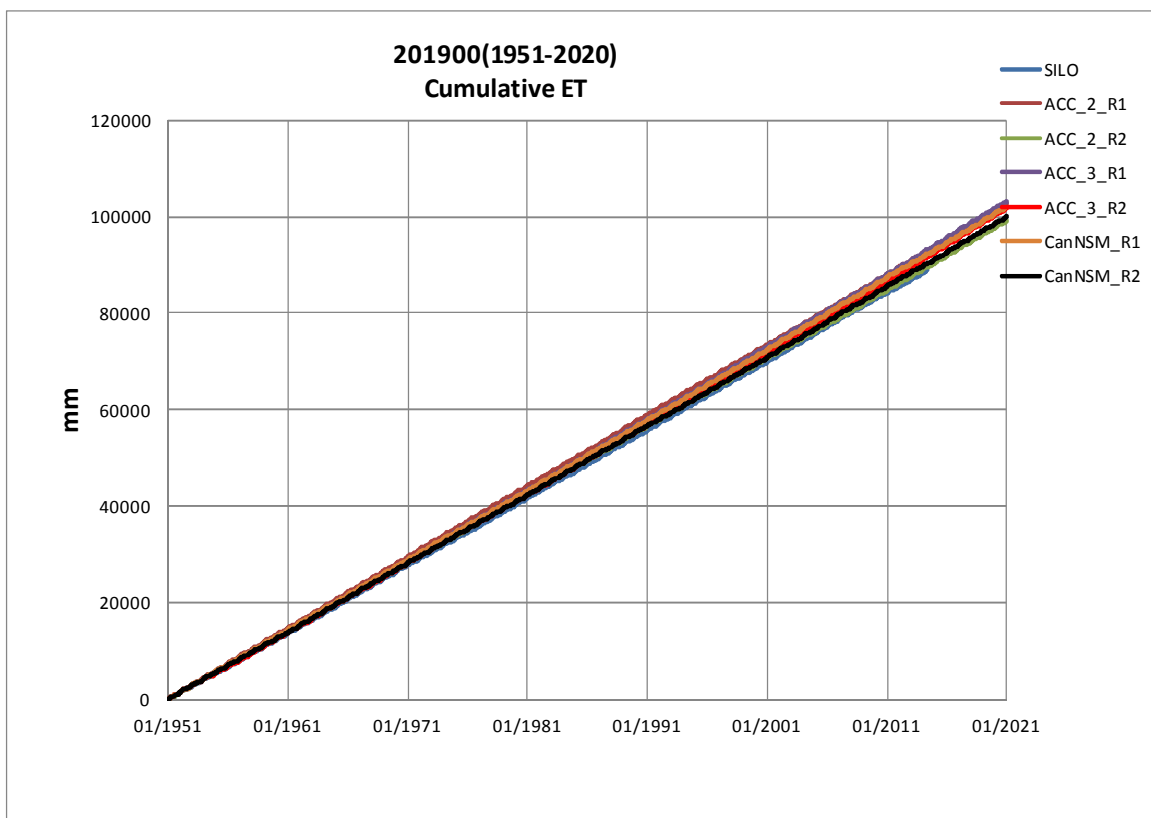
The lower plot provided to better show example separation from SILO Data

Figure 51: Gauging Station 201011 Subcatchment Evapotranspiration



The lower plot provided to better show example separation from SILO Data

Figure 52: Gauging Station 201015 Subcatchment Evapotranspiration



The lower plot provided to better show example separation from SILO Data

Figure 53: Gauging Station 201900 Subcatchment Evapotranspiration

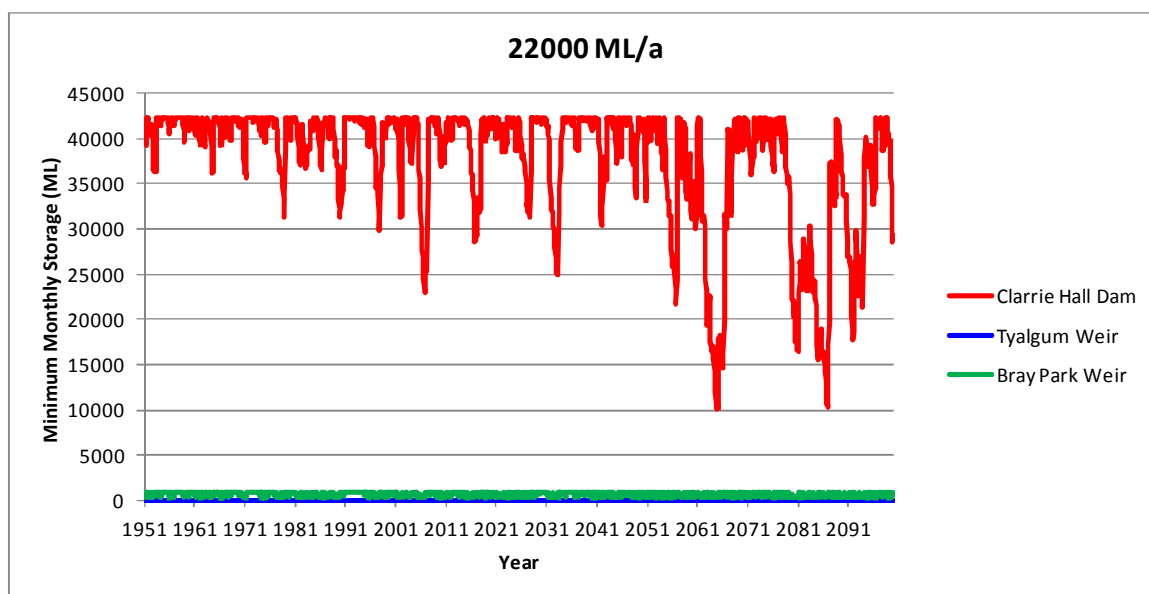


Figure 54: Stress Test Modelled Storage Behaviour

9 Appendices

Appendix A – Model Results for 15 GCMs and corresponding Historic Base

Refer to Chapter 5 for Details.

Note that in each case shown on the following pages the data is based on modelled flow information (from a data base of daily rainfall and daily evapotranspiration) and not observed flow data. The adopted historical secure yields uses observed flow data and a longer period and are those provided in Chapter 4 Tables 4.1&4.2. The following data is used to adjust the yield in Chapter 4 Tables 4.1 & 4.2 in accordance with the DPIE Water guidelines.

Existing Clarrie Hall Dam (16000 ML)

Tweed, Run 511CC

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Restricted**Critical Drought**

		Storage						
	Run	Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
LOWEST	1	16839	13460	65	3.05	9.48	19/10/1901	27/02/1903
	2	16839	15618	65	2.66	9.48	19/10/1901	25/02/1903
	3	16839	13792	65	2.81	9.48	12/10/1901	25/02/1903
	4	16839	11254	60	2.62	6.90	05/09/1901	25/02/1903
	5	16839	14330	65	2.75	9.48	19/10/1901	25/02/1903
	6	16839	14038	65	2.76	9.48	12/10/1901	25/02/1903
	7	16839	15323	65	2.64	9.48	19/10/1901	25/02/1903
	8	16839	14176	65	2.78	9.48	12/10/1901	25/02/1903
	9	16839	13389	60	1.78	4.31	12/10/1901	25/02/1903
	10	16839	17401	65	2.34	8.62	23/10/1901	25/02/1903
MEDIAN	11	16839	14683	65	2.51	9.48	19/10/1901	25/02/1903
	12	16839	14301	65	2.86	9.48	12/10/1901	25/02/1903
	13	16839	11907	60	2.35	6.90	12/10/1901	25/02/1903
	14	16839	15684	65	2.57	8.62	19/10/1901	25/02/1903
HISTORICAL	15	16839	16073	65	2.56	9.48	23/10/1901	25/02/1903
	16	16839	15831	65	2.51	8.62	23/10/1901	25/02/1903
10/15/25	4	16839	12794	60	3.74	14.66	05/09/1901	25/02/1903

Proposed Raised Clarrie Hall Dam (42300 ML)

Tweed, Run 515CC

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Restricted**Critical Drought**

	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
	1	43139	23028	60	2.64	9.48	12/10/1901	27/02/1903
	2	43139	25983	65	2.53	9.48	19/06/2001	01/02/2003
	3	43139	23694	60	2.30	9.48	13/06/2001	01/02/2003
LOWEST	4	43139	19778	55	2.60	9.48	04/09/1901	27/02/1903
	5	43139	24280	60	2.13	6.90	13/06/2001	01/02/2003
MEDIAN	6	43139	24231	60	2.35	9.48	12/10/1901	27/02/1903
	7	43139	25430	65	3.04	9.48	16/06/2001	01/02/2003
	8	43139	23898	60	2.08	5.17	12/10/1901	27/02/1903
	9	43139	24067	60	2.83	9.48	09/06/2001	01/02/2003
	10	43139	29747	65	2.41	9.48	27/07/2001	01/02/2003
	11	43139	24999	60	1.89	4.31	22/06/2001	01/02/2003
	12	43139	24069	60	2.08	6.90	12/10/1901	27/02/1903
	13	43139	20848	60	2.98	9.48	05/09/1901	27/02/1903
	14	43139	26065	65	2.64	9.48	17/06/2001	01/02/2003
	15	43139	26834	65	2.68	9.48	16/06/2001	01/02/2003
HISTORICAL	16	43139	26869	65	2.47	9.48	20/06/2001	01/02/2003
10/15/25	4	43139	21848	50	3.16	11.21	04/09/1901	27/02/1903

APPENDIX D

Concept Design Report





Clarrie Hall Dam Raising Concept Design Report

Report Number: ISR18033

Date: October 2018

Clarrie Hall Dam Raising

Concept Design Report

Report Number: ISR18033

Document Control

Issue / Revision	Authors	Reviewer	Approved for Issue	
			Name	Date
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Cover Image: Clarrie Hall Dam

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All references to Public Works Advisory are references to the Minister of Finance, Service & Property for and on behalf of the State of New South Wales through the Department of Finance, Services & Innovation.

Executive Summary

This report concerns concept design for the raising of Clarrie Hall Dam. The proposed raised dam will increase the existing storage at Full Supply Level (FSL) from 16,000 ML to 42,300 ML and is expected to meet the additional water security requirements of the Tweed Shire community well into the future.

The preferred dam raising option incorporates increasing the height of the existing concrete faced rockfill embankment and construction of a new concrete lined spillway higher up in the left abutment. The existing intake tower and access bridge will also be raised.

In accordance with NSW Dams Safety Committee (DSC) guidelines, Clarrie Hall Dam has been assigned an EXTREME Consequence Category which requires safe passage of the Probable Maximum Flood (PMF). Studies have identified that the optimum raising of the dam is with FSL at RL70.0m(AHD). The associated maximum flood level is at RL77.0m(AHD).

Concept design for the raised dam and its components has been based on updated hydrological and geotechnical investigations, seismic and structural assessments. This report presents three options for spillway upgrade but provides more detailed concept design for the preferred option and associated raised dam arrangement. Drawings and cost estimate are included as well as discussion on project risks and constructability.

Concept design has been undertaken in full compliance of DSC and ANCOLD requirements and current best practice.

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APPENDIX F PROJECT TIME LINE

APPENDIX G PROJECT RISK MATRIX

APPENDIX H PROJECT COST ESTIMATE AND COST RISK ASSESSMENT

Glossary of Terms / Abbreviations

Abutment

That part of the valley side against which the dam is constructed.

AHD

Australian Height Datum.

A datum for the recording of elevations. Zero metres AHD approximates mean sea level along the coast.

ANCOLD

Australian National Committee on Large Dams.

Annual Exceedance Probability (AEP)

The probability of a specified magnitude of a natural event being exceeded in any year.

BOM

Bureau of Meteorology

Catchment

The land surface area that drains to a specific point, such as a reservoir.

Computational Fluid Dynamics (CFD)

3D hydraulic modelling program

Consequence

Effects of an action or event (e.g. the potential for loss of life, property or services).

Consequence Category

The scale of adverse consequences subsequent to a dam failure. Refer also Flood Consequence Category and Sunny Day Consequence Category.

Council

Tweed Shire Council (TSC).

Dam Crest Flood (DCF)

The flood event which, when routed through the reservoir, results in a still water reservoir level at the lowest crest level of the dam.

DSC

NSW Dams Safety Committee.

Flood Consequence Category (FCC)

An estimate of the adverse consequences emanating from flood failure of the dam, such as loss of life, property and services damage and environmental effects.

Foundation

The undisturbed material on which the dam structure is placed.

Freeboard

The vertical distance between a stated water level and the top of the non-overflow section of a dam.

Full Supply Level (FSL)

The maximum normal operating water surface level of a reservoir.

H & V

Horizontal and Vertical e.g. 3.5H to 1V describes the steepness of a slope or batter.

Height of Dam

Normally the maximum height from the lowest point of the general foundation area to the top of the dam.

MDE

Maximum Design Earthquake.

ML

Megalitre (measurement of water volume).

MPa

Megapascal (unit of pressure, measurement of strength, equivalent to about 145psi).

OBE

Operating Basis Earthquake.

Probable Maximum Precipitation (PMP)

The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular catchment area.

Probable Maximum Flood (PMF)

The flood resulting from PMP and, where applicable, snow melt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

Probable Maximum Precipitation Design Flood (PMPDF)

The flood derived from the PMP using AEP neutral assumptions, and as such it is estimated to have the same AEP as the PMP.

PWA

Public Works Advisory (formerly NSW Public Works).

RL

Reduced Level (Survey).

RORB

The software program used to analyse the hydrology (rainfall–runoff processes) of the catchment and calculates hydrographs and peak discharges.

SCADA

Supervisory Control and Data Acquisition, a means of remote access, associated with telemetry.

Sunny Day Consequence Category (SDCC)

An estimate of the adverse consequences emanating from the non-flood (e.g. earthquake) failure of a dam, such as loss of life, property and services damage and environmental effects.

WAE

Work As Executed

1. Introduction

1.1 Background

Tweed Shire Council has engaged Public Works Advisory within the Department of Finance, Services and Innovation to undertake concept design for the proposed raising of Clarrie Hall Dam. The raising of Clarrie Hall Dam seeks to increase the storage level from the current Full Supply Level (FSL) of RL61.5m(AHD) to RL70.0m(AHD). The proposed raised dam will increase the dam's storage capacity from 16,000 ML to 42,300 ML. The project aims to meet the additional water security requirements of the Tweed Shire community into the future.

This report presents discussion of associated investigations and concept designs and includes drawings and cost estimate for the preferred dam raising option. This report has also been prepared as further background information to support the environmental impact assessment process and Council's business case for investment purposes.

Site locality and location plans covering the study area are provided at the end of this section as **Figure 1-1**.

1.2 Project Deliverables

The key deliverables of this project include the following:

- Updated hydrology study including flood hydrographs and flood frequency curves;
- Geotechnical investigations of the site geology and suitability of the rockfill for the raised embankment;
- Separate hydrological, seismic and geotechnical reports produced by sub-consultants which are summarised in this Concept Design Report;
- Computational Fluid Dynamics (CFD) analysis of the preferred spillway option to confirm the dimensions and hydraulic performance; and
- A comprehensive Concept Design Report incorporating discussion of all investigations, analyses and results and including drawings and cost estimate of the preferred dam raising arrangement.

Construction methodology and timing are discussed in **Section 8**. Project risk and cost estimate are presented in **Section 9** and **Section 10** respectively.

1.3 Reference Documents

Reference documents used for concept design of the proposed dam raising and associated works are mentioned in relevant sections of this report and are fully listed in **Section 12**.

It is noted that, because of its historic and close involvement with Clarrie Hall Dam, Public Works Advisory (formerly NSW Public Works and Public Works Department) has maintained in its

possession, and therefore made available for this project, all relevant reference documents including from investigation and design of the original dam (completed in 1984) and later upgrade works (completed in 2014) as well as previous dam raising option studies.

1.4 Design Criteria

The dam raising option developed for this concept is based on NSW Dams Safety Committee (DSC) requirements and is also consistent with Australian National Committee on Large Dams (ANCOLD) guidelines. According to the latest Dambreak Study (NSW Public Works, 2007), Clarrie Hall Dam is assigned a HIGH A Sunny Day Consequence Category (SDCC) and a HIGH A to EXTREME Flood Consequence Category (FCC). Generally, concept design of Clarrie Hall Dam Raising has adopted the greatest assessed Consequence Category from the Dambreak study, that is EXTREME.

The Acceptable Flood Capacity (AFC) starting point, as outlined in DSC3B (June 2010) for EXTREME FCC dams, is the PMF flood. The PMF flood has therefore been used as a basis for key design requirements.

The Maximum Design Earthquake (MDE) from DSC3C (June 2010) for HIGH A SDCC dams is assessed to be the 0.01% AEP (10,000 year) event.

Further discussion regarding the AFC and MDE is provided at **Sections 4.1 and 4.2** respectively.

1.5 Concept Design Drawings

Drawings of the existing dam are attached at **Appendix A**.

Concept design drawings which show the key features, dimensions and extent of the Clarrie Hall Dam Raising project are provided at **Appendix B**. These drawings are listed below.

Drawing No.	Drawing Title
Figure 1	Existing Site Plan
Figure 2	Option 1A General Arrangement
Figure 3	Option 1B General Arrangement
Figure 4	Option 2 General Arrangement
Figure 5	Option 1A/1B Spillway Layout and Long Section
Figure 6	Option 1A/1B Spillway Details and Cross Sections
Figure 7	Option 2 Spillway Layout and Typical Sections
Figure 8	Option 2 Spillway and Training Wall Long Sections
Figure 9	Dam Embankment Raising Plan and Long Section
Figure 10	Dam Embankment Raising Typical Cross Section
Figure 11	Intake Tower General Arrangement
Figure 12	Intake Tower Upgraded Work Details
Figure 13	Intake Tower Upgraded Access Bridge Details

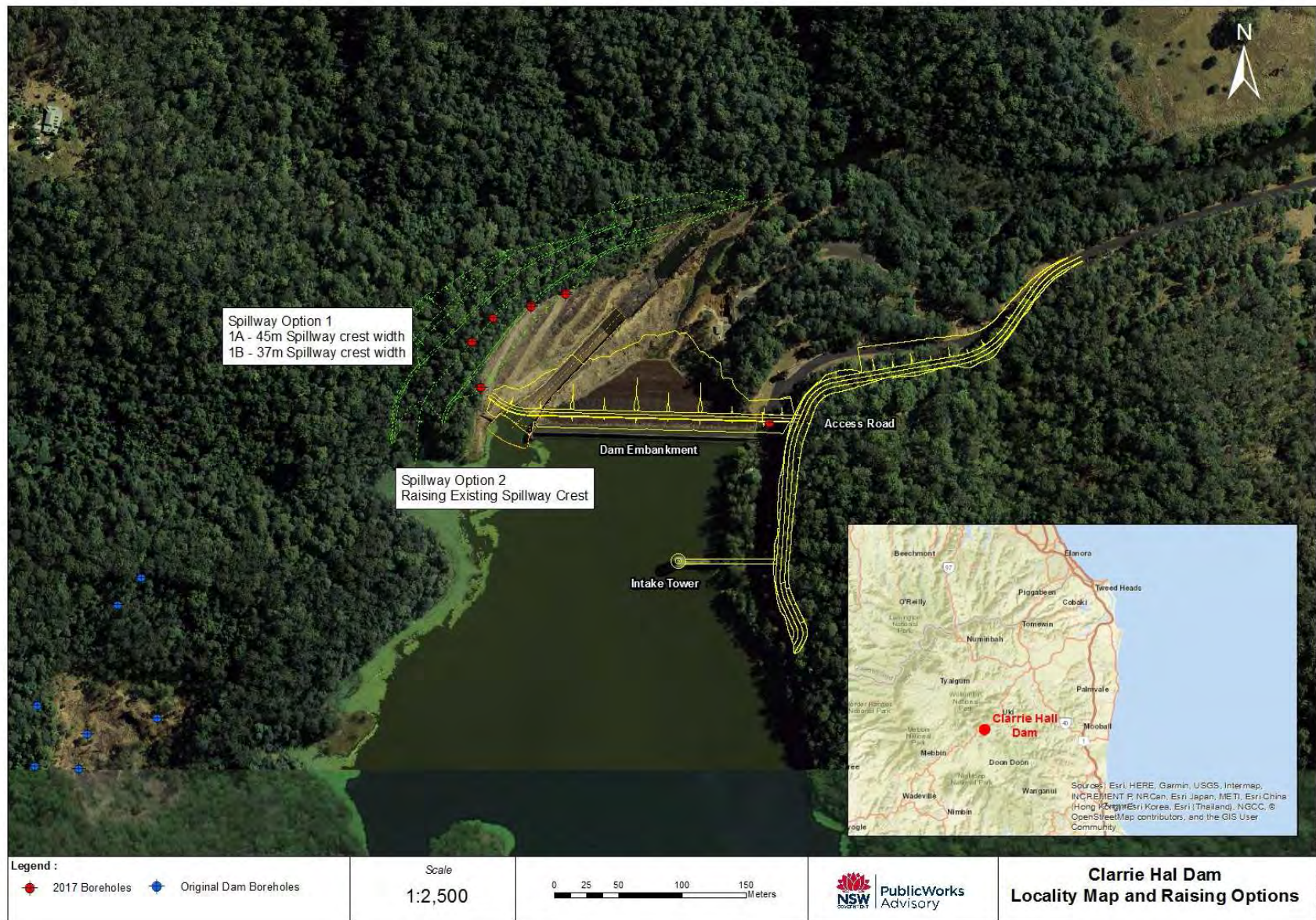


Figure 1-1: Locality and Option Map for Clarrie Hall Dam Raising

2. Description of Existing Dam

Clarrie Hall Dam is located on Doon Doon Creek, some 15 kilometres south-west of Murwillumbah. Doon Doon Creek is a generally north flowing tributary of the South Arm of the Tweed River. Water is released down Doon Doon Creek to the Tweed River, where it is subsequently harvested at the Bray Park weir.

The dam was designed by NSW Public Works (now Public Works Advisory or PWA) and construction was completed in 1984. Clarrie Hall Dam consists of a concrete faced rockfill embankment, a concrete lined spillway, intake and outlet works constructed on a foundation of very hard/strong rhyolite rock (of volcanic origin). The rockfill embankment has a height of 43 metres, crest length of 175 metres and a volume of about 160,000 cubic metres. The crest width is 6 metres; the upstream and downstream slopes are 1V to 1.3H. The upstream slope is covered by a 300mm thick concrete face slab which connects at the top to a wave wall along the embankment crest. Precast concrete parapet wall units are located adjacent to the wave wall which were installed as part of the recent spillway upgrade works. The bottom of the face slab is tied to the embankment's upstream concrete toe slab which also acts as the grout cap. A grout curtain comprising a single line of holes is located under the slab.

The dam is founded on a relatively uniform sequence of hard rhyolite rock with minor welded tuff. Geotechnical investigations have revealed very high to extremely high Uniaxial Compressive Strengths (UCS) for a great part of the rhyolite rock foundation.

Rockfill for construction of the embankment had been sourced from a nearby quarry site located approximately 300m south-west of the dam site.

The embankment profile includes the following zones underneath the upstream concrete face slab described above:

- Zone 1 - a semi permeable zone comprising moderately weathered rhyolite;
- Zone 2 – a permeable intermediate zone comprising slightly weathered to moderately weathered rhyolite;
- Zone 3A – a permeable zone comprising fresh rhyolite; and
- Zone 3B – a downstream mesh and face zone comprising selected fresh rhyolite.

The spillway is an ungated concrete chute with ogee weir and flip bucket located on the left abutment. The spillway chute, and approach area between the dam toe slab and spillway crest, are fully lined and have 6m to 10m high walls. The spillway chute is 110m long. The spillway crest is 36m wide and the chute width narrows to 12m for much of its length. The spillway was upgraded in 2014 (again designed by NSW Public Works), along with placement of precast concrete parapet wall units on the embankment crest, to pass the then probable maximum discharge of 1,355m³/s.

The intake/outlet system consists of a 34m high, 4m outside diameter reinforced concrete tower of the wet well type situated on a tower base structure at the head of the outlet tunnel which is located under the right abutment.

A concrete lined tunnel through the lower right abutment connects the intake tower with a valve house, located adjacent to the creek approximately 40 metres downstream of the embankment.

The present full supply level (i.e. top water level) of the dam is RL61.5m(AHD) which is 8.9 metres below the embankment wall crest level (i.e. the top of the precast concrete parapet wall on the dam crest). The dam has a catchment area of 60 square kilometres and a storage capacity of 16,000ML.

According to the latest dambreak study (NSW Public Works, 2007), Clarrie Hall Dam is classified as HIGH A Sunny Day Consequence Category and HIGH A to EXTREME Flood Consequence Category.

The existing dam and its components are illustrated on Drawings attached at **Appendix A**.

3. Dam Raising Options Study

A previous study investigating the optimum size and raising options for Clarrie Hall Dam was completed by PWA (NSW Public Works, 2007) and forms the basis of the current concept design. The study assessed five dam raising options:

- Single stage construction to FSL at RL70.0m(AHD);
- Single stage construction to FSL at RL67.0m(AHD);
- Single stage construction to FSL at RL64.5m(AHD);
- Two stage construction, to FSL at RL67.5m(AHD) and then from FSL at RL67.5m(AHD) to FSL at RL70.0m(AHD); and
- Two stage construction, to FSL at RL64.5m(AHD) and then from FSL at RL64.5m(AHD) to FSL at RL70.0m(AHD).

The study showed that the maximum optimum dam size for Clarrie Hall Dam was considered to have a FSL of RL70.0m(AHD). Inundation mapping of the storage levels showed that above a storage level of RL70.0m(AHD) significant breakouts occurred in the upstream storage and would result in the need for saddle dams, significantly increasing the cost of the project. The inundation extent of the dam storage with FSL at RL70.0m(AHD) is provided in **Figure 3-1**.

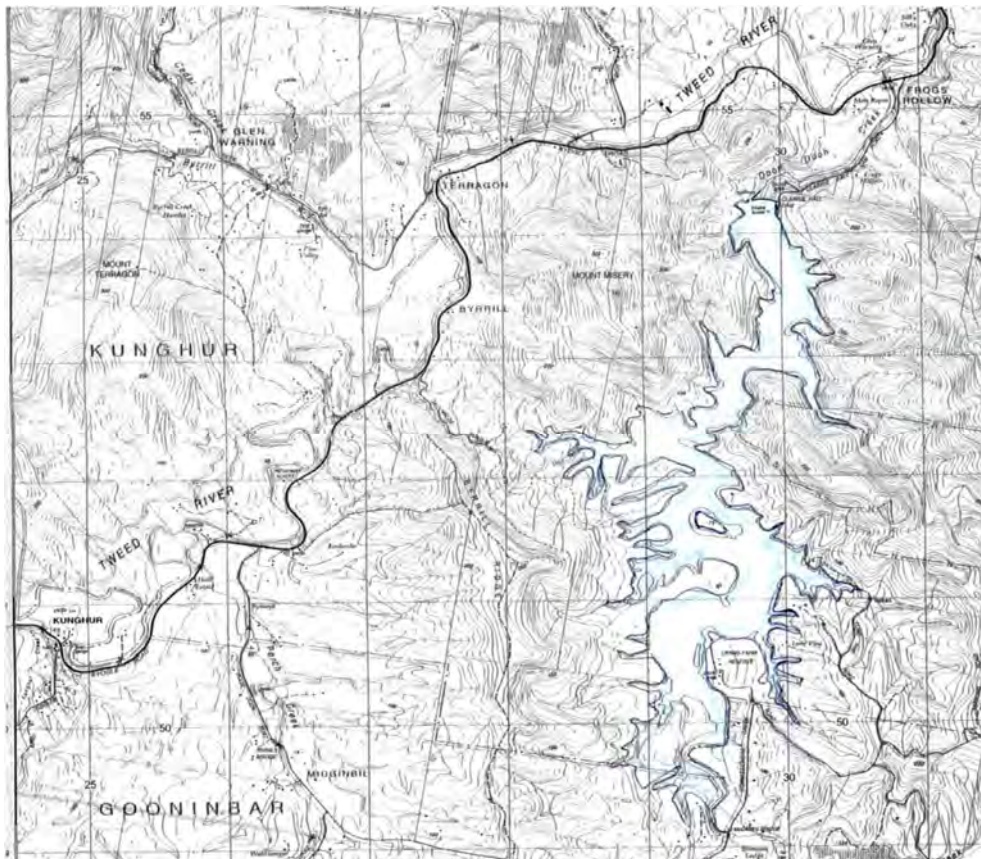


Figure 3-1: Upstream Storage Inundation for FSL 70.0m(AHD)

Cost estimates were completed for each option and they showed that the single construction option was far more economical than raising the dam in stages. It was also noted that single stage dam raising had less impact on the surrounding environment and constructability of the works. Operation of the dam was also disrupted further by staged dam raising. It was therefore a recommendation of the study that single stage construction to FSL RL70.0m(AHD) be adopted for concept design.

4. Dam Safety Design Standards

4.1 Acceptable Flood Capacity

The latest dambreak study carried out by PWA (NSW Public Works, 2007) assigned Clarrie Hall Dam a HIGH A Sunny Day Consequence Category (SDCC) and a HIGH A to EXTREME Flood Consequence Category (FCC). The NSW Dams Safety Committee (DSC) starting point, for any dam assessed as having an EXTREME FCC, is for it to pass the PMF flood event (DSC3B).

WRM Water and Environment Pty Ltd carried out an updated hydrological investigation for the Clarrie Hall Dam (WRM, 2017). The updated hydrological model produced a peak inflow of 3,503 m³/s for the critical 2-hour PMF storm event. The inflow hydrograph developed in the hydrological study was then used in the concept design for the raising of Clarrie Hall Dam to ensure that the flood was successfully passed. The PMF flood level was used to set the design level of the embankment wall height. See also **Section 5** of this report.

4.2 Design for Earthquake

An updated seismic hazard study was carried out by OZROCKS Geoservices Pty Ltd (OZROCKS, 2017). As Clarrie Hall Dam has been assigned a HIGH A SDCC, the DSC prescribes the maximum design earthquake to be the 0.01% AEP (10,000 year) event (DSC3C). See further discussion in **Section 5** of this report.

4.3 DSC Endorsement of Design Standards

The design characteristics previously outlined in **Section 4** and adopted for this concept design are in accordance with DSC guidelines. The DSC was consulted regarding the determination of the Consequence Category used for Clarrie Hall Dam. The maximum Flood Consequence Category resulting from the Dambreak was HIGH A to EXTREME. The EXTREME Flood Consequence Category was selected in discussion with the DSC and Tweed Shire Council in order to allow for future development in the downstream catchment and potential increase to the Clarrie Hall Dam storage. It is noted that, while the adoption of the EXTREME consequence category assigns the raised dam to withstand a high level of flood impact, it also provides long-term assurance of its integrity and safety.

The concept design as outlined in this report not only satisfies DSC requirements but is also in accordance with all relevant ANCOLD guidelines, Australian Standards and current best practice.

5. Supplementary Investigations and Reports

5.1 Hydrology

An updated hydrological study was undertaken for Clarrie Hall Dam (WRM, 2017). The RORB model was used to develop the hydrological conditions of the Clarrie Hall Dam catchments and the residual Tweed River catchments downstream. The model was successfully calibrated against three flood events; January 2008, January 2012 and January 2013. The calibrated hydrological model was then used to model design flood events for a number of critical storm durations.

The hydrological model became the basis for determining the Clarrie Hall Dam raising options with a varying spillway width. The preferred raised dam arrangement included a new spillway channel higher in the left abutment with sill level at the raised FSL of RL70.0m(AHD) and designed to pass the PMF.

A constant coefficient of discharge (C_D) of 1.8 was used in the hydrological model to equate the actual discharge to the theoretical discharge. The key results are provided in **Table 5-1** and show that a 55m spillway width is required to reduce PMF surcharge levels below RL77.00m(AHD) which is the maximum flood level acceptable by Council (following discussions with the community and surrounding landowners). The results are discussed further in **Section 6.5**.

Table 5-1: Design PMF key reporting hydraulics as reported in the WRM Hydrological Investigation

Spillway Length	Peak PMF inflow (m ³ /s)	Peak PMF outflow (m ³ /s)	Peak Water Level (m AHD)
40	3,503	1,714	78.27
55	3,503	1,797	76.90

5.2 Survey

Tweed Shire Council carried out a survey of the area of interest for the Clarrie Hall Dam raising project. The area of interest was provided by PWA and is shown in **Figure 5-1**. The survey objectives were to provide the following features:

- 0.5m contours of the area of interest;
- Location of above and underground services within the area of interest;
- Location of any fences within the area of interest; and
- Cadastral layers.

PWA received the 3D survey model in *.dwg (AutoCAD) and *.dgn (MicroStation) format in October 2017. The data was suitable for use in the concept design for the raising of Clarrie Hall Dam.



Figure 5-1: Clarrie Hall Dam Survey Extent

5.3 PWA Geotechnical Investigations

The Clarrie Hall Dam site is generally underlain by pink to grey coloured rhyolite. Generally, it is slightly porphyritic, with medium-grained phenocrysts in a fine-grained groundmass. The majority of rhyolite is flow banded to some degree, although there are exposures of welded rhyolitic tuff recorded in the middle third of the left abutment. Essentially, welded rhyolitic tuff has similar engineering properties to flow banded rhyolite.

Substantial geotechnical work was carried out by NSW Public Works (now PWA) before, during and after construction of the original dam. Information and reports from this work have been retained by PWA and have been reviewed as part of this concept design for dam raising. The review has complimented the data provided by recent geotechnical investigations undertaken by PWA.

Geotechnical investigations were carried out between July and September 2017 (PWA, 2018), specifically for the purpose of:

1. developing the preferred raised spillway option (Option 1) on the left abutment of the dam, and
2. assessing the suitability of the excavated material for use as rockfill for the raised embankment.

Investigation at the dam site and adjacent areas included: geological mapping, diamond drilling and laboratory rock testing. The location of boreholes drilled during the investigation is shown in **Figure 5-2**.

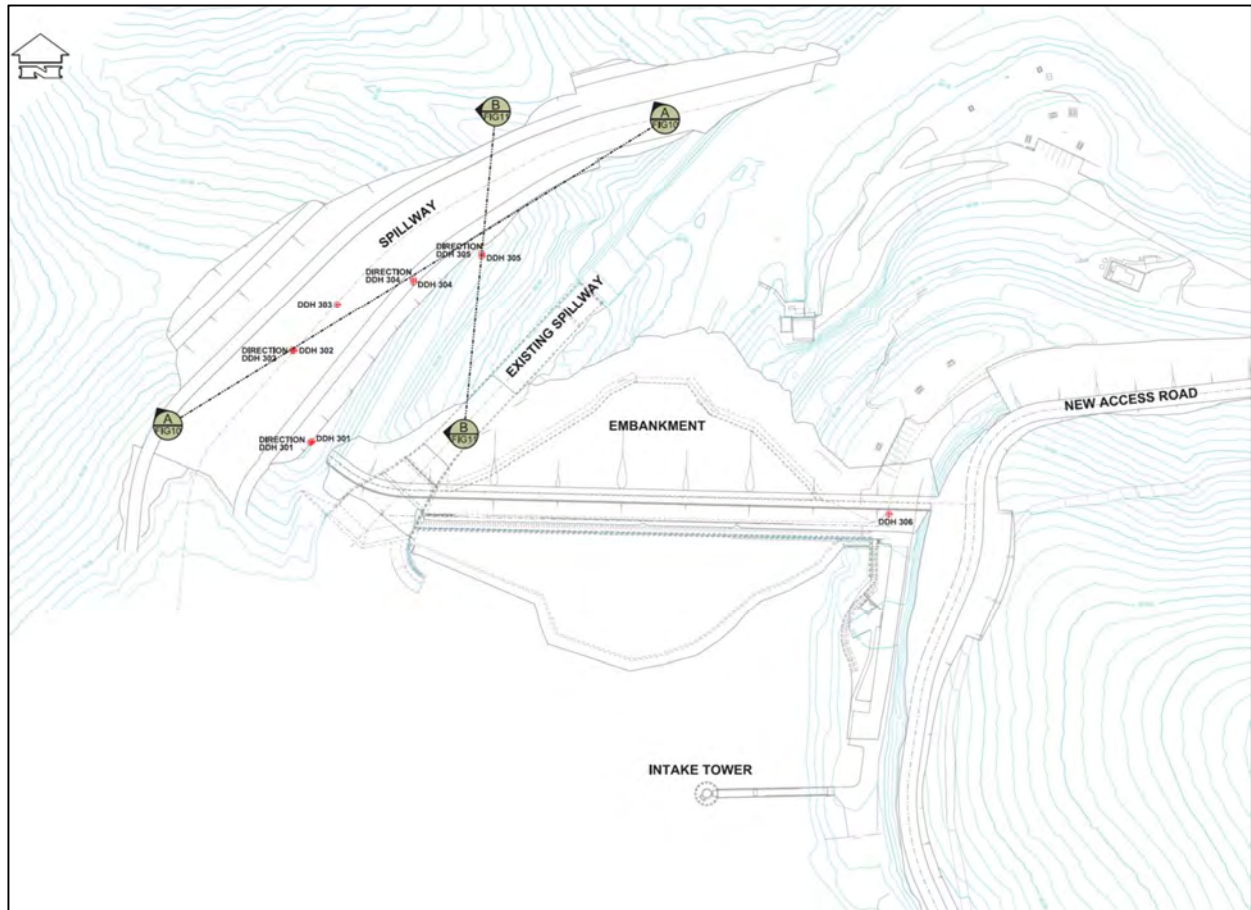


Figure 5-2: Location of Boreholes and Interpreted Geological Sections

The boreholes show that the depth of weathering in the left abutment ridge is deep, with predominately extremely weathered/highly weathered and some moderately weathered rhyolite to considerable depth. The moderately weathered rock and slightly weathered rock depths have been targeted to form the foundation conditions of the new spillway channel foundation due to their suitable characteristics for pinned floor linings and wall linings. The extent of weathered rock on the left abutment means that material excavated from the channel has limited use for the dam embankment raising.

The interpreted geology along the Option 1 spillway alignment is shown in **Figure 5-3 and 5-4**. It is anticipated that, of the excavated material from the Option 1 alignment, there is adequate material to be used in the raised embankment Zone 1 (8,000m³), an unknown quantity could be used in Zone 2 (30,000m³) and no material could be used in Zone 3A/3B (95,000m³). Thus, the investigations reveal that the vast amount of material required for use in the raising of Clarrie Hall Dam embankment would need to be sourced from elsewhere. This is likely to come from the existing rock quarry that was used in the original dam construction. An examination of previous geotechnical investigations of the quarry site indicate that sufficient volumes are available.

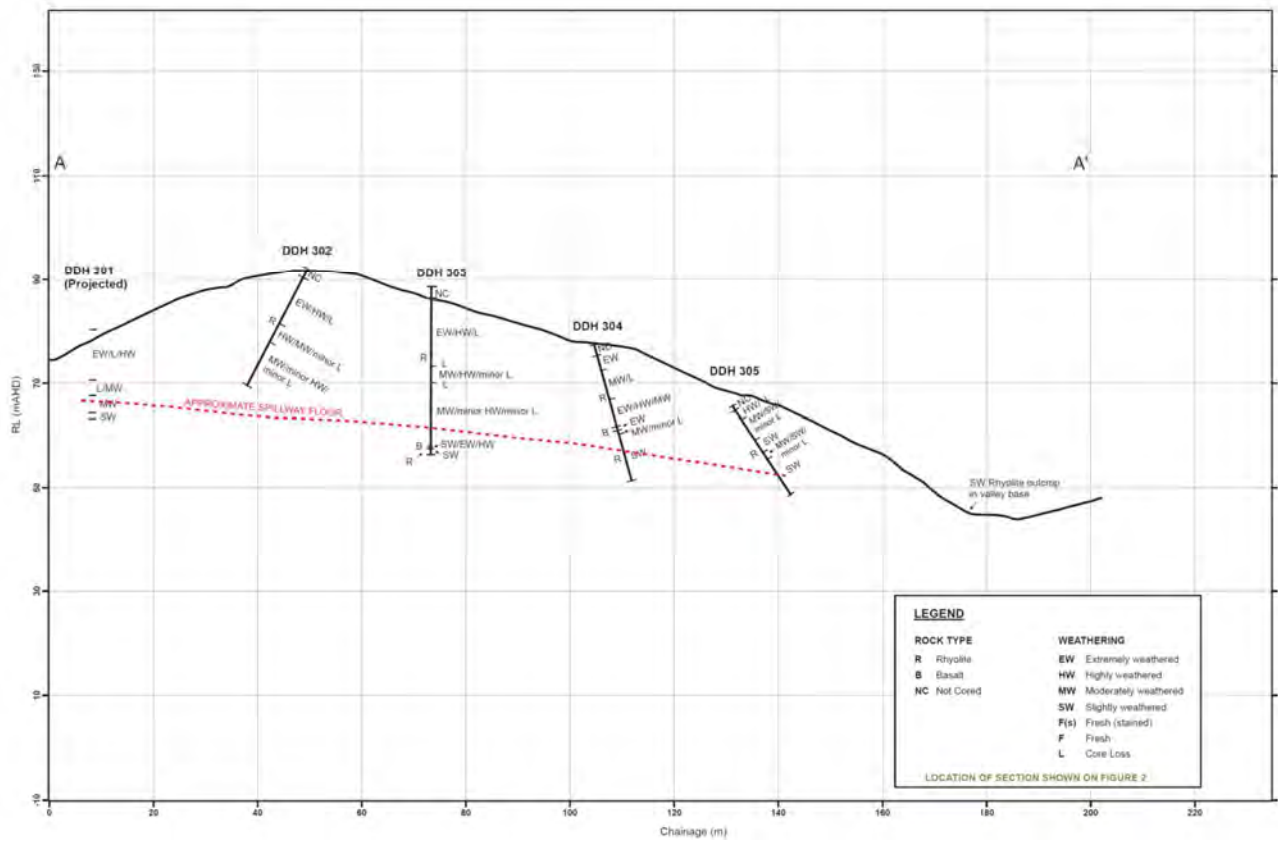


Figure 5-3: Section A Spillway Alignment Interpreted Geology



Figure 5-4: Section B Spillway Alignment Interpreted Geology

Investigation of foundation conditions under the proposed raised embankment reveals that the raised portion of the embankment should sit essentially on slightly weathered rhyolite with pockets of moderately weathered rock. Existing loose materials would be removed.

For the extended left abutment upstream toe slab, the majority of the foundation should comprise moderately weathered or moderately weathered/slightly weathered rhyolite, with potential for thin basaltic dykes. For the extended right abutment toe slab, overriding the existing access road, the foundation should comprise essentially slightly weathered rhyolite and a thick, slightly weathered basaltic dyke.

Curtain grouting along the alignment of the extended toe slab will be required to control leakage beneath the raised embankment. Grouting to the pattern and standard of the existing toe slab curtain should be undertaken under the extended toe slab and new spillway crest. Primary and Secondary holes should extend to 10 m depth, with Tertiary and Quaternary holes extending to 5 m. The length of holes may alter depending on actual site conditions found.

The extended intake tower bridge is expected to be found on sound slightly weathered rhyolite.

5.4 Seismic Hazard Assessment

Peak Ground Accelerations (PGAs) for Clarrie Hall Dam have been adopted from the seismic hazard study carried out by OZROCKS Geoservices Pty Ltd (2017). PGA values for a range of AEPs reported by OZROCKS are provided in Error! Reference source not found..

Table 5-2: Peak Ground Accelerations (PGAs) reported for Clarrie Hall Dam

Earthquake (AEP)	PGA (g)
0.2% AEP (500 Year)	0.028
0.1% AEP (1,000 year)	0.047
0.02% AEP (5,000 year)	0.124
0.01% AEP (10,000 year)	0.179
0.002% AEP (50,000 year)	0.363
0.001% AEP (100,000 year)	0.474

The results were used to determine the response spectrum and accelerations for different return periods that provided key important inputs for the seismic design of the raising of Clarrie Hall Dam.

Mean Peak Ground Velocities (PGVs) for a range of AEPs are shown in **Table 5-3** below.

Table 5-3: Peak Ground Velocities (PGVs) reported for Clarrie Hall Dam

Earthquake (AEP)	PGV (mm/sec)
1.39% AEP (72 year)	2.25
0.2% AEP (500 year)	13.2
0.1% AEP (1,000 year)	21.6
0.02% AEP (5,000 year)	59.1
0.01% AEP (10,000 year)	87.0
0.002% AEP (50,000 year)	195.0
0.001% AEP (100,000 year)	266.0

The expected level of ground motion at the Clarrie Hall Dam site in the form of Modified Mercalli Intensity (MMI) was assessed using intensity maps of southeast Australian earthquakes and a MMI hazard curve has been produced. Based on the results, it is expected to have a felt earthquake of MMI 3 every 22 years (vibrations are strong enough to be felt). This parameter might be not interesting for the engineering community; however, it helps in discovering the seismic hazard level in any region. MMI 6 is often used as a comparison to strong shaking that may be experienced by housing, in this case it is expected to be felt approximately every 830 years.

Table 5-4 shows all earthquakes that have occurred surrounding Clarrie Hall Dam within 100 kilometres of the site, with at least a Modified Mercalli Intensity of MMI1+, along with the recorded PGA (in mm/s²). Note there is only one event with MMI3+ in the area that may have been felt.

Table 5-4: Earthquakes Within 100km of Clarrie Hall Dam

Date	Long (deg E)	Lat (deg S)	Depth (km)	Agency	Mag	Dist (km)	MMI	PGA (mm/s ²)
23/08/1979	153.49	-28.21	0	BRS	3.2	31	3.8	190.09
12/08/2008	153.37	-28.40	9	MEL	1.7	8	2.7	143.45
5/10/1965	152.55	-28.47	10	BRS	3.4	74	2.2	50.80
8/12/2000	153.46	-28.68	1	SEQW	2.1	31	2.1	78.79
17/01/2008	153.51	-28.34	5	MEL	1.6	22	1.9	79.39
22/09/1976	154.00	-28.00	10	BRS	3.1	83	1.5	32.32
11/06/2008	153.57	-28.25	10	MEL	1.8	33	1.5	53.12
27/08/1977	153.65	-28.29	1	GSQ	1.8	37	1.4	47.69
21/02/1991	153.59	-28.19	6	GSQ	1.8	39	1.2	43.16

6. Dam Raising Concept Design

6.1 General

This concept design builds on previous work investigating the optimum size and raising options for Clarrie Hall Dam (PWA, 2007). Suitable options have been developed from this work with two key requirements determined by Tweed Shire Council:

- FSL of RL70.0m(AHD). This follows on from the 2007 report that determined that the dam's optimum maximum raising height was with FSL at RL70.0m(AHD). This corresponds to a storage volume of 42,300ML that is aligned to meet the ongoing water security of the community; and
- The PMF flood level of the storage be limited to RL77.0m(AHD) to prevent upstream inundation of private land.

The options are based on engineering, social and environmental factors whilst consideration has been given to constructability, efficiency, risks and associated costs.

In association with embankment raising, three spillway options have been investigated as part of this concept design study and are summarised below. All options incorporate construction of a fully lined spillway channel,

6.2 Embankment Raising

Raising of the concrete face rockfilled embankment is proposed as shown on **Figures 9 and 10** at **Appendix B**.

The crest level of the raised embankment will be RL77.0m(AHD) to match the maximum flood level.

In accordance with DSC3B, the dam should accommodate a 600mm freeboard above the maximum flood level. However, following consultation with the DSC, it has been decided that no additional freeboard would be required on top of the maximum flood level since this type of dam would be able to withstand a 600mm depth of overtopping without major failure, in the event of a PMF event occurring.

The proposed raised dam embankment sits well within the local topography and the PMF flood surcharge will not adversely affect upstream private property.

The precast concrete parapet wall units, removed from the existing embankment, will be used on the raised dam embankment and abutting the raised portions of the upstream concrete face.

In terms of the raised embankment's configuration, the crest pavement level behind the parapet wall will be at RL75.5m(AHD), crest pavement width will be 5m, the embankment upstream and downstream slopes will be 1V to 1.3H, matching the existing embankment slopes and considered stable for fresh rockfill construction.

The upstream concrete toe slab would be extended on both left and right abutments. Geotechnical investigations indicate that the upstream toe slab extension would be found on slightly weathered rhyolite. Extension of the grout curtain under the raised embankment into both abutments will also be required in a similar pattern to the existing curtain in order to control leakage beneath the raised

embankment. Primary and Secondary holes should extend to 10m depth, with Tertiary and Quaternary holes extending to 5m.

The existing high concrete training walls at the entrance of the current spillway would need to be demolished to make way for the raised embankment fill and upstream face.

The raised embankment fill will continue the current dam zoning profile and comprise:

- a semi-permeable Zone 1 immediately under the upstream concrete face slabs (moderately weathered rhyolite);
- a permeable intermediate Zone 2 (slightly weathered to moderately weathered rhyolite); and
- a permeable fresh rock Zone 3A/3B in the downstream part (slightly weathered rhyolite).

As indicated previously in this report, the majority of material for Zone 1 and Zone 2 would be obtained from the spillway excavations. Zone 3A/3B rockfill would be resourced from the old quarry site.

A new seepage measurement weir will be provided downstream of the raised embankment downstream toe along with a SCADA/telemetry facility to enable continuous monitoring of leakage.

6.3 Spillway Options

As noted previously, three spillway options have been investigated for the raised dam and these are summarised below. All spillway options have been designed to pass the PMF.

Option 1A

Spillway Option 1A general arrangement is illustrated on **Figure 2 at Appendix B** of this report.

The existing spillway is covered over by the raised embankment and a new spillway channel is proposed higher in the left abutment.

This option was targeted to balance the required volume of rock excavated from the spillway channel and that needed for the raised dam embankment. It was developed under the initial assumption that all of the material from the spillway excavation would be suitable for placing on the raised embankment.

The spillway crest is designed at RL70.0m(AHD) which corresponds to the raised dam's FSL. The spillway crest width is 45m and the channel reduces to 15m wide at the downstream end.

The spillway channel is fully concrete lined channel due to the highly fractured nature of the rock. Although the excavations will be in hard rock, investigations indicate close joint spacings and pockets of weak and fractured rock. The existing spillway was fully lined for this reason. The concrete floor of the new spillway is anchored to the rock and a flip bucket is proposed at the downstream end.

Option 1B

Spillway Option 1B is illustrated on **Figures 3, 5 and 6 at Appendix B**.

Again, the existing spillway is covered over by the raised embankment and a new spillway channel is proposed higher in the left abutment.

This option was targeted to minimize the amount of rock excavated from the spillway channel excavation when it became apparent during the project that the excavated rock may not be suitable for the raised dam embankment.

The spillway crest is designed at RL70.0m(AHD) which corresponds to the raised edam's FSL. The spillway crest width is 40m and the channel reduces to 15m at the downstream end with a flip bucket and, similar to Option 1A, the spillway channel is fully concrete lined and anchored to a sound rock foundation.

Option 2

Spillway Option 2 is illustrated on **Figures 4, 7 and 8** at **Appendix B**.

This option was developed as an alternative to Option 1B above following awareness that the excavated material from the left abutment under spillway Option 1A would not be suitable for the raised dam embankment.

For this option, the existing spillway is maintained, a new raised crest structure is constructed within the approach channel and the spillway is widened upstream to provide a semicircular 36m spillway crest to provide adequate additional discharge capacity. No excavation is required for this option and the raised dam embankment would meet raised concrete training walls and be covered by a culvert spillway.

6.4 Review of Storage Volume

The original storage volume was calculated using 1:25,000 topographical maps around the time of the original dam construction. PWA carried out a review of the available stage versus storage relationships for Clarrie Hall Dam. Two data sets for Clarrie Hall Dam were found; 1981 storage relationship from the construction drawings and a volume versus area relationship that was used in the 2007 dambreak modelling. The two datasets were compared and the volumes were extracted at key stage points which are provided in **Table 6-1**. The results show that significant differences were found between the two datasets, with the greatest variation occurring at the higher water levels that are now of consequence due to the proposed raising option for Clarrie Hall Dam.

Table 6-1 : Key stage volume comparisons of the original 1981 drawings and the 2007 dambreak

Water Level (m AHD)	1981 Clarrie Hall Dam Construction Drawings Storage Volume (ML)	2007 Dambreak Model Storage Volume (ML)
61.5	16,000	16,721
70.0	41,331	45,750
77.0	64,038	93,006

PWA contacted NSW Lands and Property Information (LPI) to ascertain whether any new topographical surveys of the site have been carried out. LPI were able to provide PWA with data from

a recently flown LiDAR of the dam. The data was processed to a Classification Level 1, meaning that verification of height data checks had not been carried out. However, the dataset provides a good basis for estimating relative height information. As the water surface level was known at the time of capture, a relative storage volume was extracted from the DEM above the water surface level. This equates to a re-estimation of the volume between RL 61.5m(AHD) and RL 77.0m(AHD); the stage range over which significant variation was shown to occur between the two datasets previously examined.

The stage relationship above RL 61.5m(AHD) was generated from the DEM using the GIS package ArcGIS 10.2. The storage relationship was then plotted and compared against the two other provided datasets and is shown in **Figure 6-6-1**.

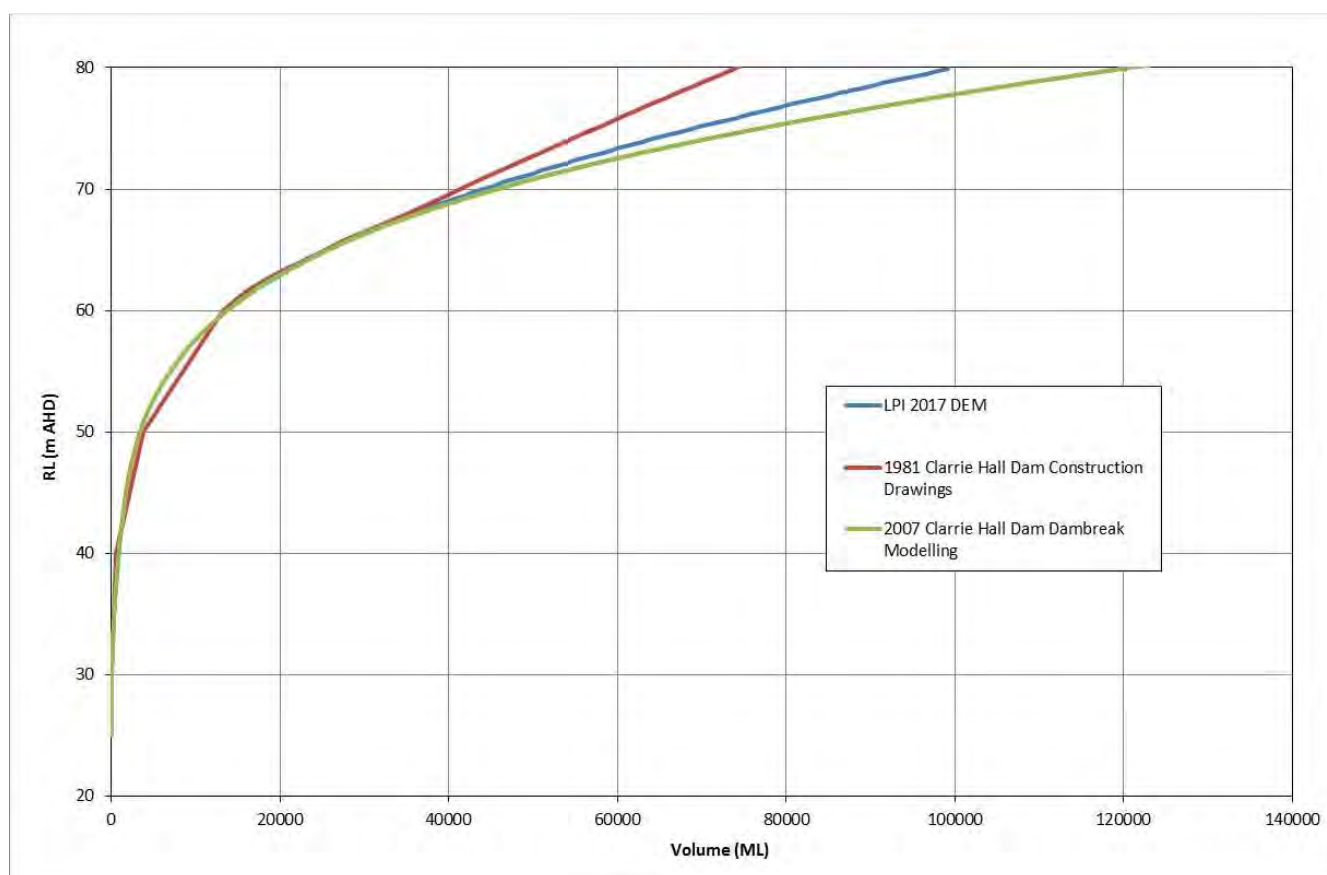


Figure 6-6-1 : Comparison of storage relationships for Clarrie Hall Dam

The result was to combine the 2007 dambreak storage volume estimates below RL 61.5m(AHD) with the 2017 LPI DEM data above this level. The new storage volumes for key reporting stages is provided in **Table 6-2**. The new storage information was then used to update the hydrological analysis, which is discussed in **Section 6.5**.

Table 6-2 : Updated key stage volumes for the merged 2007 dambreak and 2017 LPI DEM

Water Level (m AHD)	Updated 2017 Clarrie Hall Dam Storage Volume (ML)
61.5	16,721
70.0	44,127
77.0	80,727

6.5 Review of the PMF Design Data

Hydrological investigations of the proposed raising were carried out by WRM, which were previously discussed in **Section 5.1** of this report. The hydrological study used a coefficient of discharge (C_D) value of 1.8; equivalent to a typical broad crested weir. The discharge coefficient is influenced by a number of factors such as depth of the approach, relationship between the actual crest shape and the ideal nappe shape, upstream face slope and downstream interferences. The design of the ogee crest of a spillway takes these factors into consideration and attempts to idealise the form in such a way that optimum discharge is achieved. The raised spillway of Clarrie Hall Dam features a nappe-shaped crest profile of the ogee crest in order to maximise discharge over the spillway and reduce the flood protection of the dam. For this reason, the coefficient of discharge will differ significantly as opposed to the value used in the hydrological modelling.

The coefficient of discharge was calculated for a range of upstream water level conditions in accordance with the practises described in the USBR Design of Small Dams (Ref. 26). The calculation used the elements of a nappe-shaped crest profile and approach depth to describe a range of flow rates against upstream water levels.

Inflow hydrographs for the PMF event were modelled using the MIKE 11 hydrodynamic model. The new storage volumes presented in **Section 6.4** were incorporated in the model. In addition, the theoretical spillway rating for each of the options was input to the model. The new spillway rating curve for each option is presented in **Figure 6-6-2**. As the ogee crest has been similarly designed for each option, the spillway discharge differs between the options due to the crest length and to a lesser degree the approach depth. The PMF results with the new spillway discharge characteristics were modelled and the results are provided in **Table 6-3**. The results show that for all the Options tested, the peak PMF water level remains below the surcharge limit of RL 77.0m(AHD). The peak PMF water levels modelled were used as the final design height of each of the Options assessed.

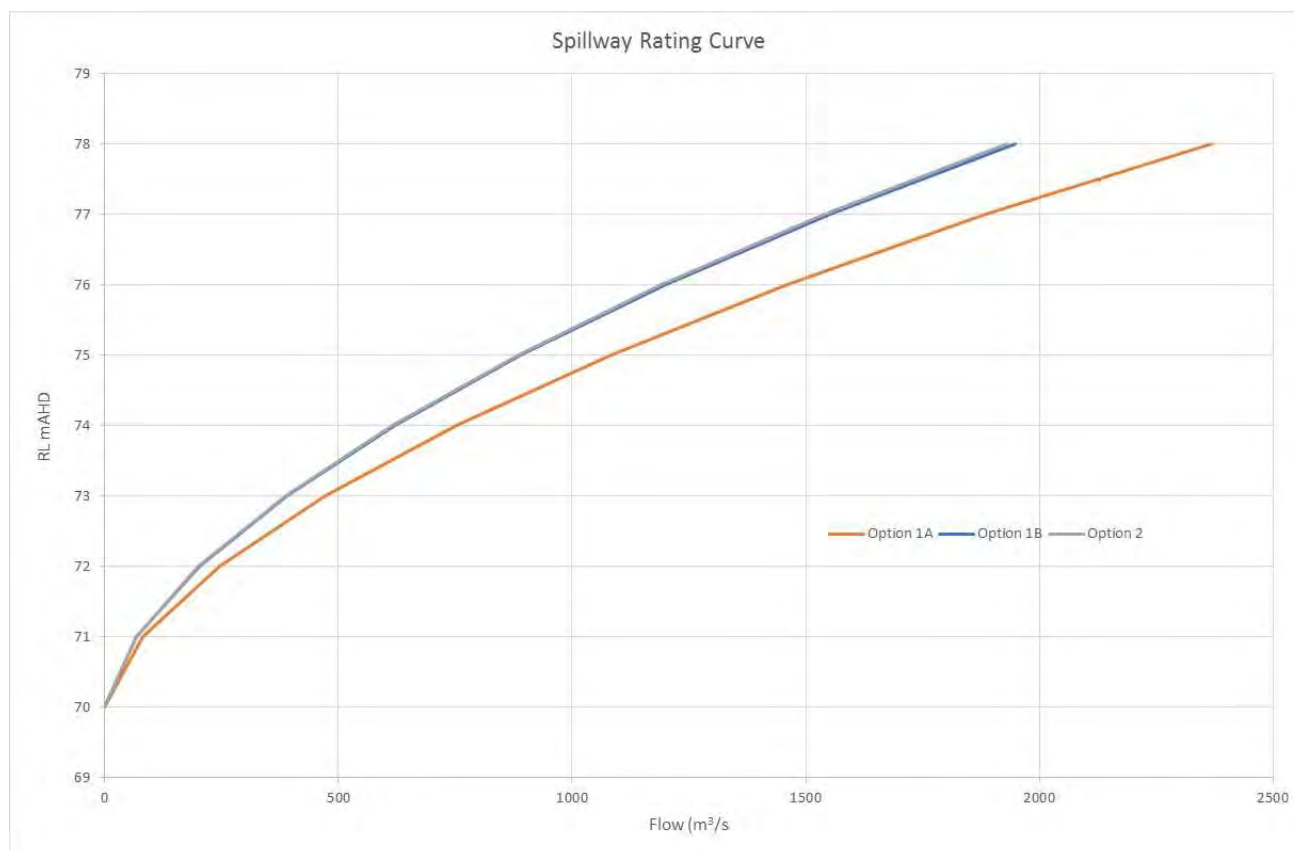


Figure 6-6-2 : Theoretical Spillway Rating Curves for the Options Analysed in this Study

Table 6-3 : Clarrie Hall Dam MIKE 11 Remodelled Results of the PMF Event

Option	Spillway Peak Water Level (m AHD)	Spillway Peak Flow (m³/s)
Option 1A	76.36	1,609
Option 1B	76.94	1,528
Option 2	76.96	1,524

6.6 The Preferred Spillway Option

As mentioned above, spillway options are illustrated on the Figures at **Appendix B**.

Further analyses and hydraulic modelling have indicated that Option 1B is the preferred option.

Option 1A was not considered further in that it was the optimum arrangement initially considered where all of the excavated material was suitable for embankment raising. Following the geotechnical investigations, which indicated that the majority of excavated material from the spillway channel was not suitable, Option 1B was developed to minimise excavation waste. Option 2 was developed as an alternative to Option 1B.

CFD modelling of the preferred spillway Option 1B was undertaken and is discussed in **Section 7** of this report.

6.7 Intake Tower and Access Bridge

Intake Tower

The existing intake tower is a vertical reinforced concrete circular shaft 33.65m high with internal diameter of 3.2m. The tower is of the wet well type and is situated on a reinforced concrete tower base structure at the head of the outlet tunnel which is located under the dam's right abutment. It has eight water inlet ports to facilitate selective water withdrawal, supporting a series of trashracks and shutters with a crane over the tower deck.

The existing intake tower is proposed to be raised by 8.5m, resulting in the total height of the intake tower to be 42.15m. The raised tower will incorporate three additional water inlet ports.

It is proposed to extend the tower by installing reinforcement bars chemically grouted into the holes drilled at the top of the tower wall. These anchored bars would be installed at spacings to match with the existing reinforcement. The installed anchor bars would then be lapped with reinforcing bars of appropriate length followed by the placement of concrete to the proposed level.

As for the existing arrangement, the raised tower will have radial beams built into the tower wall and a peripheral beam to support the floor slab and the new hoist house super structure. Corbels will be built into the raised tower wall, similar to the existing ones, to support the new access bridge.

The preferred tower raising arrangement is illustrated on **Figures 11 and 12** at **Appendix B**.

Hoist House

A new hoist house similar to the existing is proposed to be constructed on top of the raised intake tower. The raised intake tower will have the radial beams built into its wall and a peripheral beam running on the outer edge of the radial beams (similar to the existing configuration) to support the floor and super structure. The existing compressed AC cladding would be replaced with other suitable material in the new hoist house.

Access Bridge

The current intake tower access bridge consists of two unequal spans 16m and 28m long, supported by a reinforced concrete pier and abutment block. Prestressed girders support an in-situ concrete deck connected by shear connectors and installed on top of the precast prestressed girders.

The existing bridge is to be dismantled, disposed of and replaced with a new bridge to match the raised height of the intake tower.

It is proposed to utilise the existing bridge support pier by raising and strengthening it and introduce one new pier and abutment block to divide the bridge length between the adjoining access road and the tower deck into three unequal spans.

The raised access bridge will incorporate prestressed Closed-Flange Super Tee sections and reinforced concrete deck, similar to the existing arrangement.

The preferred new access bridge arrangement is illustrated on **Figure 13** at **Appendix B**.

7. Raised Dam Analyses

7.1 General

This Section discusses the analyses undertaken in conjunction with the dam raising concept design. These include:

- Embankment stability;
- Intake tower and access bridge structural assessments; and
- CFD modelling with the preferred spillway (Option 1B).

7.2 Embankment Stability

There are no specific design analyses required for a conventional concrete face rockfill dam (CFRD). The concrete face ensures a dry rockfill with no pore pressure. Studies have indicated that horizontal stability is ensured by total vertical loads on any section exceeding total horizontal loads by a factor of at least seven (7). The water load on the concrete face is taken almost entirely by rockfill upstream of the embankment centreline and passes into the foundation upstream of the centreline (Ref. 6).

The NSW Dams Safety Committee notes in guidance sheet DSC3C:

“Concrete Faced rockfill dams of free draining rockfill are often designed empirically on the basis of precedent performance. The DSC will accept such a design basis”.

The existing Clarrie Hall Dam embankment comprises fresh to slightly weathered free draining rockfill zones with upstream and downstream slopes of 1V to 1.3H and is founded on a uniform sequence of hard rhyolite rock with minor welded tuff. Geotechnical investigations have also revealed very high to extremely high Uniaxial Compressive Strengths (UCS) for a great part of the rhyolite rock foundation. The 1V to 1.3H embankment slopes are considered acceptable based on precedence and prior research, so no stability analysis was undertaken in the original design of the Clarrie Hall embankment. The slopes were selected without calculations. Trial embankment studies were carried out which confirmed the embankment profile and slope stability.

For the raised embankment, fresh to slightly weathered free draining rockfill is also proposed as outlined in **Section 6**. The batter slopes will be 1V to 1.3H to match the existing profile. As noted above, stability analysis is not required for this type of embankment and was therefore not undertaken.

7.3 Embankment Seismic Considerations

It is widely accepted that the modern compacted CFRD has a high resistance to seismic loadings and this has been confirmed by precedence and theoretical analyses (Ref.7). The high seismic resistance is due to:

- The upstream concrete face providing a dry fill with no possible build up of pore pressures;
- The compacted rockfill developing high frictional resistance.

Clarrie Hall Dam is located in a low seismicity area, as indicated in **Section 6**. In the event of an earthquake, it is expected that the dam embankment would undergo small deformations only during periods of shaking.

Since the entire embankment is dry, earthquake shaking cannot cause pore pressure in the rockfill voids. At Clarrie Hall Dam, the foundation is rock, which does not magnify the incoming acceleration forces. The embankment is well compacted in layers to a dense state with vibrating rollers.

Earthquakes can only cause small deformations during the short period of shaking. After the earthquake is over, the CFRD embankment is as stable as before.

In very strong earthquakes, the concrete face may be cracked, increasing leakage. The potential cracking and leakage cannot threaten the overall safety of the dam because the amount of leakage which can get through the cracks, and the zone of small rock under the face slab, can easily be passed safely through the main rockfill embankment.

The expected effects of a major seismic event (based on previous international observations and studies), such as a CFRD located near the epicentre of a MMI 7.5 earthquake, would be:

- some disturbed slumping of the embankment with a maximum settlement less than 1% of the embankment height, about 50mm for the raised Clarrie Hall Dam;
- some cracking of the upstream face. Cracking of the concrete face slab may produce some increase in leakage but cannot threaten the overall safety of the dam.

Current practice is that no special considerations are required for CFRD's that may be subject to seismic events unless there is close proximity to major faults capable of producing earthquakes of MMI 7.5 or greater (Ref.10). The raised Clarrie Hall Dam embankment is not in this situation and therefore no specific seismic analyses has been undertaken.

7.4 Intake Tower and Access Bridge

Intake Tower

A 3D finite element analysis has been carried out on the existing and raised intake tower taking into account all applicable water and structural loads as well as updated seismic effects.

For the raised intake tower, results show that the tower section is adequately reinforced to handle the base shear for seismic loading up to the required 0.01% AEP (10,000 year) event. However, this is not the case with the design moment. It appears that tower section is likely to handle moment resulting from seismic loadings between the 0.1% AEP (1,000 year) and 0.05% AEP (2,000 year) events. For the 0.02% AEP (5,000 year) and less frequent (but more intense) earthquakes, the tower is likely to experience distress and possible structural damage.

Clarrie Hall Dam has been assigned a HIGH A Sunny Day Consequence Category and is therefore required to withstand the Maximum Design Earthquake (MDE), a 0.01% AEP (10,000 year) event. However, it could be argued that the intake tower could be accepted as having to handle a lower return period earthquake based on the fact that structural damage of the intake tower is not likely to:

- result in an uncontrolled flow of stored dam water downstream; or
- cause damage to valves and pipework. The valves and pipework are expected to remain operational following any earthquake as these fixtures are located downstream of the concrete plug approximately mid-way along the wet/dry outlet tunnel.

Having regard to the above, it is considered acceptable that the raised intake tower withstand an Operating Basis Earthquake (OBE) of much smaller intensity than the 0.01% AEP (10,000 year) event. The acceptance of an OBE for the raised intake tower, between the 0.1% AEP (1,000 year) and 0.05% AEP (2,000 year) events, would not require any additional post-tension strengthening works to be carried out on the structure.

Details of the intake tower structural analysis are included at **Appendix C**.

Access Bridge

As indicated in **Section 6**, for the raised tower access bridge, it is proposed to utilise the existing bridge support pier by raising and strengthening it and introduce one new pier and abutment block. A 3D finite element analysis of the existing and raised pier has been carried out taking into account all applicable water, structural and bridge traffic loads as well as updated seismic effects.

Results show that the existing access bridge pier section is adequately reinforced to handle the base shear for seismic loading up to the required 0.01% AEP (10,000 year) event and bending moment for seismic loading up to the 0.2% AEP (500 year) event. The pier is required to be enlarged in cross section to satisfy code requirements. The enlarged section of the pier, as shown on the attached drawings at **Appendix B**, improves its bending capacity and can handle the bending moment for seismic loading up to the 0.01% AEP (10,000 year) event.

The main dam, having a HIGH A Sunny Day Consequence Category, is required to withstand the Maximum Design Earthquake (MDE), a 0.01% AEP (10,000 year) event. However, it could be argued that the access bridge pier could be accepted as having to handle a lower return period earthquake based on the fact that structural damage of the pier is not likely to:

- cause dam failure resulting in an uncontrolled flow of water downstream
- cause threat to the integrity of the outlet system.

In light of the above facts, it is considered acceptable that both raised access bridge piers (as shown on the drawings at **Appendix B**) withstand an operating basis earthquake (OBE) of much less than the 0.01% AEP (10,000 year) event. The acceptance of an OBE for the piers of 0.1% AEP (1,000 year) would not require any additional post tension strengthening works to be carried out on the pier.

It is also noted that for seismic loading up to the 0.1% AEP (1,000 year) event, the pier foundation (concrete base/rock interface) remains intact for the full base area as stresses remain in compression.

Details of the raised bridge pier structural analysis are included at **Appendix D**.

7.5 CFD Modelling with Preferred Spillway Option

Computational Fluid Dynamic (CFD) analysis has been carried out by Advisian Pty Ltd of the preferred Spillway Option 1B to confirm flow performance and section dimensions. After initial testing of spillway options, as discussed in **Section 6**, Spillway Option 1B was selected as the preferred and most practical option.

The proposed 3D model of the preferred spillway arrangement with the surrounding digital terrain model was provided to Advisian from the civil computer package 12d. The proposed spillway included an excavated ogee crest and entrance channel with a width of 40m. The spillway width decreases downstream of the ogee crest linearly to be 15m wide at the flip bucket. The CFD model was used to check the theoretical rating curve analysis of the spillway and confirm the PMF flood design level. As reported previously, the modelled PMF flood event with a theoretical spillway rating curve yielded the following results:

- Peak water level – RL 76.94 m(AHD)
- Peak flow – 1,528 m³/s

The CFD model was set up using a multi-mesh block approach that enables the capture of finer details where it is necessary. Mesh sizes range from 2m upstream of the reservoir and up to 0.5m at the spillway. Approximately 4 million cells were used for the overall CFD fluid domain. The CFD model is shown in **Figure 7-1**.

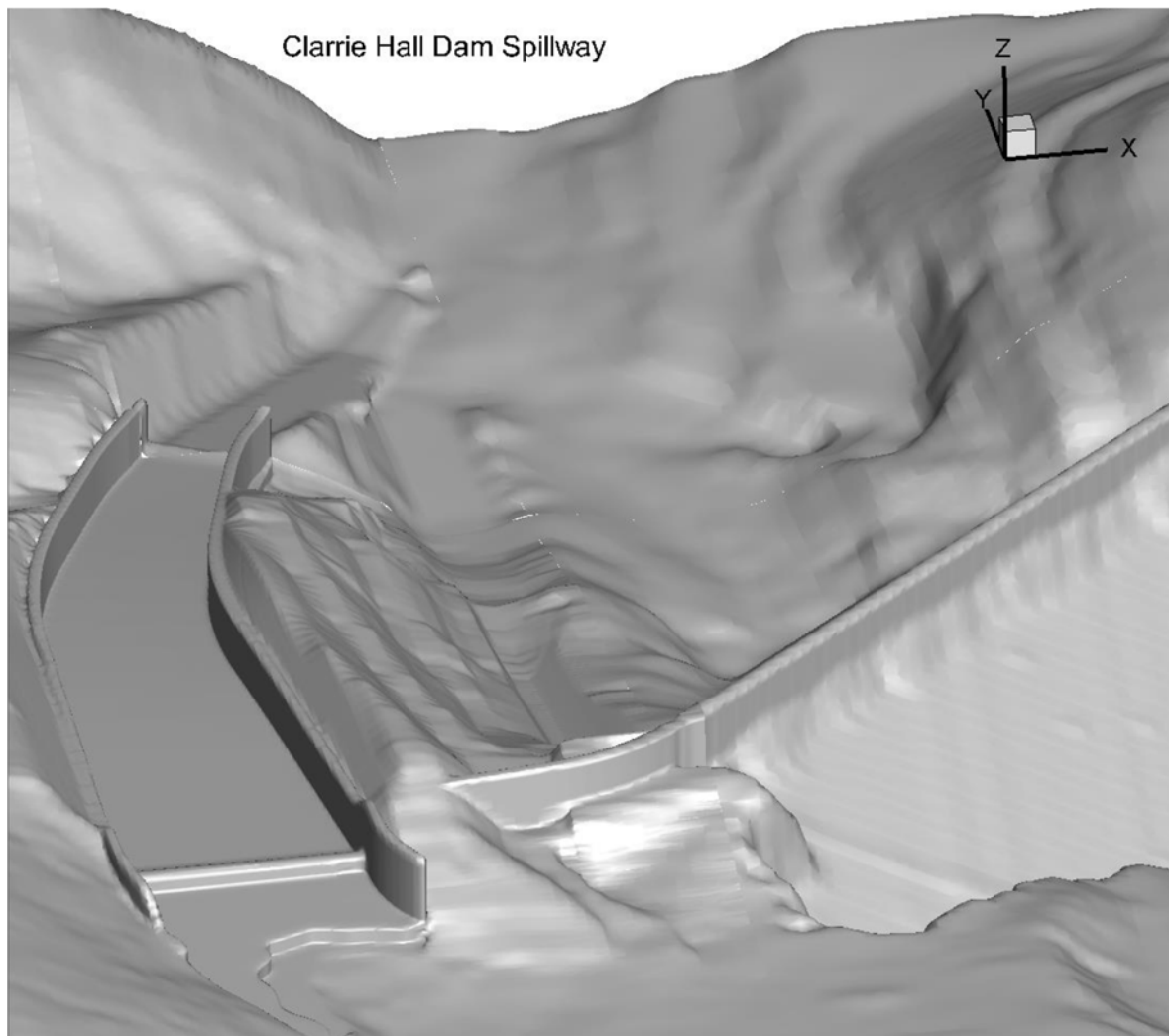


Figure 7-1 – Proposed Raised Dam and Spillway for Clarrie Hall Dam CFD Model, Looking Downstream

The CFD model was first used to confirm that the peak PMF flood conditions were satisfied by the proposed spillway. An upstream water level boundary condition of RL 76.94 m(AHD) was inserted into the CFD model. The discharge measured through the spillway crest in the CFD model was 1,548 m³/s, which was around one percent more than required to keep the design objective PMF water level below RL 77.0 m(AHD). This result confirmed that the proposed spillway was expected to match the theoretical results for the routed PMF flood event. The CFD model also confirmed some key hydraulic performance characteristics of the proposed spillway option:

- Flow was subcritical upstream of the spillway crest and changed to supercritical immediately downstream of the crest, indicating that the control section was located at the crest. This implies the spillway dimensions are satisfactory in align with the design water levels.

- Negative pressure of -10kPa is observed at the spillway crest but it is unlikely that cavitation will occur. The floor pressure immediately downstream of the flip bucket is reduced to less than 10kPa, whilst the peak pressure where the jet impacts with the downstream channel is 105kPa. The average pressure on the spillway floor is 75kPa. The floor pressures are shown in **Figure 7-2** (at the spillway crest) and **Figure 7-3** (at the flip bucket).

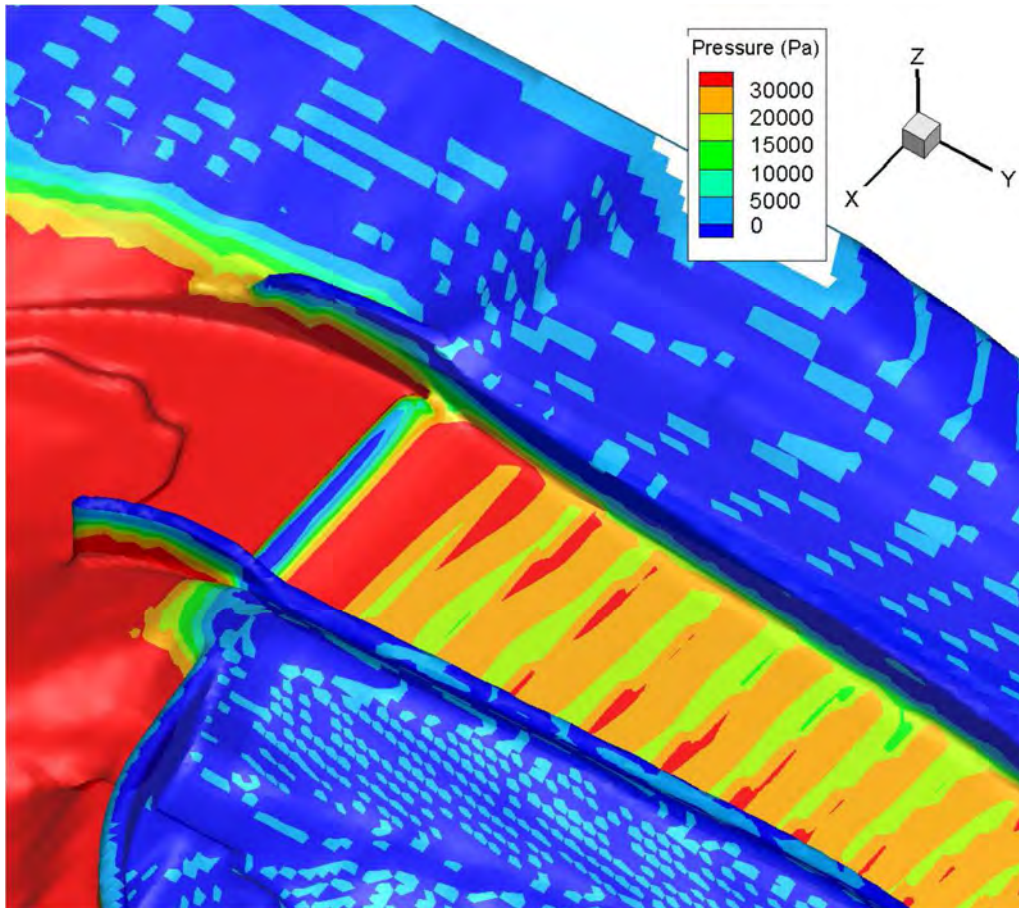


Figure 7-2 – Modelled CFD Floor Pressures of the peak PMF flood event, Spillway Crest

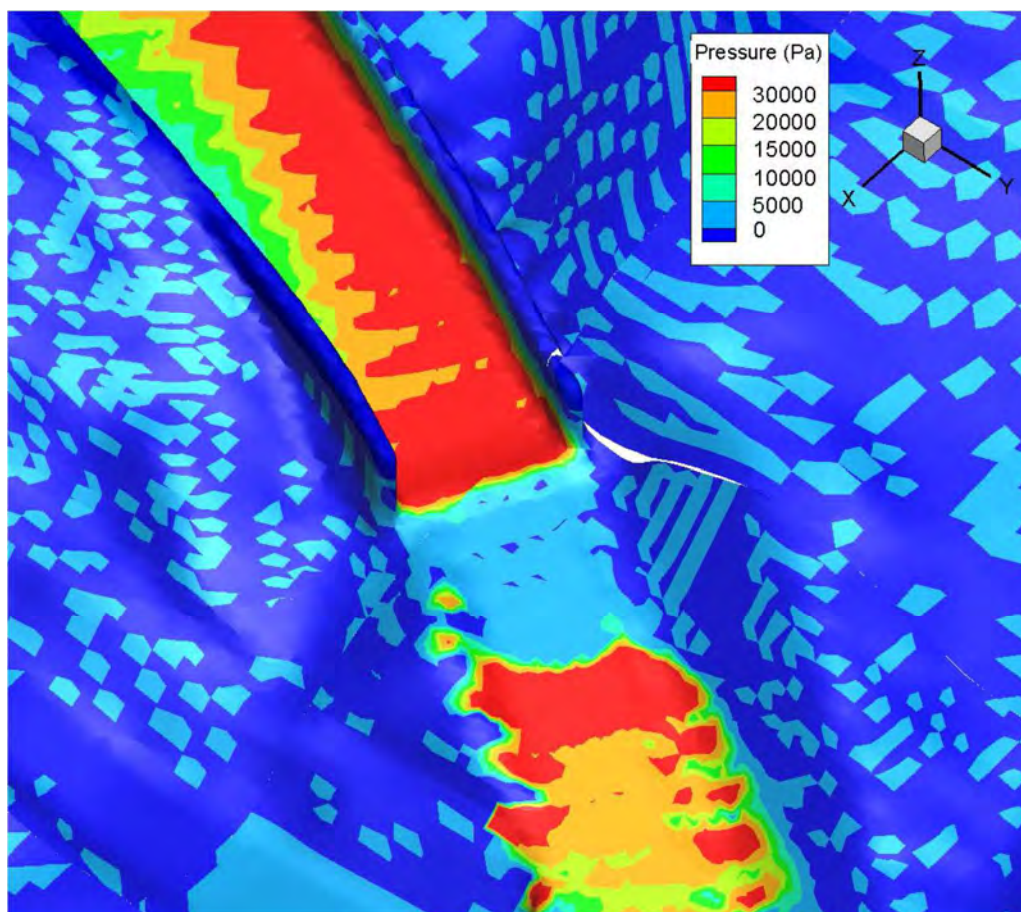


Figure 7-3 – Modelled CFD Floor Pressures of the peak PMF flood event, Flip bucket

The CFD model was then used to produce a new rating curve for the proposed raised spillway option. A continuous rating curve was produced from the rising head model using the computed total flow rate and reservoir water level as a function of time. The new spillway rating curve was then provided and is presented in **Figure 7-4**. The rating curve was then used to re-route the PMF flood event in the one-dimensional MIKE 11 model with the new peak water level of 76.88 m(AHD).

It is noted from the modelling that, at the PMF event, the flow jetted from the flip bucket and impacted on the floor of the downstream channel. There was decrease in the near floor velocity immediately downstream of the flip bucket. This showed that the flip bucket is dissipating the energy of the flow as it travels downstream of the chute.

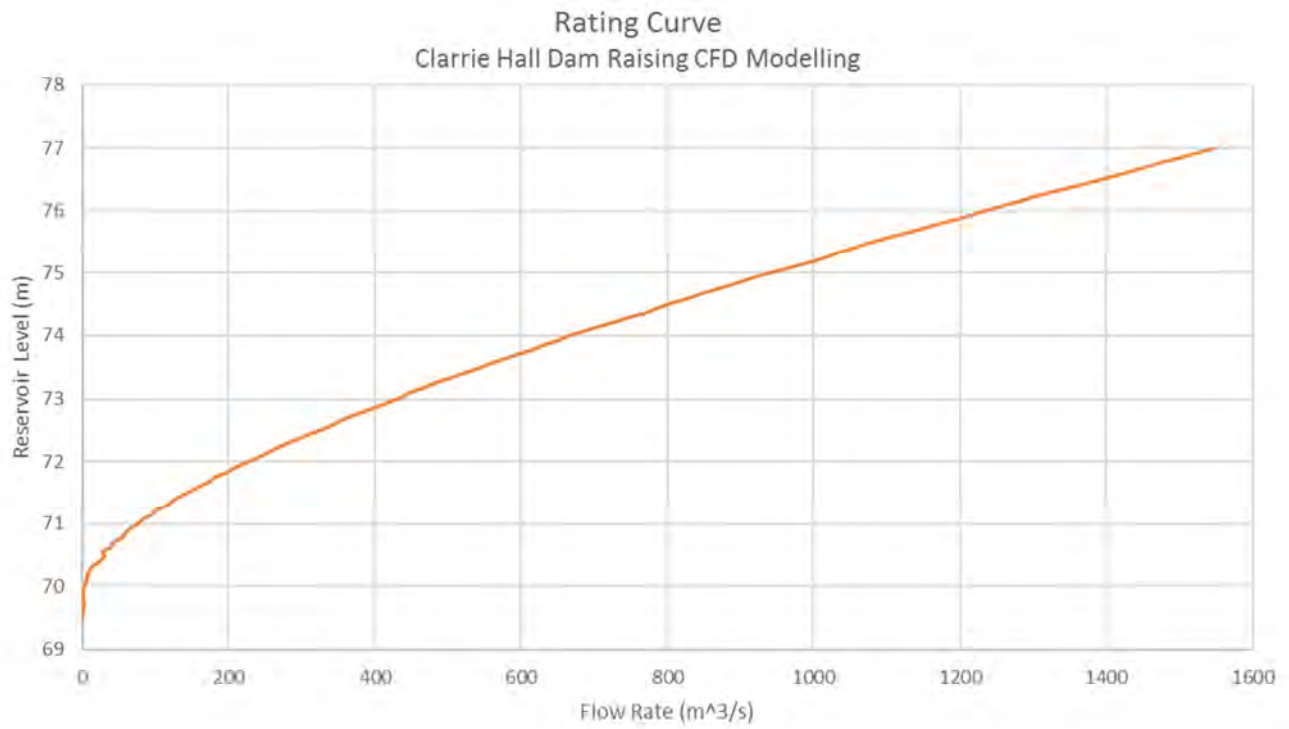


Figure 7-4 – Updated CFD Rating Curve

CFD modelling information above was sourced from *Clarrie Hall Dam Raising: Computational Fluid Dynamics Modelling*, Advisian July 2018 (ref.25).

8. Construction Methodology and Timing

8.1 General

It is proposed to raise the full supply level (FSL) of Clarrie Hall Dam from RL61.5m to RL70.0m. The commensurate maximum flood level will be at RL77.0m. Storage capacity is increased from 16,000ML to 42,300ML.

With the raising of the dam, it is proposed to excavate a spillway channel higher in the left abutment with spillway sill level at RL70.0m(AHD). This is based on the preferred spillway option 1B as described previously in this report.

It was considered originally that material from the raised spillway excavation would be fully utilised as rockfill for the raised embankment. However, geotechnical investigations have revealed that only about 20% of the excavation would be suitable for rockfill construction. As a result, it is proposed to obtain the remaining required rockfill volume from the original quarry site where the rock quality is known and is suitable. The old rock quarry is about 300m upstream of the dam site on the left bank of the storage.

Refer concept drawings attached at **Appendix B** which illustrate the proposed dam raising.

8.2 Lowering of the Storage

Some lowering would be required to allow for construction of the raised embankment including toe slab extension, grout curtain extension and upstream concrete face slab extension. Possibly a 300mm lowering below full supply level would suffice (depends on the Contractor's methodology). Some diversion/dewatering works would also be required to ensure flood free construction, particularly on the abutments of the raised embankment.

8.3 Establishment for Construction

Contractor site facilities, workshops and material storage areas would be established. Suitable sites appear to be downstream of the dam but final locations would depend on the Contractor. Access for construction and environmental protection works would also be required.

Concrete batching plant and concrete material storage will have to be established, again sites downstream of dam seems most suitable.

8.4 Material Transport

Rock would be transported from the new spillway excavation to stockpile (probably downstream of the dam site) and to disposal (could be on or off site depending on Council). As mentioned previously, some 38,000 cubic metres of rock from the spillway excavation would be suitable (and therefore hauled) for fill placement on the raised embankment.

Rock will be delivered progressively to the dam site from the quarry along Contractor's haul roads through the left bank of the storage. It is estimated that approximately 95,000 cubic metres of rock would be transported from the quarry for placement on the raised embankment.

Existing access routes to the site will have to be altered to allow for a new main access road higher in the right abutment and for construction access generally.

8.5 Order of Work

With respect to overall construction approach, the following general order of work is envisaged –

1. Establishment, including environmental and other approvals
2. Removal of the existing concrete parapet wall from the current dam embankment including removal and storage of the recyclable precast concrete panels
3. Removal of the crest pavement from the existing embankment to expose underlying rockfill
4. Excavation of the left and right abutments for the upstream concrete toe slab extension
5. Stripping of the foundation downstream of the existing embankment for the raised embankment footprint including removal of concrete gutter and seepage weir
6. Demolition of the concrete walls at the existing spillway entrance and disposal to waste
7. Excavation for the new spillway channel higher in the left abutment (some blasting may be required in the lower downstream areas)
8. Excavation for the new permanent access road higher in the right abutment
9. Stockpile of suitable rock from the spillway excavation, and suitable disposal of the rest
10. Establishment of haul routes to the old quarry site from the dam site – probably along the edge of the raised storage level in the left bank
11. Construction of the upstream concrete toe slab extension in both the left and right abutments
12. Installation of the grout curtain extension through the upstream toe slab extension on the left and right abutments (no blasting envisaged but slope correction may be required)
13. Stripping of the old quarry site and excavation of suitable rockfill (excavation of the quarry will probably require some blasting)
14. Establishment of a large crane or other means to transfer rock delivered from the quarry across the length of the raised embankment as required
15. Placement and compaction of rockfill on the raised embankment (within configured zones as per the design)
16. Extension of the upstream concrete face slabs (possibly by slip forming)
17. Construction of the concrete sill, floor and walls for the raised spillway (including anchors and drainage)
18. Large rock protection below the flip bucket downstream of the new spillway channel and entry to the creek
19. Installation of precast concrete parapet wall units obtained from the existing embankment on to the raised embankment and connection of the parapet wall units to the raised upstream concrete face slabs
20. Supply and installation of new precast concrete parapet walls on the ends of the raised embankment
21. Removal of the existing intake tower house
22. Demolition of the existing intake tower deck

23. Removal of the existing tower access bridge deck
24. Raising of the concrete intake tower
25. Raising of the existing concrete pier, construction of a new concrete pier and construction of new concrete abutment support
26. Construction of the raised concrete tower deck
27. Construction of the raised bridge deck
28. Construct of a new tower house
29. Installation of all mechanical equipment including additional shutters, trashracks and crane in the raised tower
30. Reinstatement of all electrical supply
31. Construction of a new permanent access road and seal on the right abutment to join the raised tower bridge and down to the new boat ramp location
32. Removal of all temporary access and haul roads
33. Rehabilitation of construction areas (including landscaping)
34. Disestablishment

By excavating for the new spillway channel early in the construction sequence, it will ensure that the dam can safely pass the PMF without overtopping the raised embankment even prior to completion of the works.

8.6 Timing

Based on the above scope of works, an estimated time line for design and construction of the Clarrie Hall Dam Raising project has been prepared and is attached at **Appendix F**.

Essentially, 26 weeks are allowed for detail design and contract documentation (including drawings and specifications) followed by a 6 weeks tender process. Environmental approvals are assumed to run concurrently.

Approximately 70 weeks are allowed for construction of the works following award of contract.

9. Risk Assessment

A risk matrix has been prepared for the Clarrie Hall Dam Raising Project and is attached to this report at **Appendix G**. The matrix has been developed from an earlier version prepared for a risk workshop held at Tweed Shire Council chambers in May 2017.

The matrix covers risk assessment issues under the following general headings:

- Design
- Community Consultation
- Site and Services
- Work, Health and Safety
- Environmental and Site Conditions
- Construction and Programming
- Additional Risks Identified.

Risks identified during both the preconstruction and construction phases of the project are included and risk mitigation strategies are presented.

10. Cost Estimate and Cost Risk Assessment

10.1 General

This section summarises the design and construction cost estimate for the raising of Clarrie Hall Dam as outlined in this report. The estimate is based on predicted construction and project costs as at June 2018.

The cost estimate incorporates a cost risk assessment.

10.2 Rates

The estimate is based on Public Work Advisory's database of rates. These rates are derived from tendered and/or constructed rates from previous projects of a similar nature. Public Works Advisory has developed an extensive database of rates through its involvement in numerous large dam projects at design and construction stages over many years.

10.3 Cost Estimate and Cost Risk Assessment Summary

Cost estimates have been based on the determination of construction methodology, material selection and the substantial experience of Public Works Advisory in the design and construction of dams. Cost risk estimates have been prepared based on estimated 10th percentile (P10), 50th percentile (P50) and 90th percentile (P90) costs.

A cost risk assessment was performed using Version 7 of the Palisade Decision Tools Software, @RISK. The software performs a Monte Carlo simulation with the output "Total Project Cost" generated by letting the computer recalculate our estimate worksheet over and over, each time using randomly selected sets of values for the triangular probability distributions assigned for each of the estimate items.

The proposed raising option for Clarrie Hall Dam incorporates FSL70.0m(AHD) with a total storage capacity of 42,300ML. The majority of the rockfill is to be obtained from the old quarry site adjacent to the dam with some smaller volumes extracted from excavation of the new spillway channel higher in the left abutment. The existing precast concrete parapet wall units would be re-used, thus saving on the required number of new units and volume of raised embankment fill.

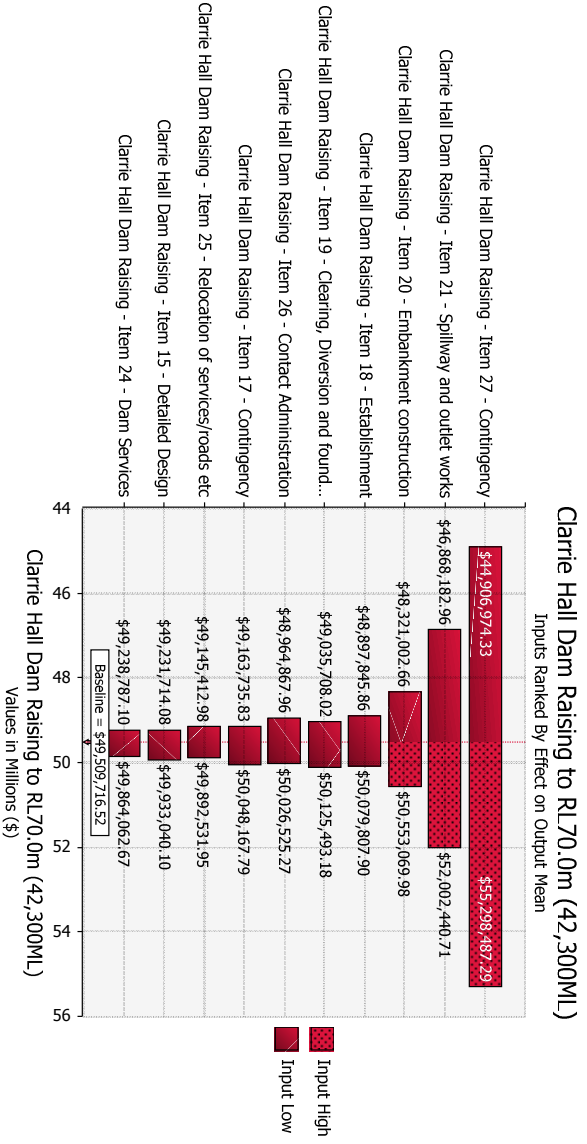
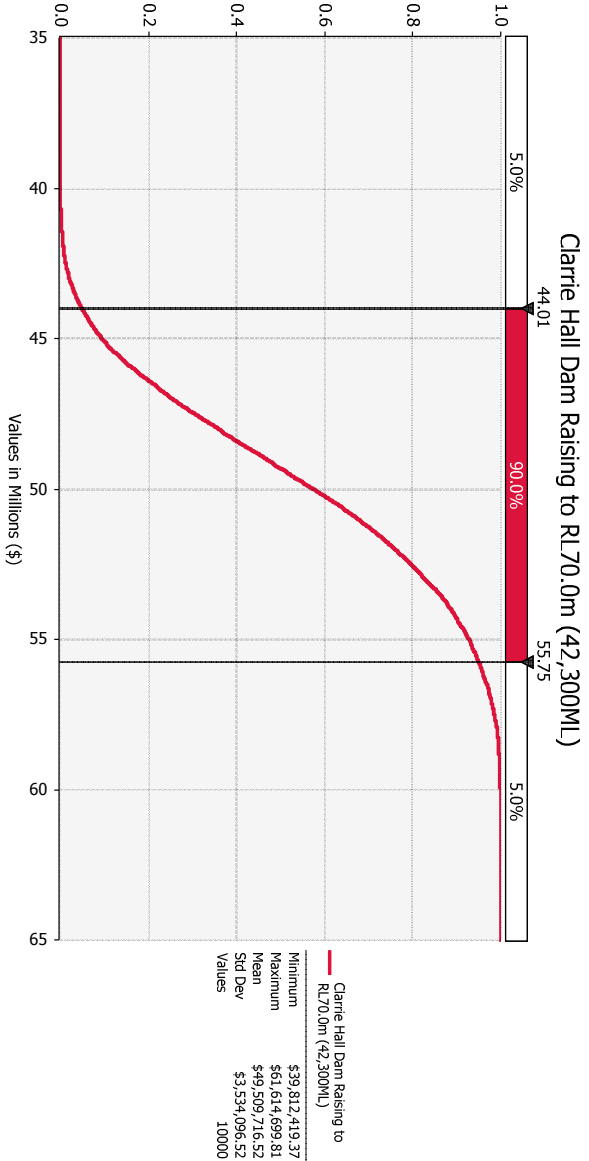
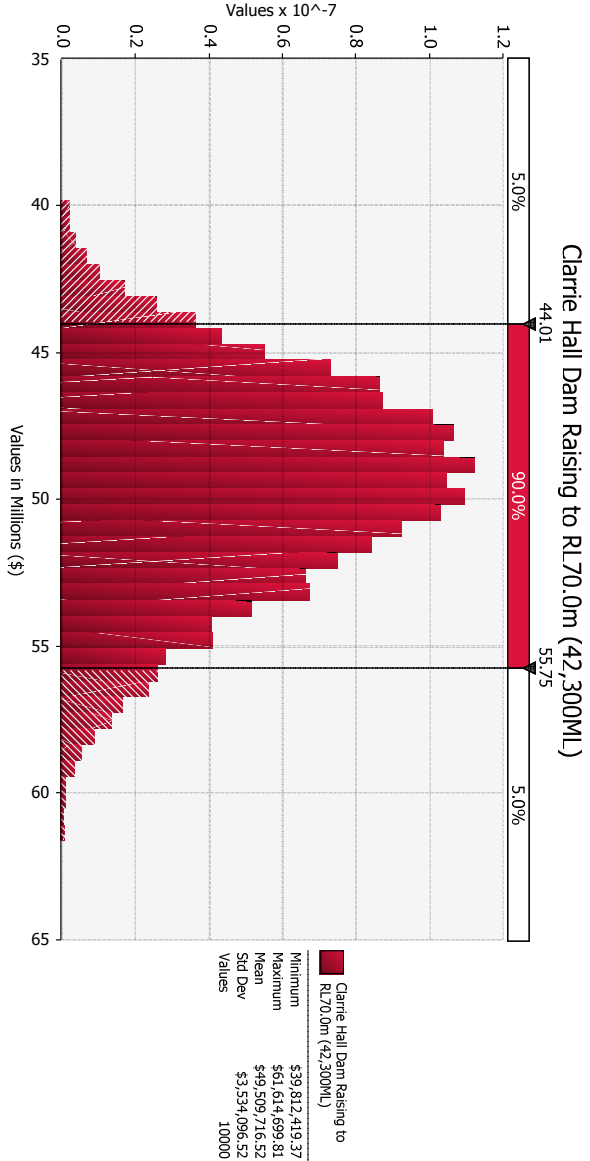
The dam raising option developed satisfies the NSW Dams Safety Committee (DSC) and the Australian National Committee on Large Dams (ANCOLD) guidelines.

Refer to Error! Reference source not found.H for a breakdown of the cost estimates.

From the risk assessment, the total project cost is forecast to be in the range of \$39.8M to \$61.6M, with our estimate of the most likely project cost being \$49.5M. The statistical analysis indicates that there is a 90% probability that the project cost will fall between \$44.1M and \$55.8M.

The results of the updated 2018 @RISK analysis are shown on the following page:

Clarrie Hall Dam Raising Concept Design Report



11. Discussion and Conclusion

This report concerns concept design for the raising of Clarrie Hall Dam. The proposed raised dam will increase the existing storage at Full Supply Level (FSL) from 16,000 ML to 42,300 ML and is expected to meet the additional water security requirements of the Tweed Shire community well into the future.

The preferred dam raising option involves increasing the height of the existing concrete faced rockfill embankment and construction of a new concrete lined spillway higher up in the left abutment. The existing intake tower and access bridge will also be raised and a new permanent road access will be provided higher in the right abutment.

Concept design for the raised dam and its components has been based on updated hydrological and geotechnical investigations, seismic and structural assessments and is in accordance with NSW Dams Safety Committee (DSC) requirements and Australian National Committee on Large Dams (ANCOLD) guidelines as well as current best practice.

Previous studies undertaken by PWA have identified that the optimum raising of the dam is with FSL at RL70.0m(AHD). The new spillway has been designed such that the maximum flood level in the raised storage does not exceed RL77.0m(AHD).

Clarrie Hall Dam has been assigned an EXTREME Flood Consequence Category (FCC) and a HIGH A Sunny Day Consequence Category (SDCC) which means that it must pass safely the Probable Maximum Flood (PMF) and withstand a 0.01% AEP (10,000 year) Maximum Design Earthquake (MDE).

The existing Clarrie Hall Dam embankment comprises fresh to slightly weathered free draining rockfill zones and is founded on a uniform sequence of hard rhyolite rock with minor welded tuff. Studies have shown that a dam of this type and configuration would be inherently safe even against large magnitude earthquakes and overall stability of the embankment is not threatened.

It was initially envisaged that rockfill for the raised embankment would be sourced from the new spillway excavations higher on the left abutment. However, geotechnical investigations revealed that the majority of the targeted rock was highly to extremely weathered (and highly fractured) which made it unsuitable for embankment rockfill. As a result, the vast amount of material required for use in the raising of Clarrie Hall Dam embankment would need to be sourced from elsewhere. This is likely to come from the existing rock quarry that was used in the original dam construction. An examination of previous geotechnical investigations of the old quarry site indicate that sufficient volumes of suitable material would be available.

Precast parapet wall units from the existing embankment would be stored and used for the raised embankment, thus saving on the number of new units required to be provided across the raised crest.

Three spillway options have been considered as part of the Clarrie Hall Dam Raising project. Spillway Option 1A was developed initially as the optimum arrangement where all of the excavated material would be suitable for embankment raising. Since this was not the case, spillway Options 1B and 2 were then developed. Option 1B is a similar arrangement to Option 1A but narrower overall to minimise excavation waste. Option 2 uses the existing spillway footprint with a raised crest structure and culvert through the raised embankment fill. Following further hydraulic and structural assessments, Option 1B was selected as the preferred spillway option. It is deemed the most practical solution.

CFD modelling of Option 1B has been undertaken which verifies spillway flow behaviour and confirms section dimensions. A summary of results is incorporated in this report.

Analysis has shown that the existing intake tower can be raised without expensive post tensioning techniques, albeit for a smaller earthquake resistance to the main embankment. Similarly, for the raised tower access bridge pier. A three span bridge is envisaged joining the raised intake tower deck level with the new permanent access road in the dam's right abutment.

Concept drawings of the proposed dam raising are attached to this report.

A time line has been developed which shows essentially a 26 weeks design and environmental assessment period followed by 70 weeks construction. Construction methodology suggests that there would be no engineering impediment to construction of the raised dam as outlined.

Risks associated with the Clarrie Hall Dam Raising project have also been identified and a risk matrix has been derived based on an earlier workshop with Council staff and further input from review of precedent projects. Generally, risks are considered manageable and not detrimental to progression of the project.

Cost estimation has included cost risk assessment. The cost risk estimates have been prepared based on estimated 10th percentile (P10), 50th percentile (P50) and 90th percentile (P90) costs. A breakdown of the estimates is presented which cover all aspects of the project.

12. References

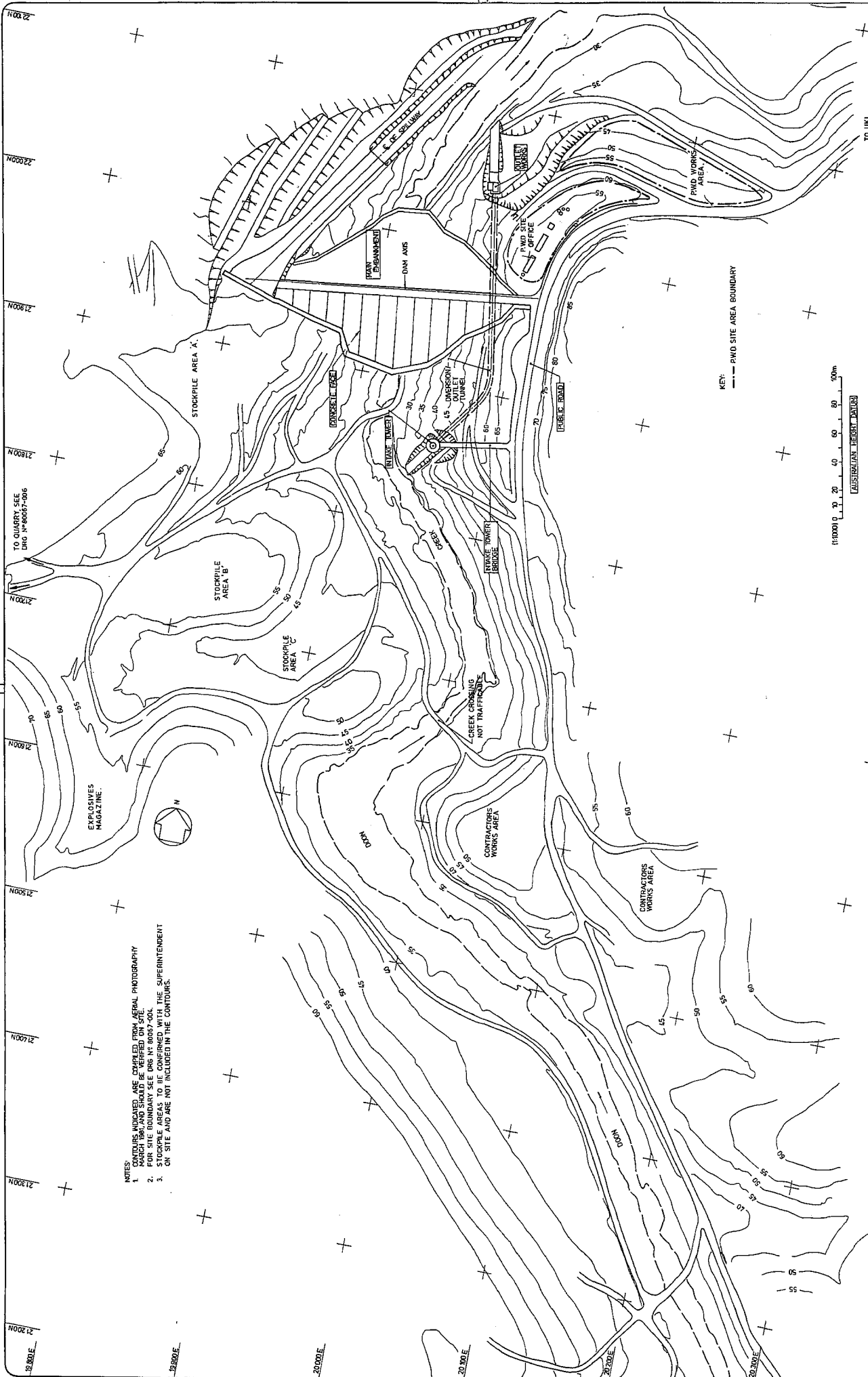
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31. NSW Dams Safety Committee, DSC3C, *Acceptable Earthquake Capacity for Dams*

Appendices

APPENDIX A

EXISTING DAM DRAWINGS



NOTES:
 1. CONTOURS INDICATED ARE COMPILED FROM AERIAL PHOTOGRAPHY
 MARCH 1984, AND SHOULD BE VERIFIED ON SITE.
 2. FOR SITE BOUNDARY SEE DRG N° 80067-004.
 3. STOCKPILE AREAS TO BE CONFINED WITHIN THE SUPERINTENDENT
 ON SITE AND ARE NOT INCLUDED IN THE CONTOURS.

"TENDER DRAWING ONLY"

FILE W5172/108
 DRAWING
 80067-002

TWEED DISTRICT W.S. AUG.
 CLARRIE HALL DAM
 SITE PLAN

PUBLIC WORKS DEPARTMENT N.S.W.
 W. R. HILL
 DIRECTOR OF PUBLIC WORKS
 TWEED SHIRE COUNCIL

DESIGNED: [Signature]
 DRAWN: [Signature]
 CHECKED: [Signature]
 APPROVED: [Signature]

ALL LEVELS ARE IN METRES.
 ALL OTHER DIMENSIONS
 ARE IN MILLIMETRES
 UNLESS STATED OTHERWISE

DETAILS OF AMENDMENTS

APPROVED DATE

SCHEDULE OF BOREHOLE LOCATIONS

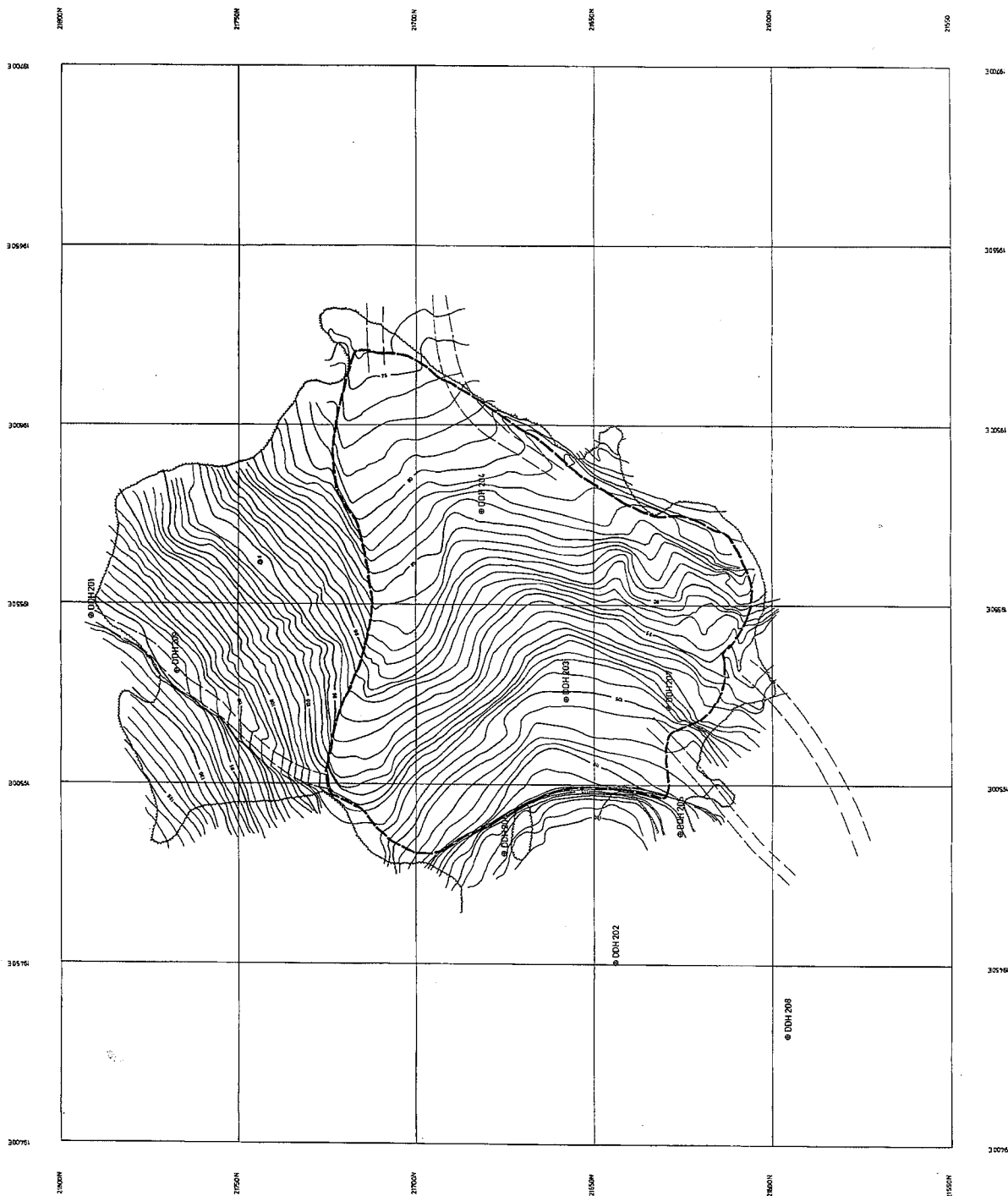
FILE	EAST	NORTH	LENGTH	RII
DDH201	9515	27971	27.50	100
DDH202	9515	27971	14.21	130
DDH203	9524	27658	20.35	108
DDH204	9524	27658	14.90	90
DDH205	9524	27658	14.90	110
DDH206	9522	27659	25.4	103
DDH207	9531	27667	30.5	114

NOTES:

1. CONTOURS INDICATED ARE COMPILED FROM AERIAL PHOTOGRAPHY. MARCH 1981 AND SHOULD BE VERIFIED BY THE CONTRACTOR. CONTOURS SHOULD BE STRIPPED OUT AND SHOULD BE VERIFIED ON SITE BY THE CONTRACTOR.
2. QUARRY OPERATIONS NOT TO EXTEND OUTSIDE STRIPPED AREA UNLESS WRITTEN APPROVAL HAS BEEN GIVEN BY THE SUPERINTENDENT.

KEY:

- DDH202 VERTICAL DIAMOND DRILL HOLE AND NUMBER
- AREA STRIPPED TO DO DOZER REFUSAL
- CLEARING LINE TO TREES



1. STRIPPING OF EMBANKMENT SITE
2. CONSTRUCTION OF UPSTREAM CONCRETE TOE SLAB
3. SPILLWAY EXCAVATION
4. UPSTREAM AND DOWNSTREAM TUNNEL PORTAL EXCAVATION
5. CONSTRUCTION OF CONCRETE LINED TUNNEL, TOWER

IN THE PERIOD FROM COMMENCEMENT OF CONTRACT TO CLOSURE OF THE DIVERSION TUNNEL THE CONTRACTOR SHALL CARRY OUT THE FOLLOWING WORKS :-

COMPLETION OF :-

1. UPSTREAM CUPPERDAN
2. STEEL MESHED EMBANKMENT
3. EMBANKMENT CONCRETE FACE AND WAVE WALL, SPILLWAY CONCRETE AND DRAINAGE, INTAKE TOWER AND ACCESS BRIDGE INSTALLATION OF EMBANKMENT

① INSTALL STOPLOOS WITH BULKHEAD GATE IN RAISED POSITION.

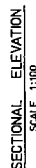
- ③ PLACE STAGE 1 TOWER BASE PLUS CONCRETE INTERFAZE DROUTING.
- ④ CLOSE 600# DATE VALVES IN TOWER BASE NOT LESS THAN 72 HOURS AFTER CONCRETE INTERFAZE DROUTING.
- ⑤ INSTALL 600# DATE VALVE 600# PIPE AND TEMPORARY FLANGE TO TUNNEL CHAMBER 201-159 INCLUDING 900# OFFTAKE AND 150# DATE VALVE FOR CROSS CONNECTION PIPE.
- ⑥ AS COMMERCE RIPARIAN RELEASE OF UP TO 11 MLD THROUGH 150# DATE VALVE AS DIRECTED BY THE SUPERINTENDENT.
- ⑦ INSTALL PERMANENT 600# PIPE VALVES AND FITTINGS DOWNSTREAM OF TUNNEL CHAMBER 201-159.
- ⑧ CLOSE 600# DATE VALVES IN TOWER BASE, PRIOR BETWEEN VALVES, CONCRETE INTERFAZE 150# TOWER BASE PLUS CONCRETE INCLUDING INTERFAZE DROUTING.
- ⑨ INSTALL 1200# OUTLET PIPE AND 1200# 9 E V, COMPLETE 150# CROSS CONNECTION PIPE AND FITTINGS.
- ⑩ PLACE TUNNEL PLUS CONCRETE INTERFAZE DROUTING.
- ⑪ OPEN TUNNEL DRAIN VALVE.
- ⑫ COMPLETE CONSTRUCTION OF 1200# DISSIPATOR.
- ⑬ COMPLETE CONSTRUCTION OF 600# DISSIPATOR.
- ⑭ COMPLETE INSTALLATION OF F. D. C VALVES.
- ⑮ CLOSE TUNNEL DRAIN VALVE.
- ⑯ BALANCE PRESSURE ON BULKHEAD DATE USING 150# CROSS CONNECTION TO FILL 1200# PIPE AND TUNNEL UPSTREAM OF TUNNEL PLUG.
- ⑰ RAISE BULKHEAD DATE.

THE SEQUENCE GIVEN ABOVE IS THAT INTENDED BY THE DESIGNERS. WHERE CIRCUMSTANCES REQUIRE THE SUPERINTENDENT MAY APPROVE A DIFFERENT SEQUENCE.

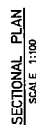


TYPICAL SECTION

SCALE 1:500

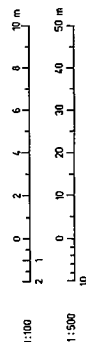


SCALE 1:100



FUNCTIONAL PLAN

SCALE 1-100



AUSTRALIAN	HEIGHT	DATUM
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"TENDER DRAWING ONI V"

 PUBLIC WORKS DEPARTMENT N.S.W.

W. K. PLZ
J. P. MEDWATER
DIRECTOR OF PUBLIC WORKS
CHIEF ENGINEER

TWEED SHIRE COUNCIL

DESIGNED BY *J. J. McDonald*
 REPRODUCTION PERMITTED 6-10-88

DATE	6-10-84
DRAWN BY	P. S. K. R.
CHECKED BY	
INSPECTING ENGINEER	

10-10-81
 CHECKED
 10-10-81
 PRINCIPAL ENGINEER WATER SUPPLY
 10-10-81

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

**ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS
ARE IN MILLIMETRES**

UNLESS STATED OTHERWISE

DETAILS OF AMENDMENTS	APPROVED DATE
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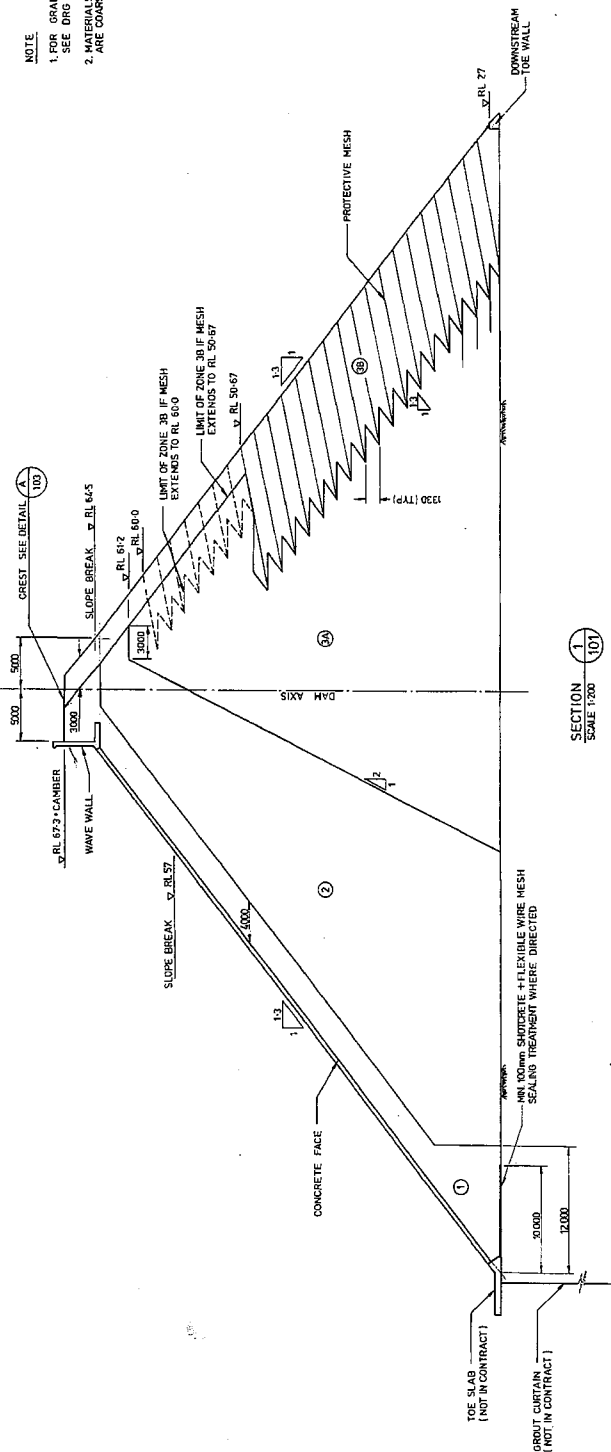
TWEED DISTRICT W.S. AUG.

CLARRIE HALL DAM

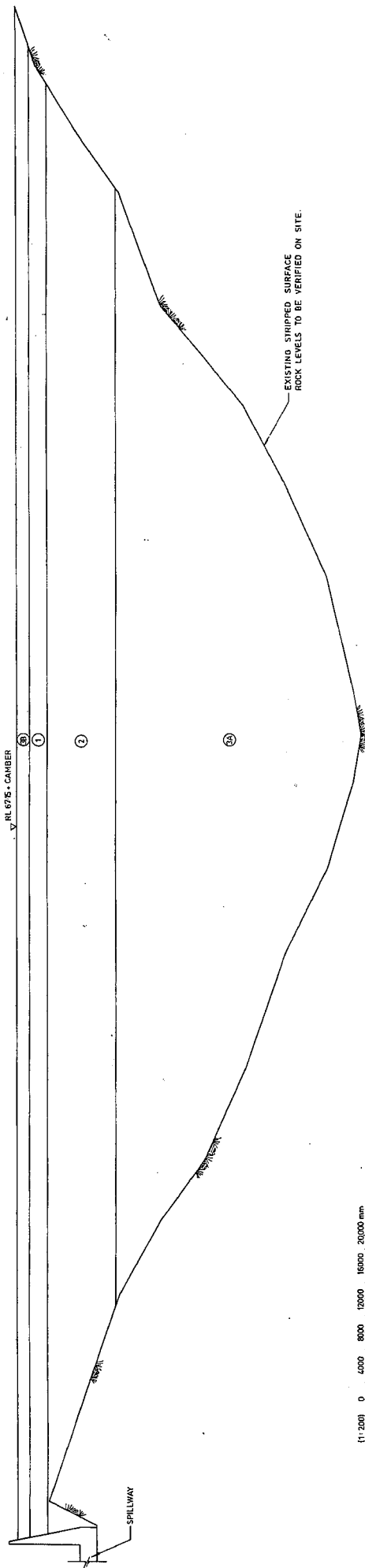
OUTLET WORKS
SEQUENCE OF DEVELOPMENT.

NOTE

1. FOR GRADATION AND DESCRIPTION OF EMBANKMENT ZONES SEE DRG 80067-101
2. MATERIALS ARE TO BE SELECTED SO THAT ZONE 3A AND 3B MATERIALS ARE COARSE AND MORE PERMEABLE THAN ZONE 2 MATERIAL.



SECTION 1/101
SCALE 1:200
TYPICAL MAXIMUM SECTION



SECTION ALONG DAM AXIS

AUSTRALIAN HEIGHT DATUM

(1:200) 0 4000 8000 12000 16000 20000 mm

"TENDER DRAWING ONLY"

DESIGNED: [Signature]
DRAWN: [Signature]
CHECKED: [Signature]
PROJECT: [Signature]
DATE: 12/10/91
PROJECT: [Signature]
DATE: 11/10/91

ALL LEVELS ARE IN METRES.
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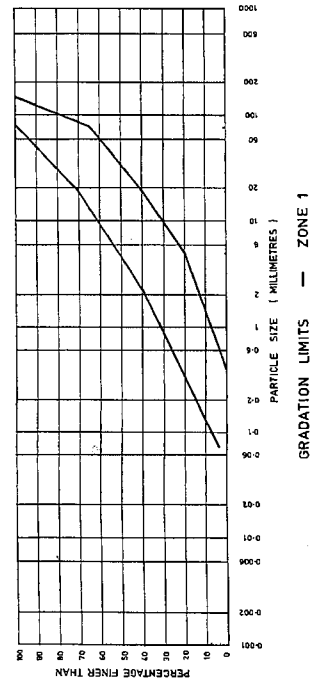
DETAILS OF AMENDMENTS
APPROVED: [Signature]
DATE: [Signature]

PUBLIC WORKS DEPARTMENT N.S.W.
DIRECTOR OF PUBLIC WORKS
W. K. HILL
J. P. WILSON
TWEED SHIRE COUNCIL

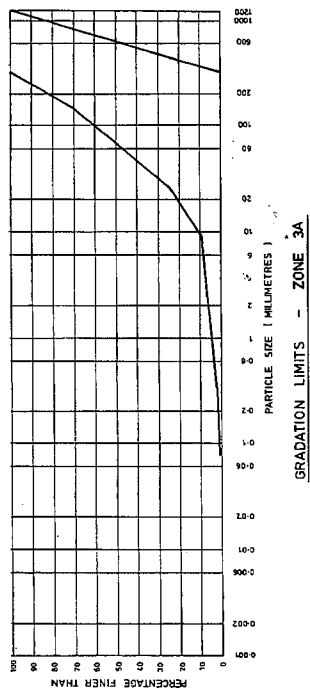
TWEED DISTRICT WS AUG
CLARIE HALL DAM
EMBANKMENT DETAILS SHEET 1.

FILE NO 1727/100
DRAWING
80067-102

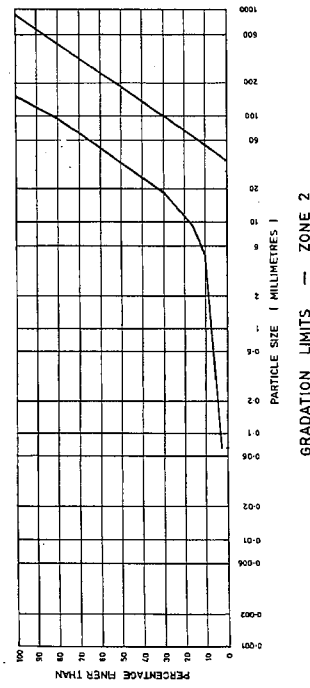
NOTES:
1. THE MATERIAL WITHIN 3m OF THE FACE IN ZONE 3B TO HAVE A SUFFICIENTLY CONSTANT GRADING AND COLOUR TO ENSURE A UNIFORM APPEARANCE TO THE FACE.



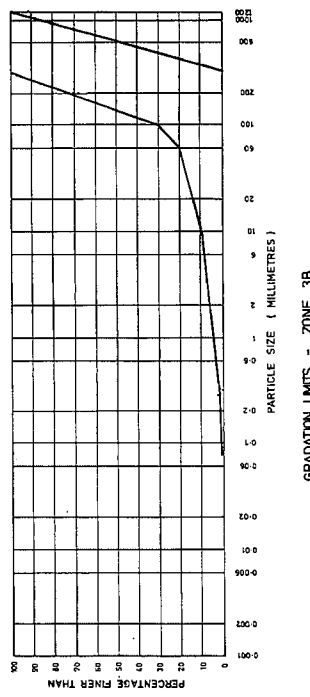
GRADATION LIMITS - ZONE 1



GRADATION LIMITS - ZONE 3A



GRADATION LIMITS - ZONE 2



GRADATION LIMITS - ZONE 3B

ZONE	FUNCTION	DESCRIPTION	LAYER THICKNESS (mm)	COMPACTION EQUIPMENT	NO OF PASSES PER LAYER	WATER % BY VOLUME
1.	SEA PERMEABLE ZONE	MODERATELY WEATHERED RHYOLITE	330	VIBRATORY ROLLER	4 x 10T	20
2.	PERMEABLE INTERMEDIATE ZONE	SLIGHTLY WEATHERED RHYOLITE	1000	VIBRATORY ROLLER	4 x 10T	20
3A.	FRESH ROCK ZONE	FRESH RHYOLITE	1300	VIBRATORY ROLLER	4 x 10T	20
3B.	MESH ZONE AND FACE ZONE	SELECTED FRESH RHYOLITE	1300	VIBRATORY ROLLER	4 x 10T	20

* ADDED WATER

EMBANKMENT ZONES

APPROVED DATE
DETAILS OF AMENDMENTS

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS
ARE IN METRES UNLESS
UNLESS STATED OTHERWISE

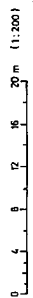
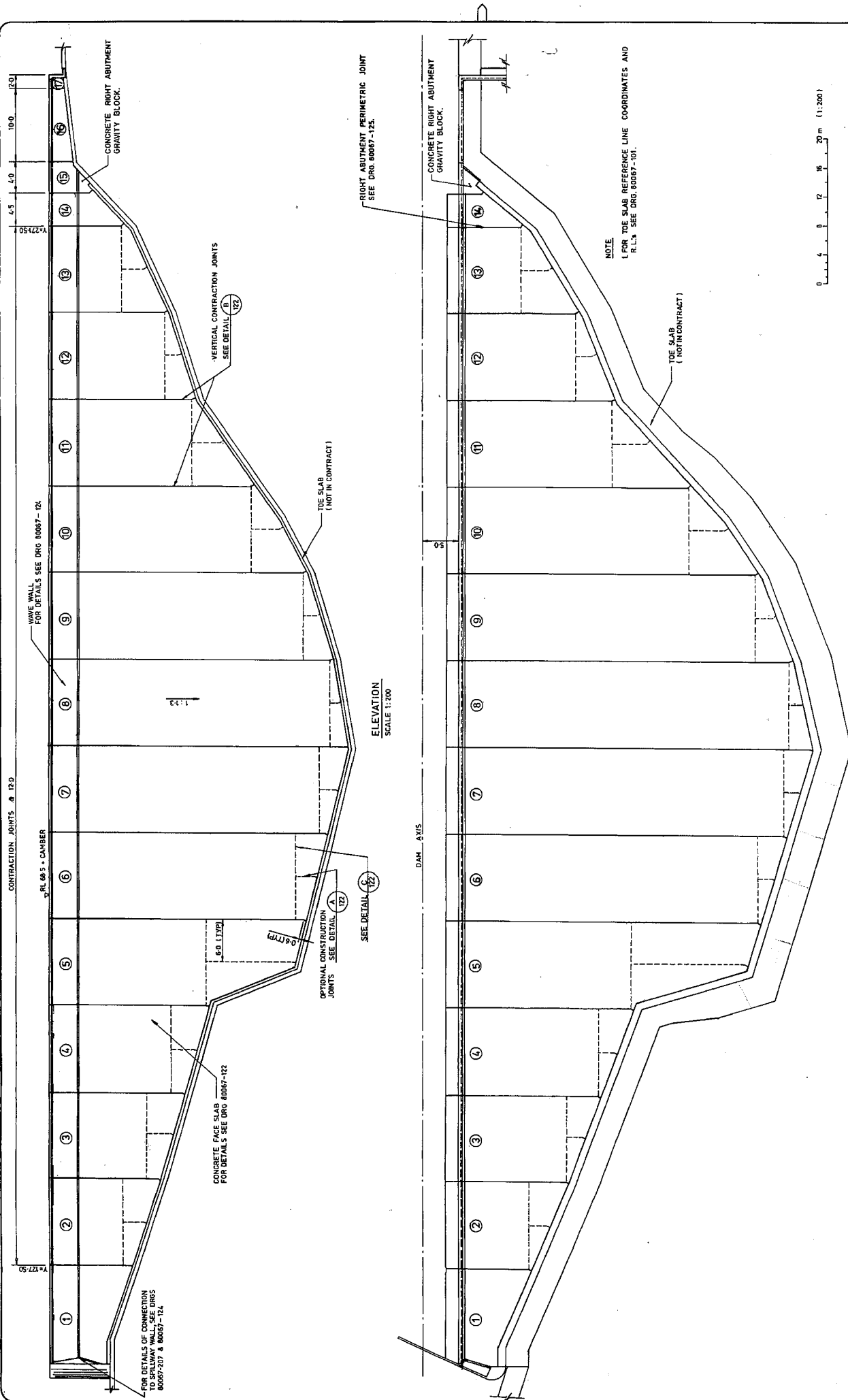
DESIGNED BY: J. P. MURPHY
CHECKED BY: J. P. MURPHY
DATE: 15/10/94
PROJECT: CLARRIE HALL DAM
DRAWING: 80067-104

PUBLIC WORKS DEPARTMENT N.S.W.
J. P. MURPHY
CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
GRADATION AND DESCRIPTION OF
EMBANKMENT ZONES

"TENDER DRAWING ONLY"

FILE W3172/106
DRAWING
80067-104



AUSTRALIAN HEIGHT DATUM

"TENDER DRAWING ONLY"

FILE
WS1172-108
DRAWING
80067-121

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
CONCRETE FACE AND WAVE WALL
GENERAL ARRANGEMENT

PUBLIC WORKS DEPARTMENT N.S.W.
IN CHARGE
CHIEF ENGINEER

TWEED SHIRE COUNCIL

DESIGNED
BY
CHIEF ENGINEER

CHECKED
BY
CHIEF ENGINEER

APPROVED
BY
CHIEF ENGINEER

17/10/81
12/11/81
11/12/81

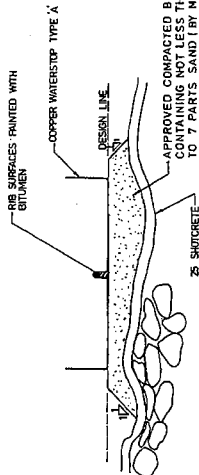
ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS
ARE IN METRES
UNLESS STATED OTHERWISE

DETAILS OF AMENDMENTS

APPROVED DATE

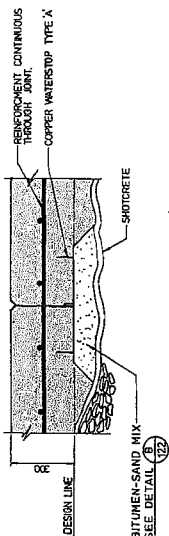
NOTES

1. FOR CONCRETE NOTES SEE ORD. 80067-125
2. SPACING AND ORIENTATION OF REINFORCEMENT BARS SHALL BE PARALLEL AND NORMAL TO THE DAM AXIS.



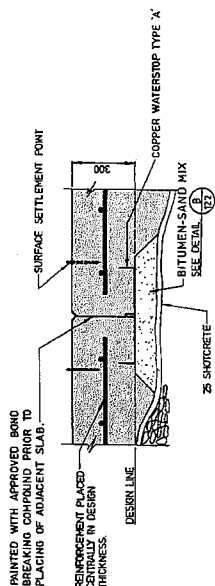
COPPER WATERSTOP ON BITUMEN-SAND PAD FOR VERTICAL CONSTRUCTION AND CONTRACTION JOINTS

DETAIL (B)
SCALE 1:10 (12)



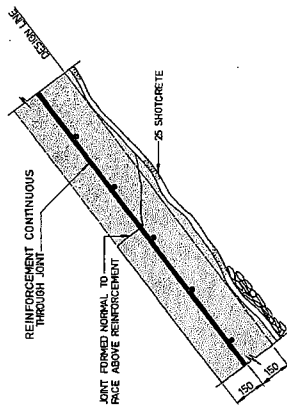
VERTICAL CONSTRUCTION JOINT

DETAIL (A)
SCALE 1:10 (12)



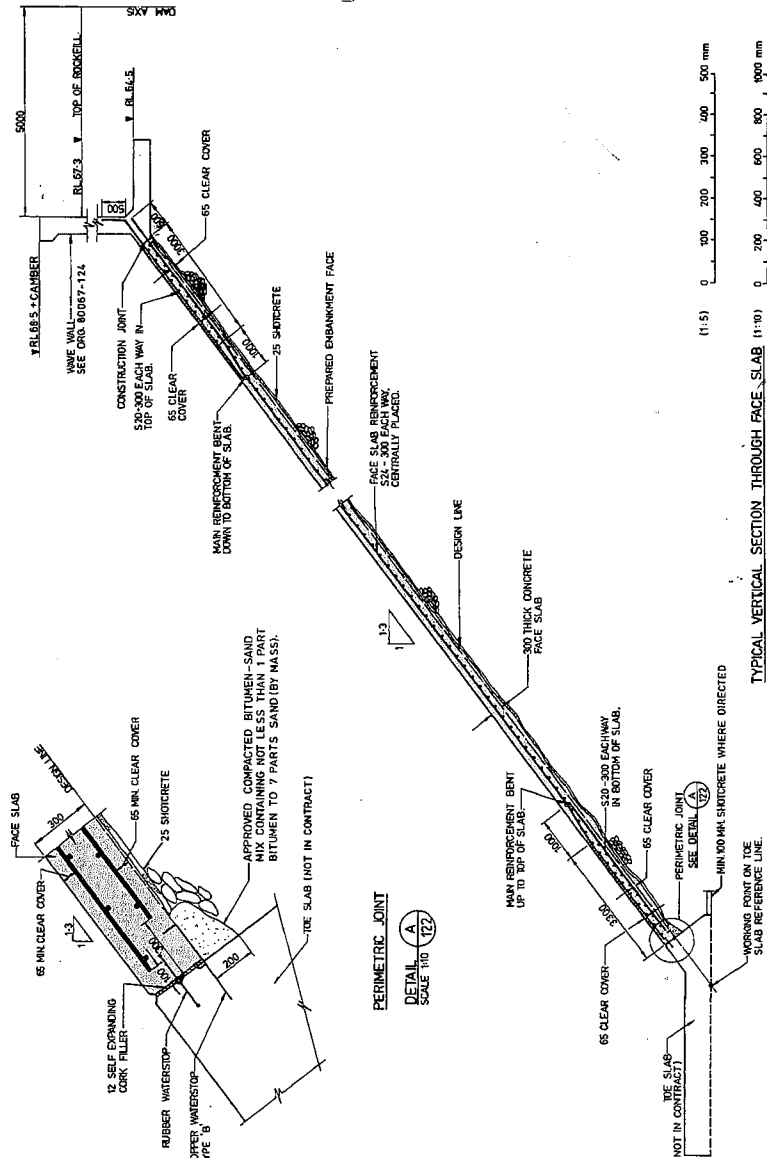
VERTICAL CONTRACTION JOINT

DETAIL (B)
SCALE 1:10 (12)



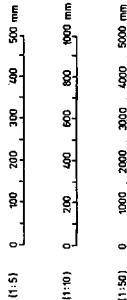
TYPICAL HORIZONTAL CONSTRUCTION JOINT

DETAIL (C)
SCALE 1:10 (12)



TYPICAL VERTICAL SECTION THROUGH FACE SLAB

SCALE 1:50



AUSTRALIAN HEIGHT DATUM

"TENDER DRAWING ONLY"

FILE W5172/108
DRAWING
80067-122

TWEED DISTRICT W.S. AUG.
CLARIE HALL DAM
EMBANKMENT
CONCRETE FACE DETAILS

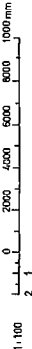
PUBLIC WORKS DEPARTMENT N.S.W.
J.R. MASON
CHIEF ENGINEER
TWEED SHIRE COUNCIL

INSPECTOR ENGINEER
J.R. MASON
16/11/91
CHIEF ENGINEER
TWEED SHIRE COUNCIL

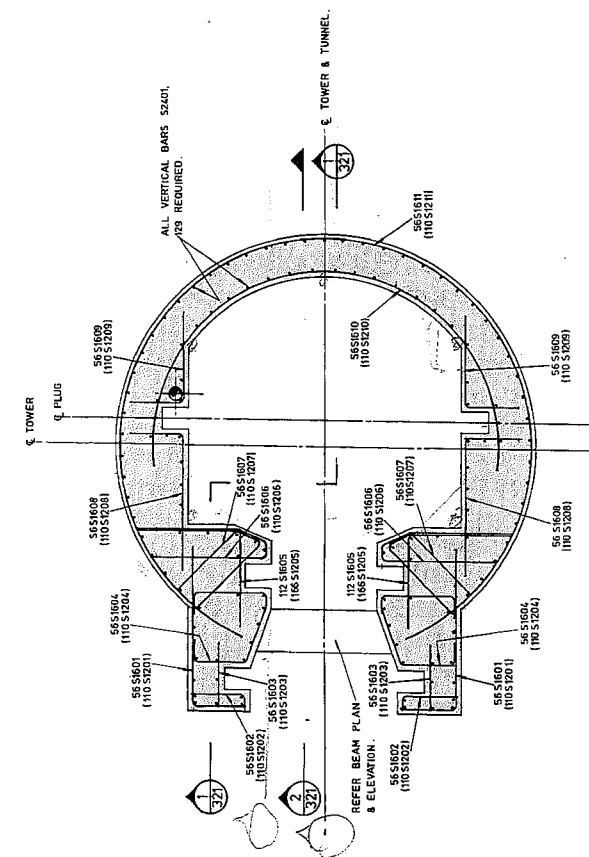
ALL LEVELS ARE IN METRES.
UNLESS STATED OTHERWISE

DETAILS OF AMENDMENTS

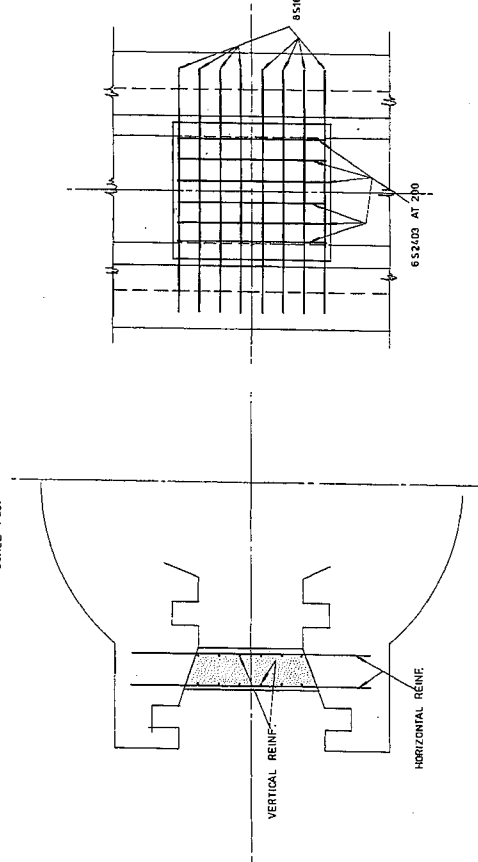
APPROVED DATE



SHUTTER, TRASH RACK & LIFTING FRAME FOR HORIZONTAL BULKHEAD GATE RECESS TOLERANCES

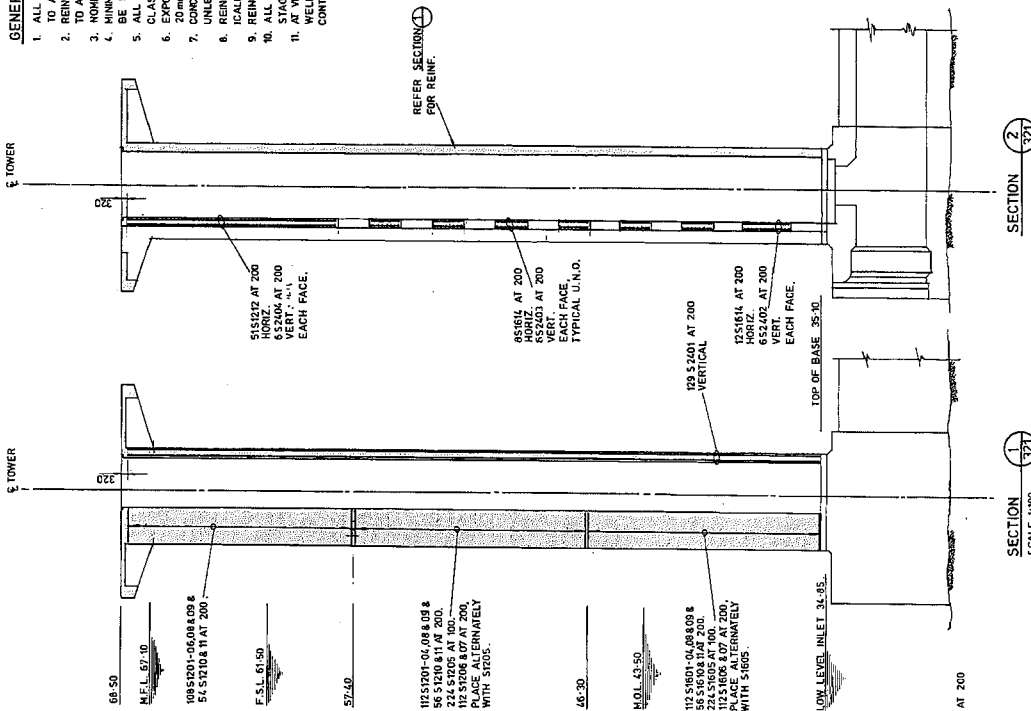


TYPICAL CROSS SECTION OF TOWER.
SCALE 1:20



TYPICAL PLAN OF BEAM.
SCALE 1:20

ELEVATION OF TYPICAL BEAM.
SCALE 1:20



SECTION 1
SCALE 1:40

SECTION 2
SCALE 1:40

GENERAL NOTES.

1. ALL REINFORCED CONCRETE TO BE GRADE 25 (F_y 250 MPa) TO A.S.1480.
2. REINFORCING BARS TO BE GRADE 200S (F_y 230 MPa) TO A.S.1037.
3. MINIMUM CLEAR COVER TO REINFORCEMENT SHALL BE 50mm.
4. ALL EXPOSED CONCRETE SURFACES SHALL HAVE CLASS F2 FINISH, UNLESS NOTED OTHERWISE.
5. EXPOSED INTERNAL & EXTERNAL CORNERS SHALL HAVE 20mm FILLETS OR CHAMFERS UNLESS NOTED OTHERWISE.
6. CONCRETE LIFTS SHALL NOT EXCEED 2m IN DEPTH UNLESS OTHERWISE APPROVED BY THE SUPERINTENDENT.
7. REINFORCEMENT SHOWN IS REPRESENTED DIAGRAMMATICALLY AND IS NOT NECESSARILY A TRUE PROJECTION.
8. ALL LAP SPICES IN REINFORCEMENT ARE TO BE STAGGERED.
9. ALL LAP SPICES EACH BAR IS TO BE TIED AND WELDED FOR A MINIMUM RUN OF 15mm FOR ELECTRICAL CONTINUITY.

"TENDER DRAWING ONLY"

FILE W5172/108

DRAWING

80067-321

TWEED DISTRICT W.S. AUG.

CLARIE HALL DAM

INTAKE TOWER

REINFORCEMENT DETAILS

PUBLIC WORKS DEPARTMENT N.S.W.

W. L. F. C. E. S.

CHIEF OF DIVISION

TWEED SHIRE COUNCIL

DESIGNED

INSPECTING ENGINEER

PRINCIPAL ENGINEER

PRINCIPAL ENGINEER DESIGN

ALL LEVELS ARE IN METRES.

ALL OTHER DIMENSIONS

ARE IN MILLIMETRES

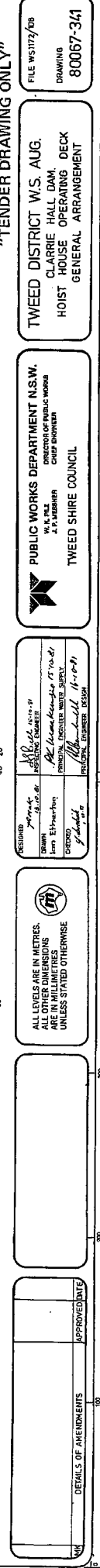
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APPROVED

DETAILS OF AMENDMENTS

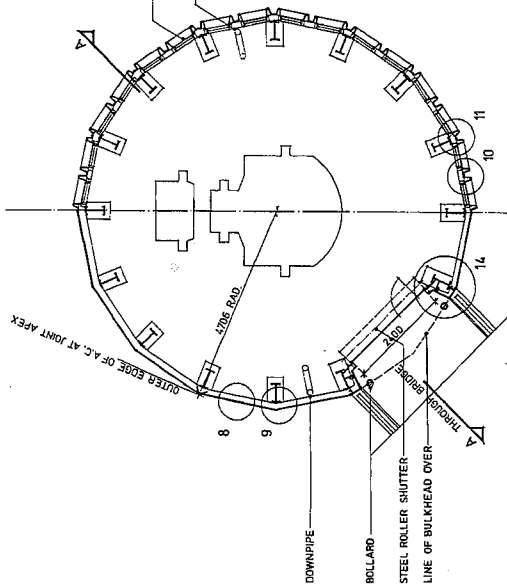
APPROVED

APPROVED



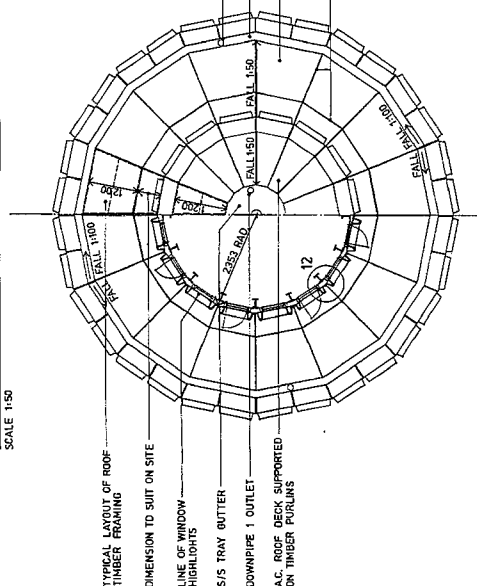
DETAILS OF AMENDMENTS		APPROVED

5



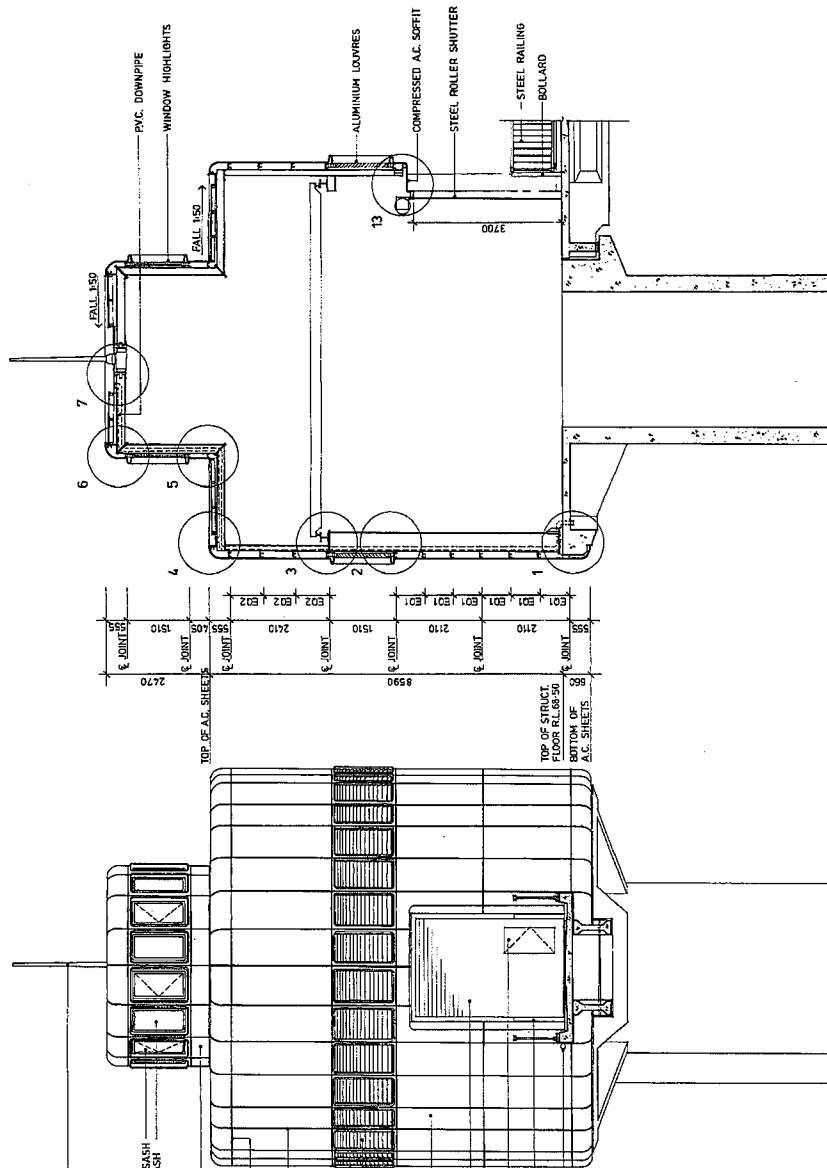
PLAN AT LOUVRES

PLAN AT ROLLER SHUTTER
SCALE 1:50



ROOF PLAN
SCALE 1:50

PLAN AT HIGHLIGHTS
SCALE 1:50



SECTION A-A
SCALE 1:50

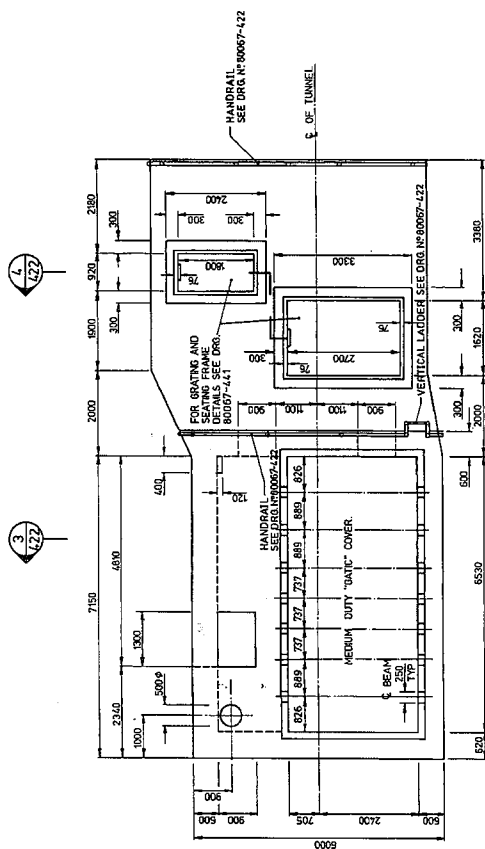
NOTE - ACTUAL SITE DIMENSIONS SHALL BE TAKEN IN PREFERENCE TO DIMENSIONS SHOWN ON DRAWING.

ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

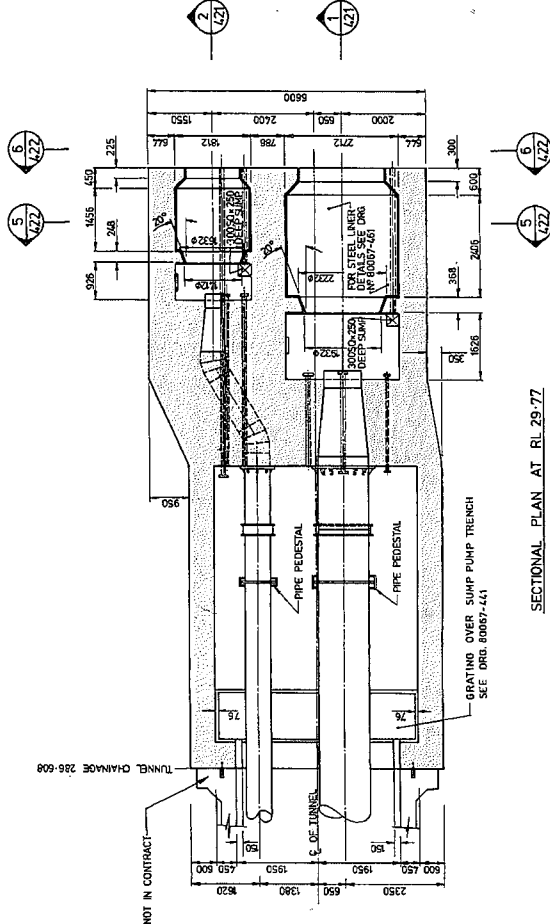
REVISIONS
VEEA SALTER
DRAWN BY
CHECKED BY
DATE
12/10/11

PUBLIC WORKS DEPARTMENT N.S.W.
DIRECTOR OF PUBLIC WORKS
W. R. FILL
J. W. HARRISON
TWEED SHIRE COUNCIL

"TENDER DRAWING ONLY"
TWEED DISTRICT W.S. AUG.
CLARIE HALL DAM
INTAKE TOWER
HOIST HOUSE ARCHITECTURAL DETAILS
SHEET 1
FILE W5 172/108
DRAWING
80067-361

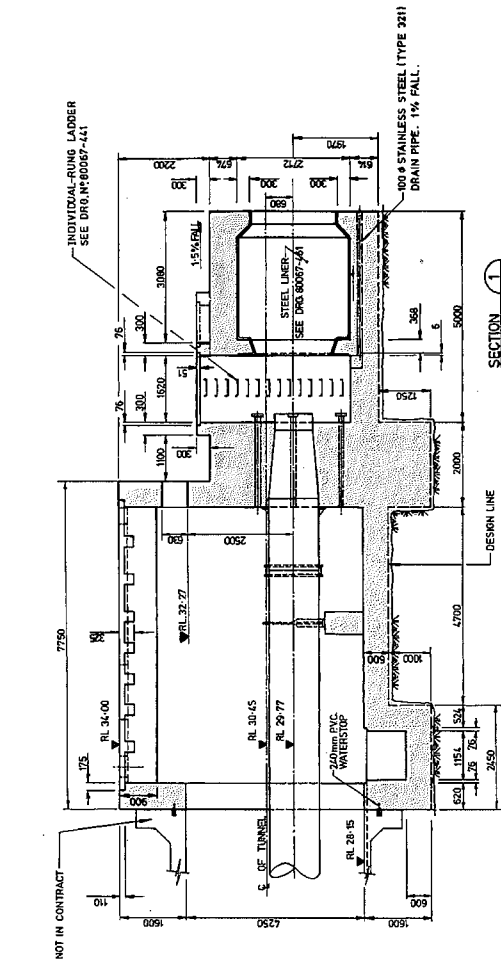


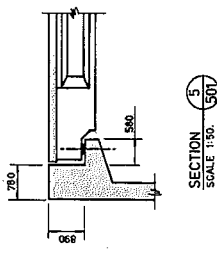
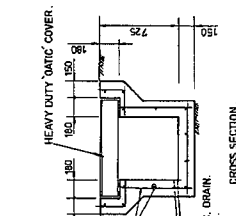
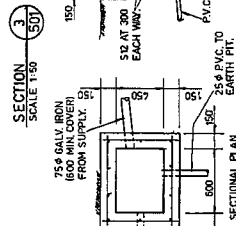
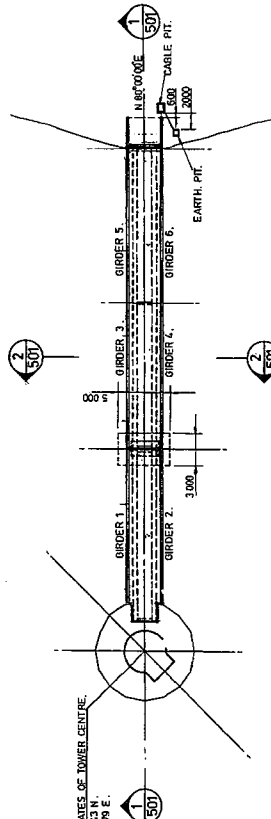
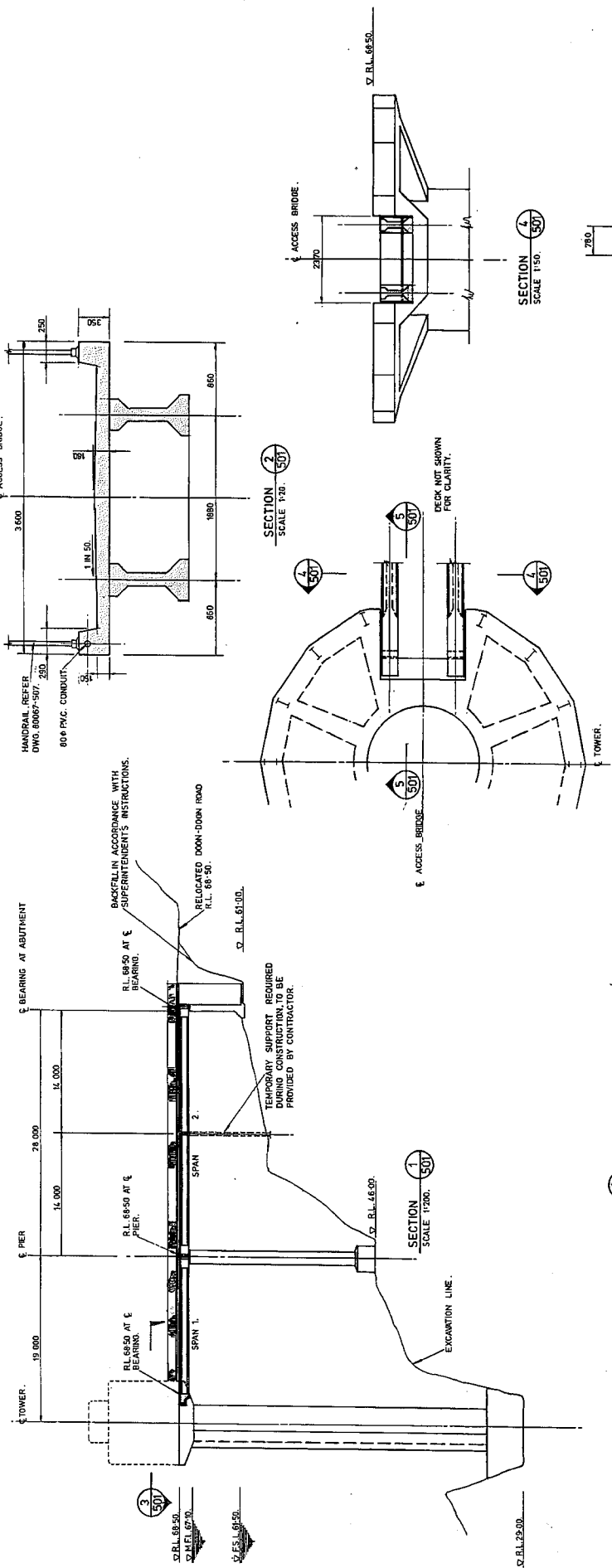
PLAN
SCALE 1:50



SECTIONAL PLAN AT RL 29.77
SCALE 1:50

(FOR PIPE AND SUMP DETAILS SEE DRG.





CONSTRUCTION & POST TENSIONING PROCEDURE.

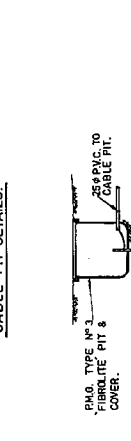
1. CONSTRUCT THE BASE OF THE ABUTMENT UP TO THE CONSTRUCTION JOINT.
2. ERECT THE TEMPORARY SUPPORT AT LOCATION SHOWN THE SUPPORT SHALL BE DESIGNED TO CARRY A LOAD OF 500KN AND ENSURE STABILITY DURING CONSTRUCTION.
3. ATTACH PERMANENT BEARINGS AT PIER AND ABUTMENT ENDS. PLACE SPAN 2 ORDERS IN POSITION AND CONCRETE THE JOINTS BETWEEN THE ORDERS CAST SPAN 2 DECK AND PERMANENT BEARINGS AT PIER AND ABUTMENT ENDS. THE CONCRETE SHALL BE OF STRENGTH OF 25MPa AND THE CONCRETE IN THE DECK HAS A STRENGTH OF 25MPa BUT NOT BEFORE IT IS 14 DAYS OLD. THE POST TENSIONING IS TO BE CARRIED OUT TO THE FOLLOWING PROCEDURE:
- a. POST TENSIONING SHALL BE CARRIED OUT FROM ONE END ONLY.
- b. UPPER TENDONS OF ORDERS ARE TO BE STRESSED FIRST.
- c. ATTACH BEARINGS FOR SPAN1 ORDERS AND PLACE ORDERS IN POSITION. CAST SPAN1 DECK AND CROSS BEAMS.
- d. REFER TO SPECIFICATION FOR POSITIONING OF ORDERS.

DESIGN LOAD.

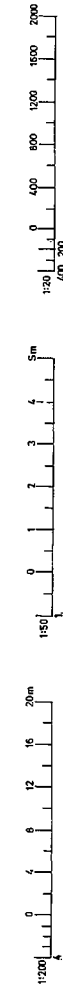
1. DESIGN LOAD—9 TONNE TRUCK.
2. ASSUMED AXLE LOADS.

72KN 4.250 18KN

CABLE PIT DETAILS.



EARTH PIT DETAIL.



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UNLESS STATED OTHERWISE

COORDINATES OF TOWER CENTRE
21 861 003 N.
19 959 779 E.

APPROVED DATE

DETAILS OF AMENDMENTS

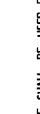
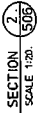
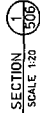
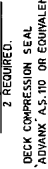
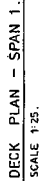
FILE W51172/108
DRAWING
80067-501

"TENDER DRAWING ONLY"

TWEED DISTRICT W.S. AUG.
CLARIE HALL DAM
INTAKE TOWER BRIDGE
GENERAL ARRANGEMENT.

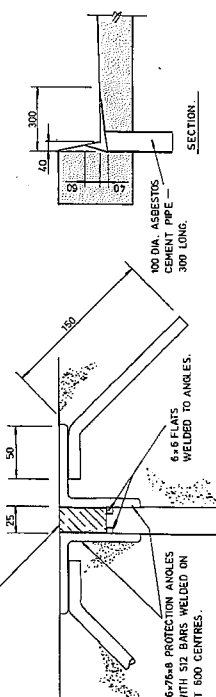
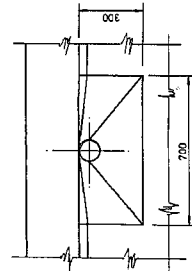
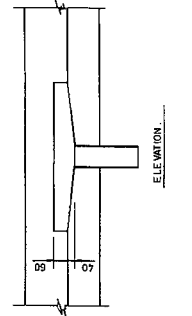
PUBLIC WORKS DEPARTMENT N.S.W.
J. A. ROSS
J. P. ROSS
CHIEF ENGINEER
TWEED SHIRE COUNCIL

DESIGNED BY
DRAWN BY
CHECKED BY
APPROVED BY
J. A. ROSS
J. P. ROSS
J. A. ROSS
J. P. ROSS
CHIEF ENGINEER
TWEED SHIRE COUNCIL



GENERAL NOTES:

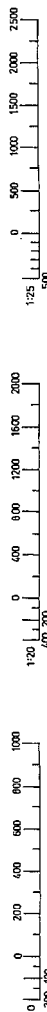
1. GRADE 30 MPA CONCRETE SHALL BE USED FOR DECK AND KERBS.
2. ALL REINFORCEMENT IN DECK AND KERBS SHALL BE GRADE 230S TO A.S. 1002.
3. CLEAR COVER TO REINFORCEMENT IN DECK AND KERBS TO BE 30 U.M.O.
4. ALL METALWORK EXCLUDING HANDRAILS SHALL BE HOT DIP GALVANISED AFTER FABRICATION TO A.S. 1650 - 1979.
5. ALL EXPOSED CONCRETE SURFACES SHALL HAVE CLASS F3 FINISH.
6. EXPOSED INTERNAL AND EXTERNAL CORNERS OF REINFORCED CONCRETE TO HAVE 20 FILLETS OR CHAMFERS U.M.O.



DETAIL

CUPPER DETAILS.

NOTE. REINFORCEMENT TO BE CUT & ADJUSTED
AT SCUPPER LOCATIONS TO PROVIDE CLEARANCE.



"TENDER DRAWING ONLY"

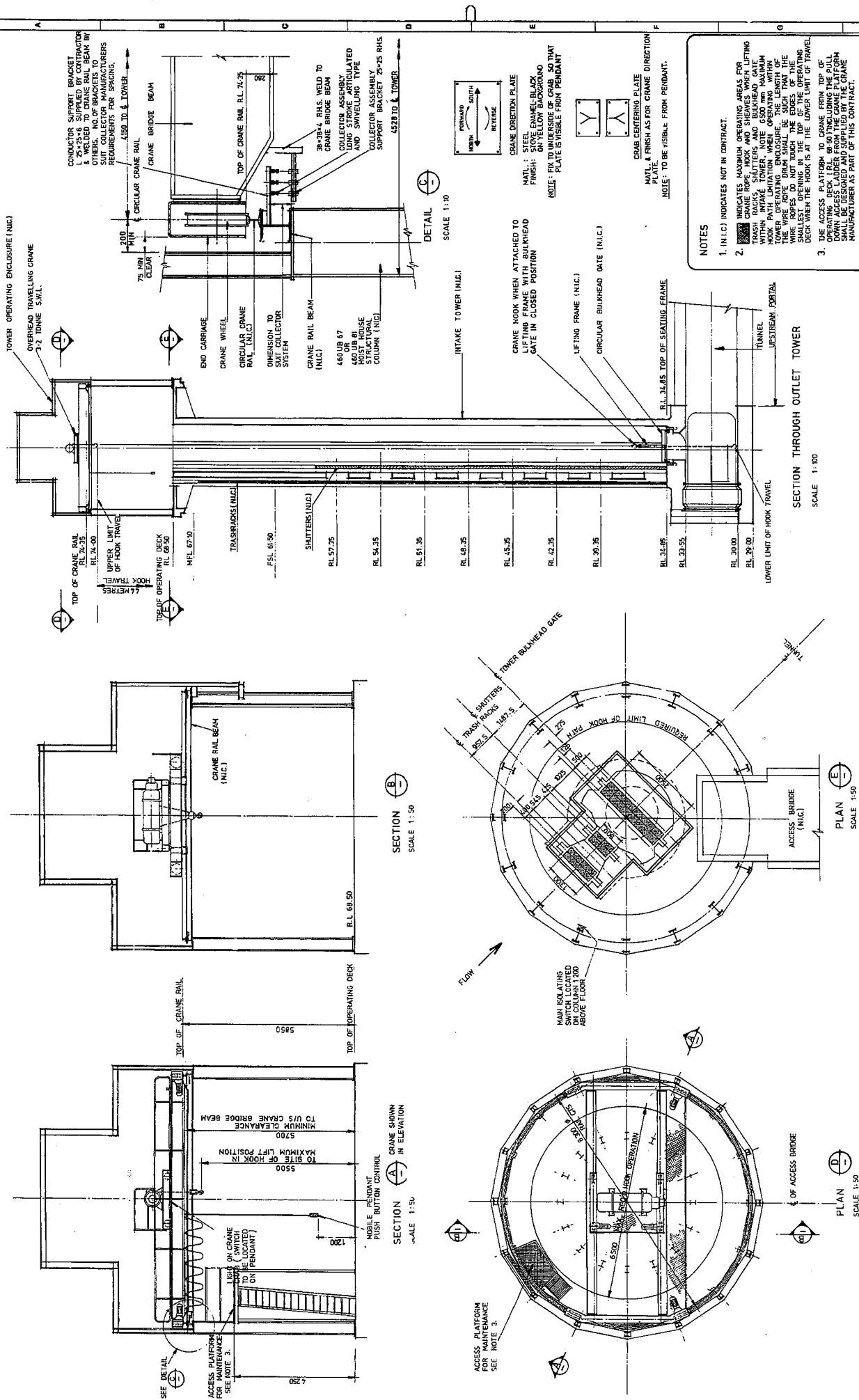


DEPARTMENT OF PUBLIC WORKS N.S.W.
W.K. PILZ DIRECTOR OF PUBLIC WORKS
J.P. MESSEUR CHIEF ENGINEER
TWEED SHIRE COUNCIL

DESIGNED	<i>J. Bell</i>	<i>15.10.81</i>	<i>J. Bell</i>	<i>15.10.81</i>
DRAWN	<i>John E. Horton</i>		<i>W. MacKinnon</i>	<i>15.11.81</i>
CHECKED	<i>[Signature]</i>		<i>W. MacKinnon</i>	<i>16.10.81</i>
			INSPECTING ENGINEER	PRINCIPAL ENGINEER WATER SUPPLY

ALL LEVELS ARE IN METRES,
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ARE IN MILLIMETRES
UNLESS STATED OTHERWISE

TWEED DISTRICT W.S.AUG.
CLARRIE HALL DAM
INTAKE TOWER BRIDGE.
DECK PLAN-SPAN 1.



NOTES

1. (N.I.C.) INDICATES NOT IN CONTRACT.
2. INDICATES MAXIMUM OPERATING AREAS FOR CRANE ROPE, HOOK AND SHEAVES WHEN LIFTING WITHIN MAKE TOWER. NOTE: 1500' MAXIMUM CRANE PATH LENGTH WHEN OPERATING WITHIN TOWER OPERATING ENCLOSURE. THE LENGTH OF THE WIRE ROPES DO NOT TOUCH THE EDGES OF THE DECK WHEN THE HOOK IS AT THE LOWER LIMIT OF TRAVEL.
3. THE ACCESS PLATFORM TO CRANE FROM TOP OF OPERATING DECK IS L. 60' 50" INCLUDING THE PULL DOWN ACCESS. THE ACCESS IS SUPPLIED BY THE CRANE MANUFACTURER AS PART OF THE CRANE. THE ACCESS PLATFORM IS NOT SUPPLIED BY THE CRANE MANUFACTURER AS PART OF THIS CONTRACT.

FILE WS 1172 / 108

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
OUTLET WORKS
3,2 TONNE SWL, CIRCULAR DOUBLE
BIRDER BRIDGE CRANE-GEN. ARRGT.



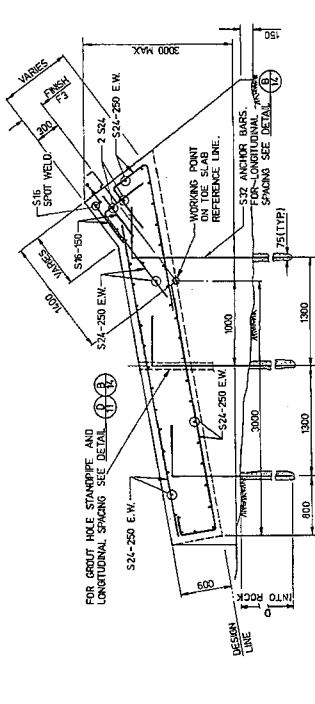
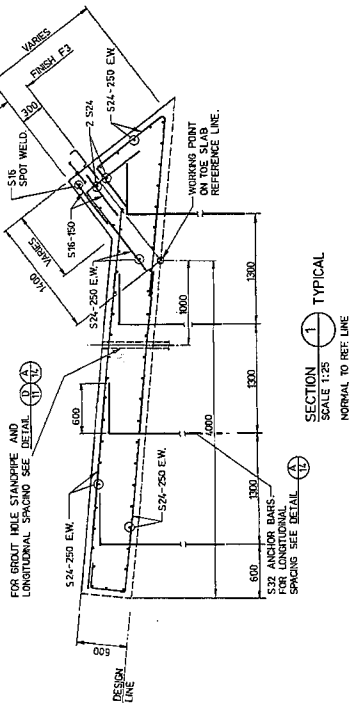
PUBLIC WORKS DEPARTMENT N.S.W.
W.A. PILZ DIRECTOR OF PUBLIC WORKS

T. A. CROWLEY & ASSOCIATES PVT. LTD.	
CONSULTING ENGINEERS	2057
10 HELP STREET CHATSWOOD	411 3933
TELEPHONE	
ISSUED	APPROVED
BY	DATE
BY	DATE

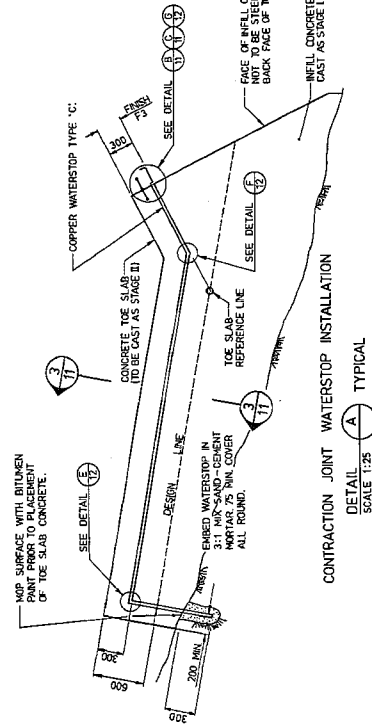
ALL LEVELS ARE IN METRES
ALL OTHER DIMENSIONS
ARE IN MILLIMETRES
UNLESS STATED OTHERWISE

CHK	DETAILS OF AMENOMENTS
-----	-----------------------

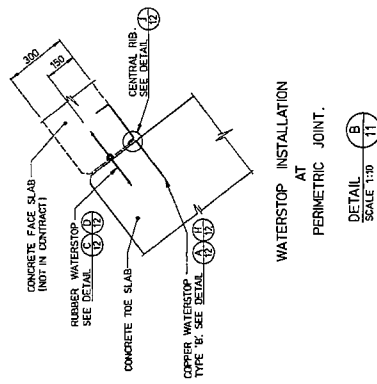
CHK	DETAILS OF AMENOMENTS
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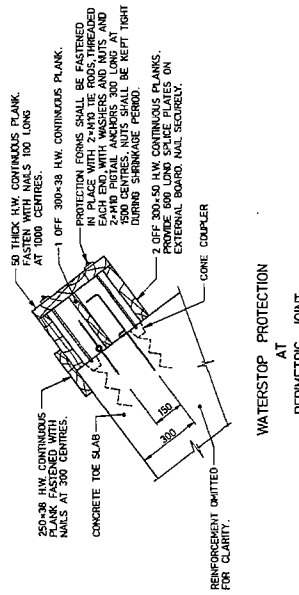
SECTION 2 TYPICAL
SCALE 1:25
NORMAL TO REF LINE



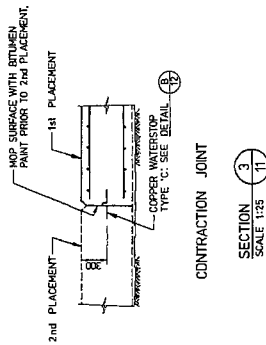
CONTRACTION JOINT WATERSTOP INSTALLATION
DETAIL A TYPICAL
SCALE 1:25



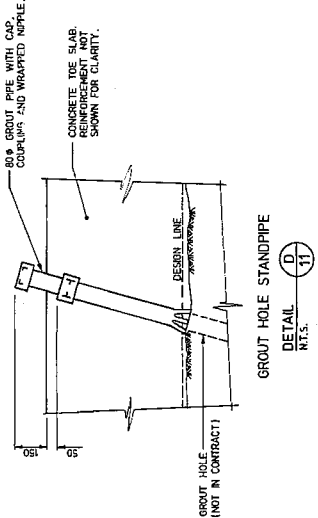
WATERSTOP INSTALLATION
AT
PERIMETRIC JOINT.
DETAIL B TYPICAL
SCALE 1:30



WATERSTOP PROTECTION
AT
PERIMETRIC JOINT.
DETAIL C TYPICAL
SCALE 1:10

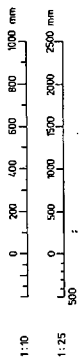


CONTRACTION JOINT
DETAIL D TYPICAL
SCALE 1:10



GROUT HOLE STANDPIPE
DETAIL D TYPICAL
SCALE 1:10

- NOTES:
1. CONCRETE SHALL BE GRADE 23 WITH 40 MAX. AGGREGATE SIZE.
 2. CLEAR CONCRETE COVER TO REINFORCEMENT SHALL BE 75 UNLESS NOTED OTHERWISE.
 3. MINIMUM CLEAR DISTANCE BETWEEN REINFORCEMENT AND WATERSTOPS SHALL BE 50 UNLESS NOTED OTHERWISE.
 4. ALL EXPOSED EXTERNAL EDGEO (INCLUDING VERTICAL AND PERIMETRIC JOINTS) TO BE CHAMFERED 20x20.
 5. CONCRETE FINISH F2 UNLESS NOTED OTHERWISE.
 6. THE LOCATION AND ORIENTATION OF ANCHOR BARS SHALL BE AS SHOWN OR AS DIRECTED.
 7. THE LOCATION AND ORIENTATION OF GROUT HOLE STANDPIPES SHALL BE AS SHOWN OR AS DIRECTED.
 8. GROUT HOLE STANDPIPES SHALL BE LOCATED 300 MM CLEAR OF ANY CONTRACTION JOINT.
 9. ANCHOR BAR DEPTH 'D' = 500 BETWEEN REFERENCE POINTS 'X' AND 'Y' AND 3000 ELSEWHERE.

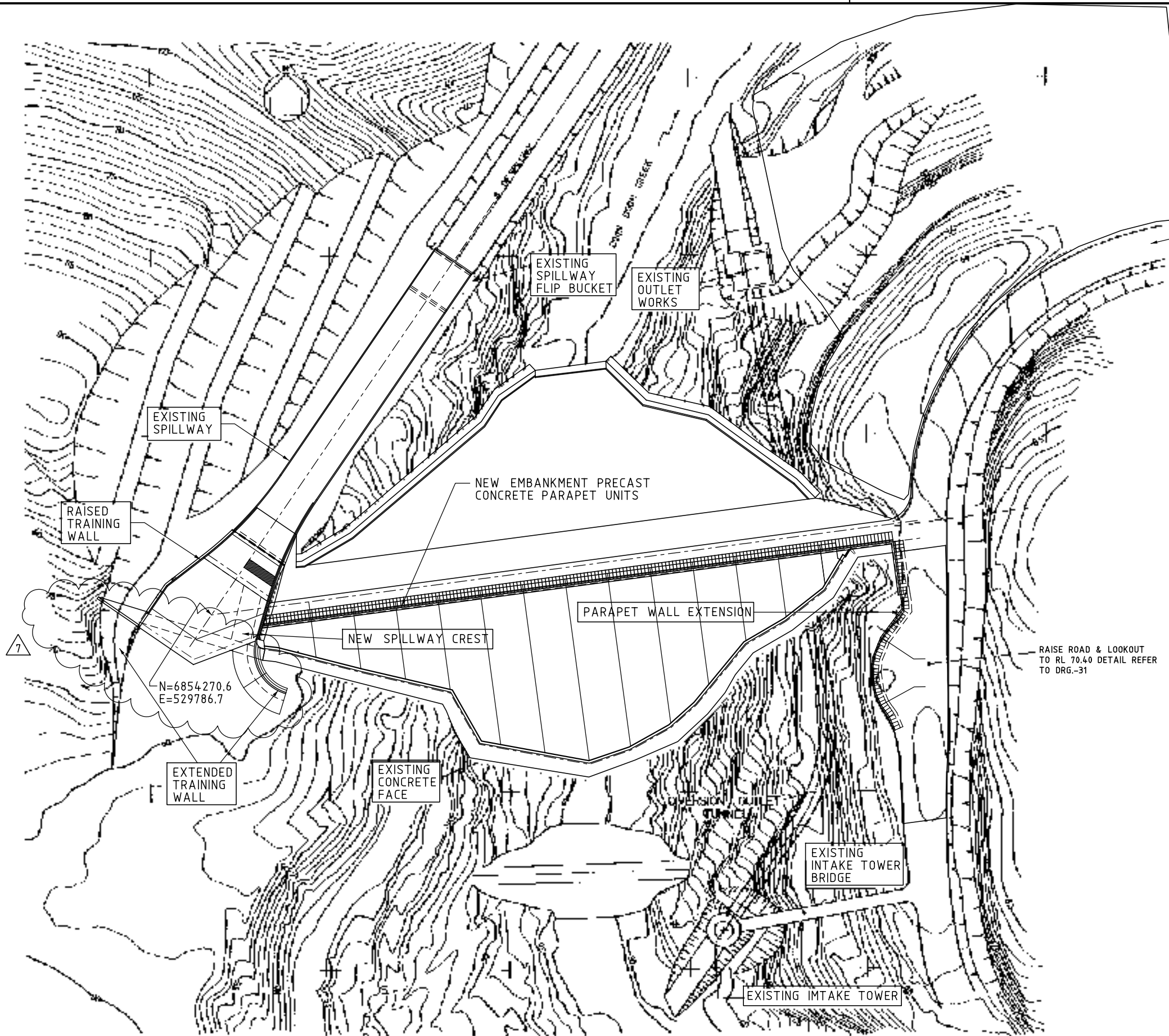


FILE W5172/108 DRAWING 80065-11	
TWEED DISTRICT W.S. AUG. CLARIE HALL DAM CONCRETE TOE SLAB TYPICAL SECTIONS AND DETAILS.	
PUBLIC WORKS DEPARTMENT N.S.W. W. & A. ENGINEER W. & A. ENGINEER TWEED SHIRE COUNCIL	
DESIGNED BY W. & A. ENGINEER CHECKED BY W. & A. ENGINEER	APPROVED BY W. & A. ENGINEER CHECKED BY W. & A. ENGINEER
ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE	
DETAILS OF AMENDMENTS	
APPROVED DATE	

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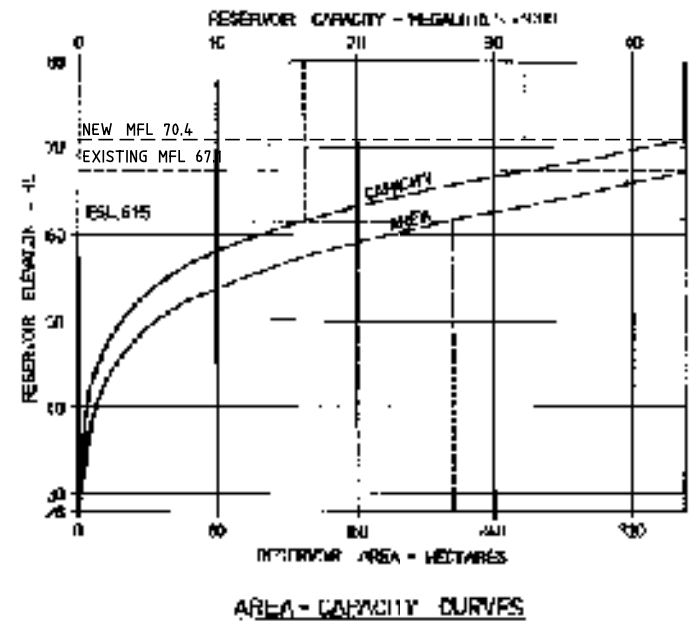
13/11/2013

679



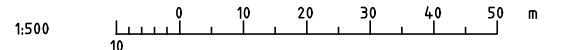
CONTRACTOR'S WORKS AREA
(REFER REF. FOR DETAILS)

CLARRIE HALL DAM ROAD



NOTES

1. CONTOURS INDICATED ARE COMPILED FROM AERIAL PHOTOGRAPHY MARCH 1981.
2. LEVELS ARE TO AUSTRALIAN HEIGHT DATUM.



ISSUED FOR CONSTRUCTION.		G.S.	05.03.2013
DETAILS OF AMENDMENTS		APPROVED	DATE

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services
NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, MCKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

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IN THE ADJACENT BLOCK

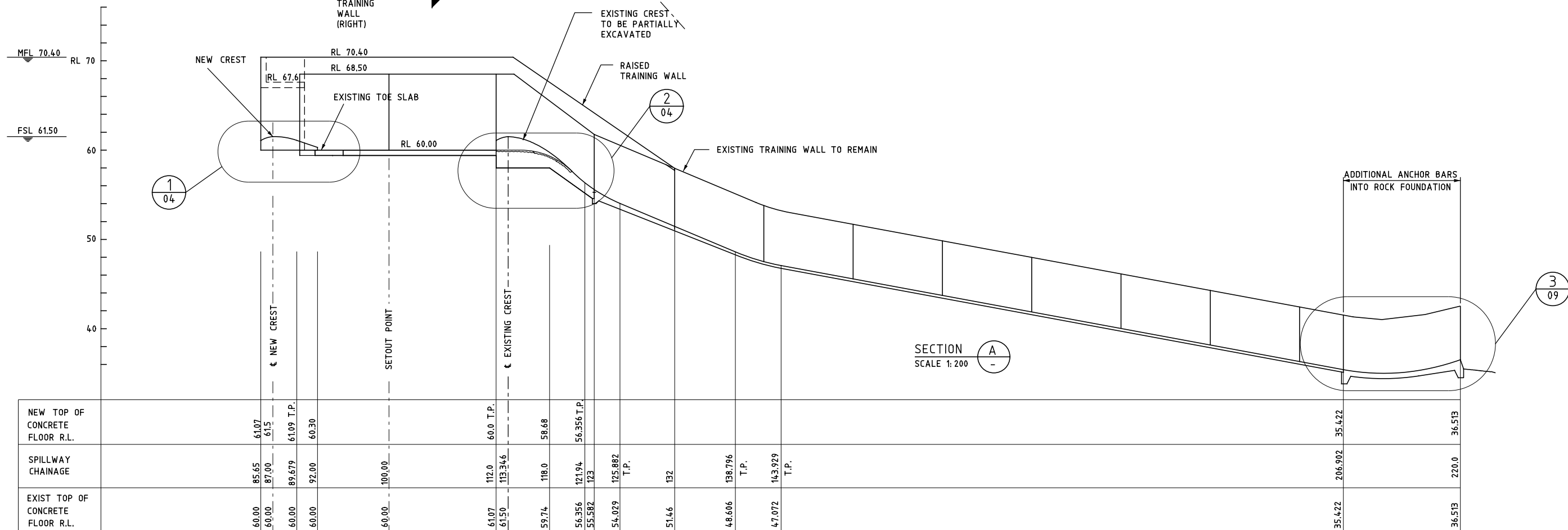
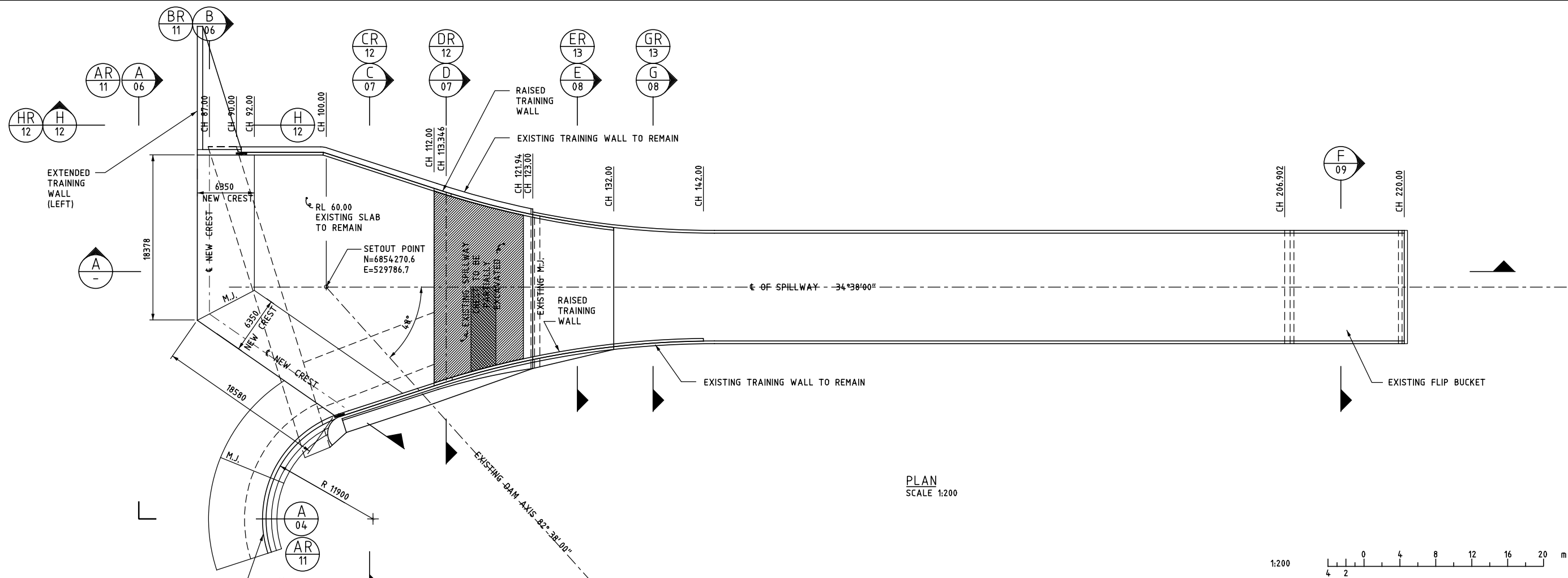
U. Basson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

DESIGNED		S.P. ENGINEER
G. SAMIOS		G. SAMIOS
DRAFTED		A/P. E. DAMS AND CIVIL
F. PANG		D. JAMIESON
CHECKED		
G. SAMIOS		



CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY
UPGRADE
DAM SITE GENERAL ARRANGEMENT

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-01
REVISION A



ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013
DETAILS OF AMENDMENTS	APPROVED	DATE

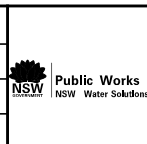
MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

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IN THE ADJACENT BLOCK

Y. Basson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

DESIGNED	S.P. ENGINEER
D.SAMIOS	D.SAMIOS
DRAFTED	A/P. E. DAMS AND CIVIL
F. PANG	D. JAMIESON
CHECKED	
G.SAMIOS	



CLARIE HALL DAM SPILLWAY FLOOD SAFETY UPGRADE	NO IN SET
SPILLWAY GENERAL ARRANGEMENT	CONTRACT NO. EC2012-191
	DRAWING NO. EC2012-191-02
	REVISION A

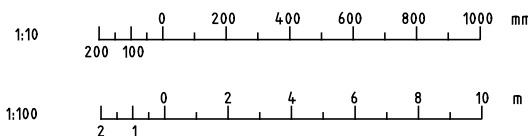
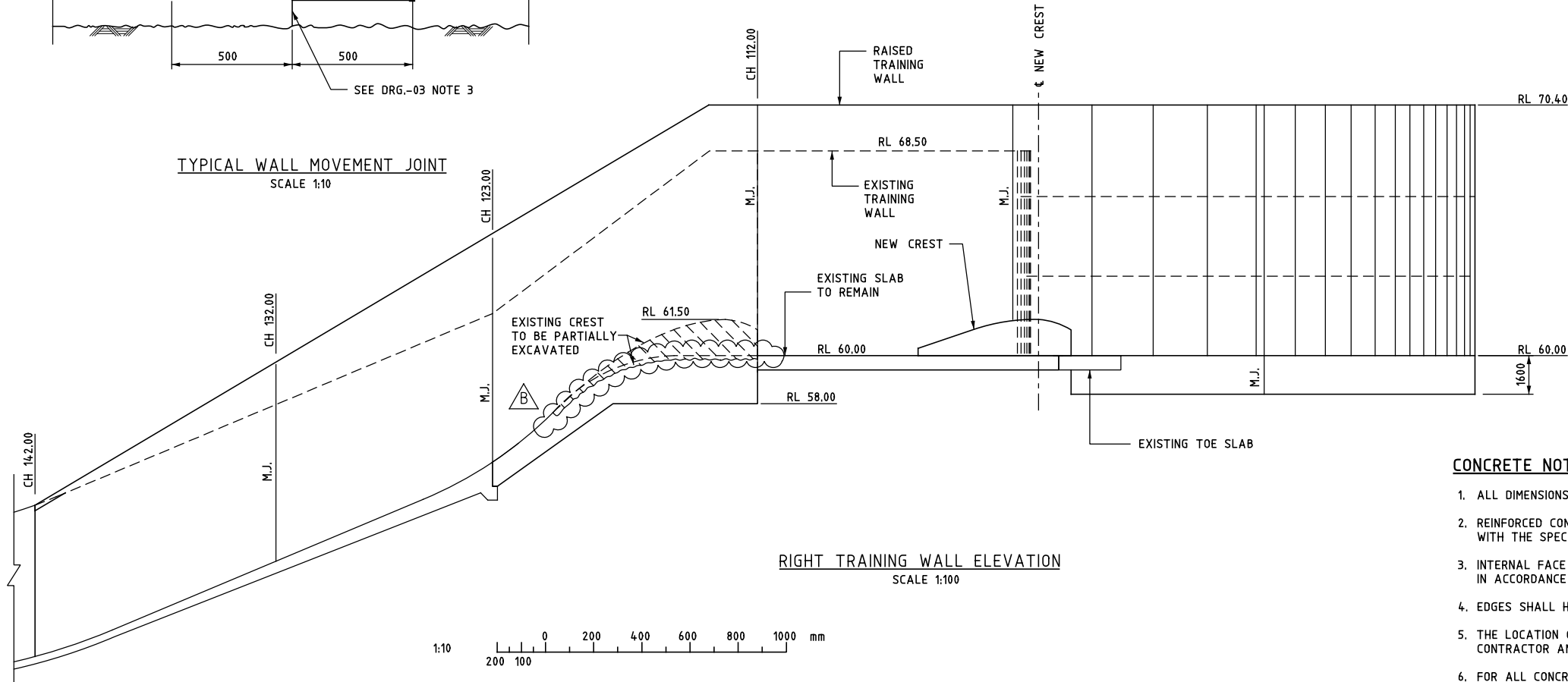
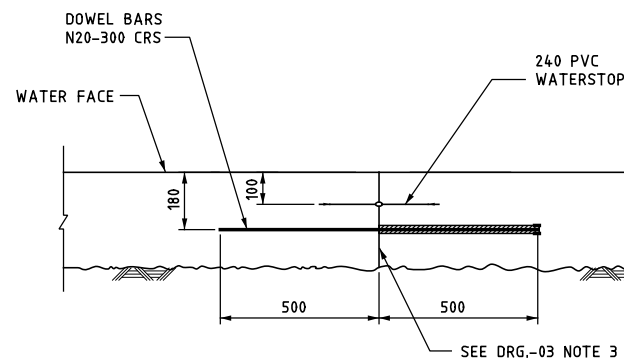
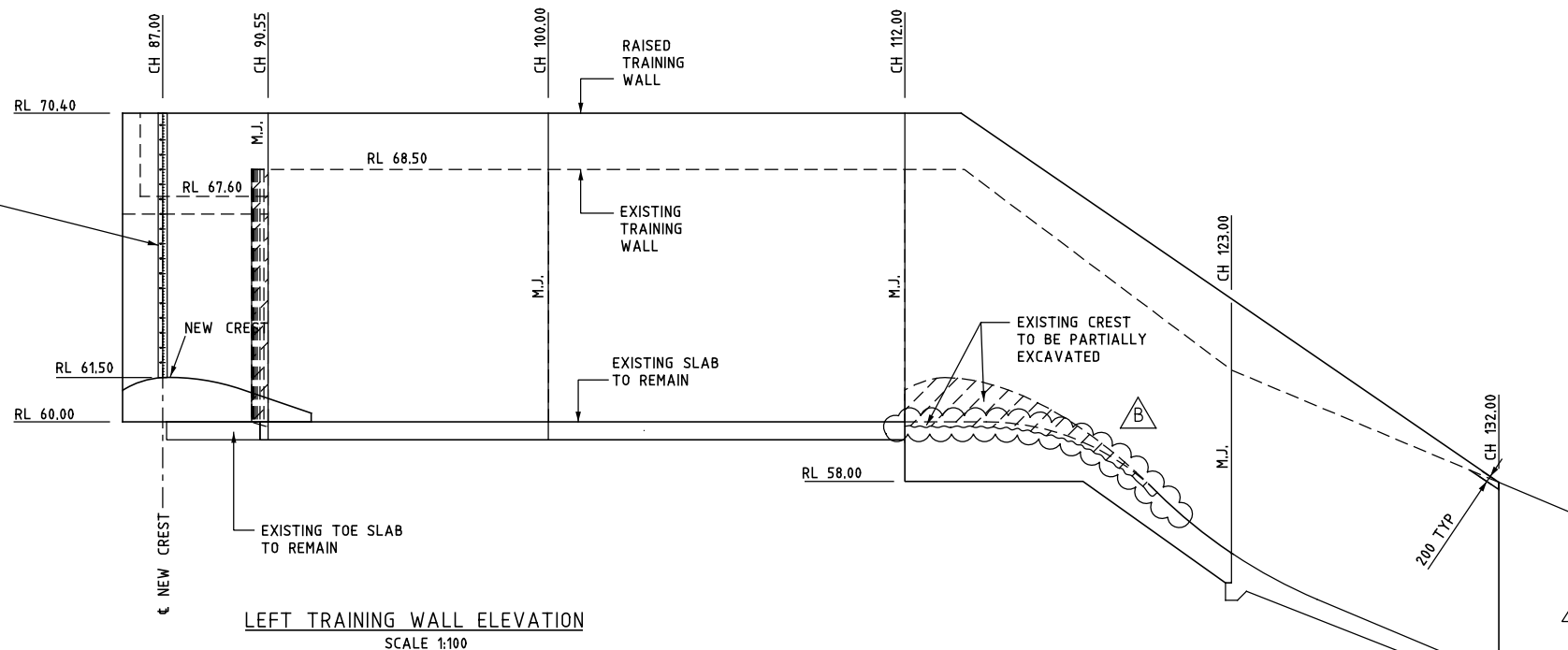
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13/11/2013

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SUPPLY AND INSTALL WATER LEVEL MARKER
FABRICATED FROM STAINLESS STEEL AND FIXED
TO WALL VERTICALLY ABOVE CREST CONTROL
LEVEL AT RL 61.50. MARKER TO INDICATE 0.1 m
INCREMENTS AS SHOWN. DETAIL SEE

1
-



CONCRETE NOTES

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. REINFORCED CONCRETE GRADES SHALL BE S40 ($F'c = 40\text{MPa}$) IN ACCORDANCE WITH THE SPECIFICATION.
3. INTERNAL FACE SPILLWAY CREST AND FLOOR SLAB SHALL HAVE F3 FINISH IN ACCORDANCE WITH THE SPECIFICATION.
4. EDGES SHALL HAVE 20mm CHAMFERS UNLESS OTHERWISE NOTED.
5. THE LOCATION OF ANY CONSTRUCTION JOINTS SHALL BE DETERMINED BY THE CONTRACTOR AND SHALL BE SATISFACTORY TO THE PRINCIPAL.
6. FOR ALL CONCRETE POURED ON THE GROUND, PROVIDE 50mm OF N20 BLINDING CONCRETE ($F'c = 20\text{MPa}$) IN ACCORDANCE WITH THE SPECIFICATION.
7. ANCHOR BARS SHALL NOT BE LOCATED WITHIN 500mm OF A MOVEMENT JOINT OR CONSTRUCTION JOINT.

DETAIL
SCALE NTS

1
-

NO	DESCRIPTION	DATE	APPROVED
B	AMENDED EXISTING CREST EXCAVATION PROFILE.	G.S. 12.06.2013	
A	ISSUED FOR CONSTRUCTION.	G.S. 05.03.2013	
MK	DETAILS OF AMENDMENTS		

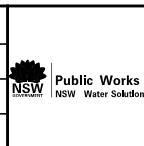
MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, MCKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

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BY THE PERSONS WHOSE NAMES APPEAR
IN THE ADJACENT BLOCK

Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

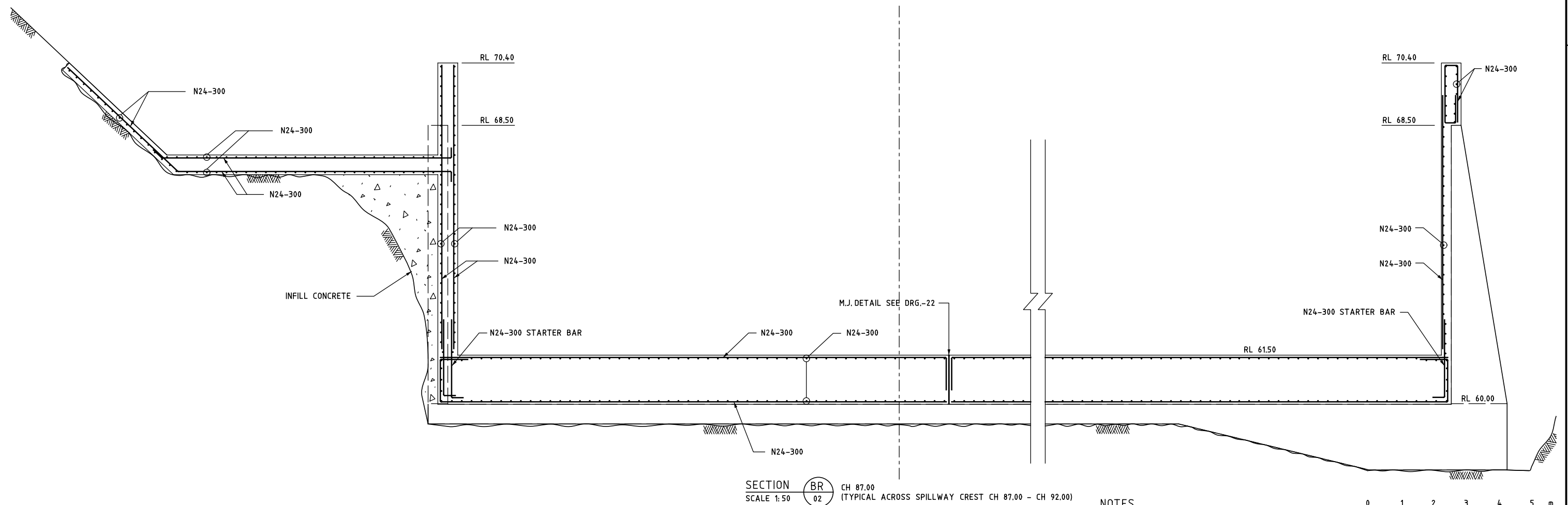
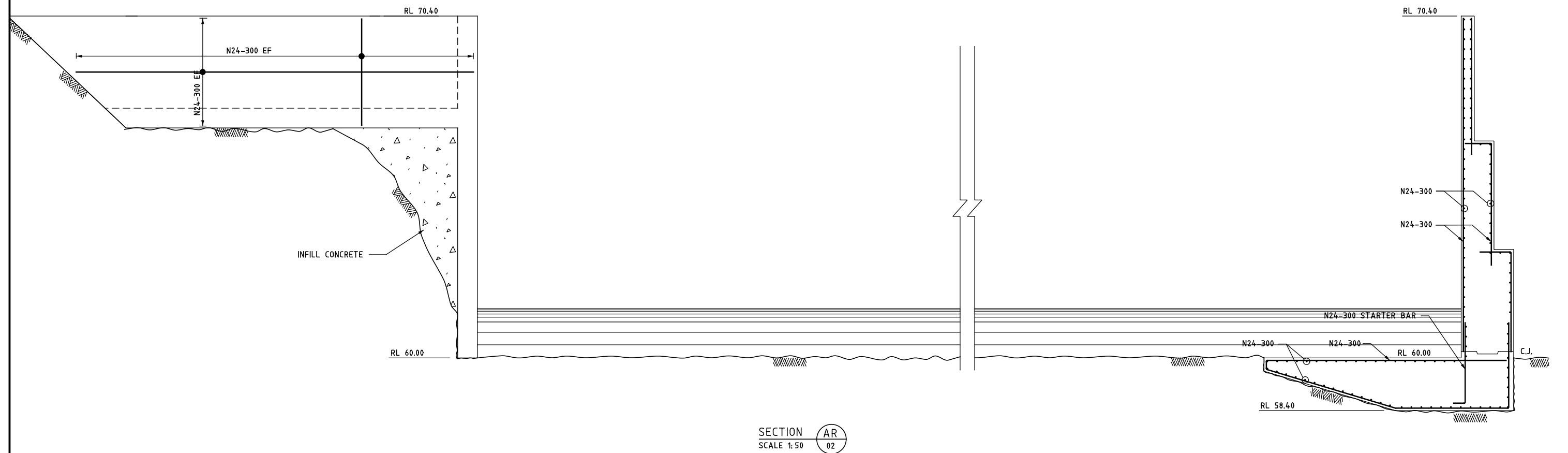
DESIGNED	S.P. ENGINEER
G. SAMIOS	G. SAMIOS
DRAFTED	A/P. E. DAMS AND CIVIL
F. PANG	D. JAMIESON
CHECKED	
G. SAMIOS	



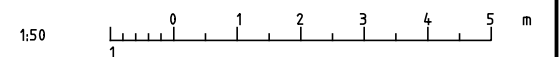
CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY
UPGRADE

CONCRETE TRAINING WALL
ELEVATION

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-05
REVISION B



NOTES
FOR REINFORCEMENT NOTES SEE DRG.-12.

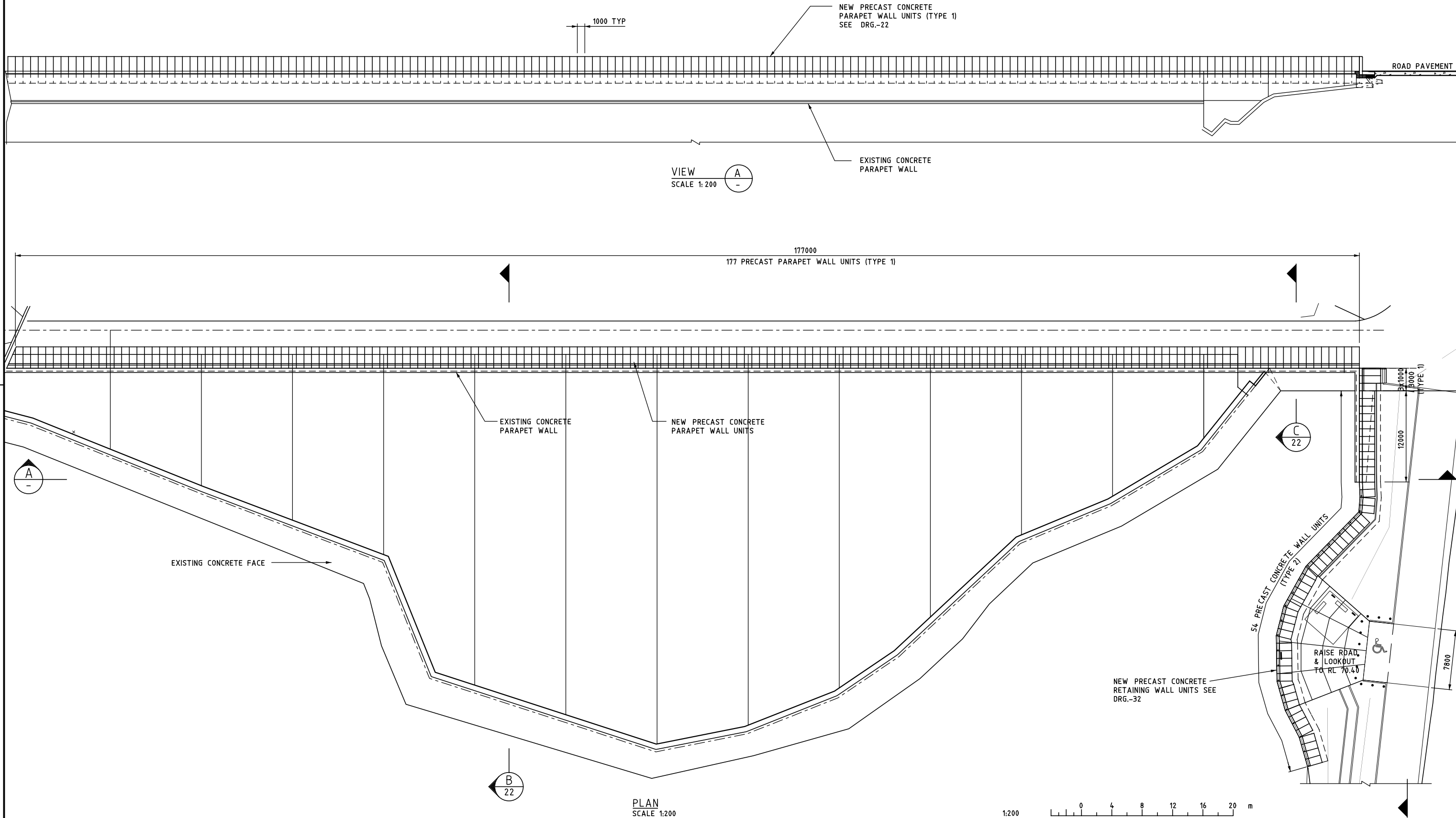


				MICHAEL COUTTS-TROTTER – Director General Department of Finance and Services	THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK	PLAN SH NO					CLARRIE HALL DAM SPILLWAY FLOOD SAFETY UPGRADE	NO IN SET
				NSW WATER SOLUTIONS DAMS AND CIVIL TECHNOLOGIES LEVEL 19, MCKELL BUILDING 2-24 RAWSON PLACE SYDNEY 2000 PHONE (02) 93727808	 TECHNOLOGY CONTROLLER WATER TECHNOLOGIES	DESIGNED G SAMIOS DRAFTED A/P.E.DAMS AND CIVIL CHECKED D. JAMIESON G SAMIOS		 Public Works NSW Water Solutions			CONTRACT NO. EC2012–191 DRAWING NO. EC2012–191 – 11 REVISION A	
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013								SPILLWAY REINFORCEMENT Sheet 1 of 4	
MK	DETAILS OF AMENDMENTS	APPROVED	DATE									

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13/11/2013

679



A ISSUED FOR CONSTRUCTION.		G.S.	05.03.2013
MK DETAILS OF AMENDMENTS		APPROVED	DATE

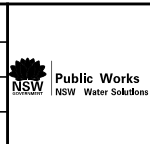
MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, MCKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

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U. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

DESIGNED G.SAMIOS S.P. ENGINEER	
DRAFTED F.PANG A/P.E. DAMS AND CIVIL	D. JAMIESON
CHECKED G.SAMIOS	

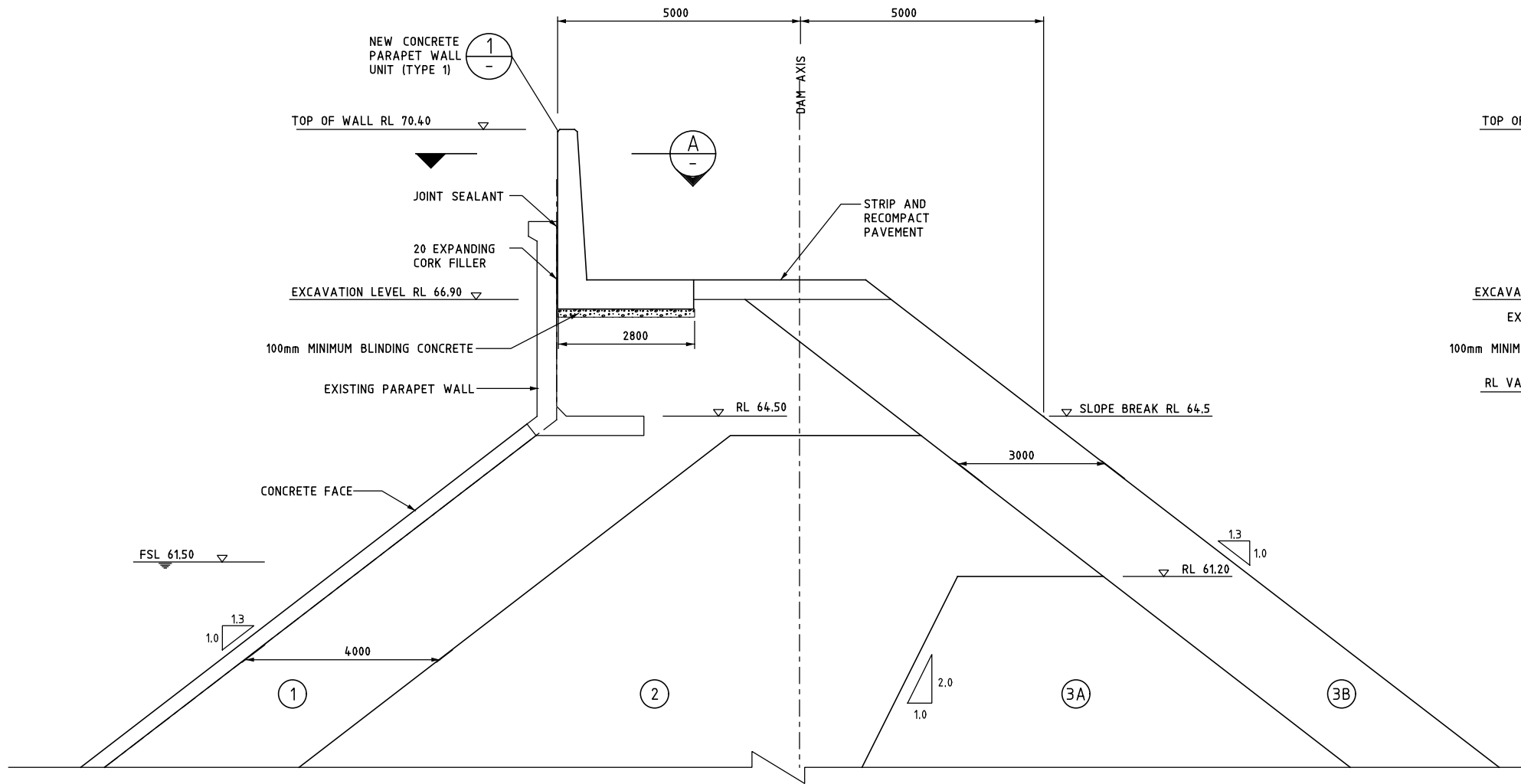


CLARRIE HALL DAM SPILLWAY FLOOD SAFETY UPGRADE EMBANKMENT PLAN SHOWING NEW PARAPET WALL UNITS	
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	DRAWING NO. EC2012-191-21
	REVISION A

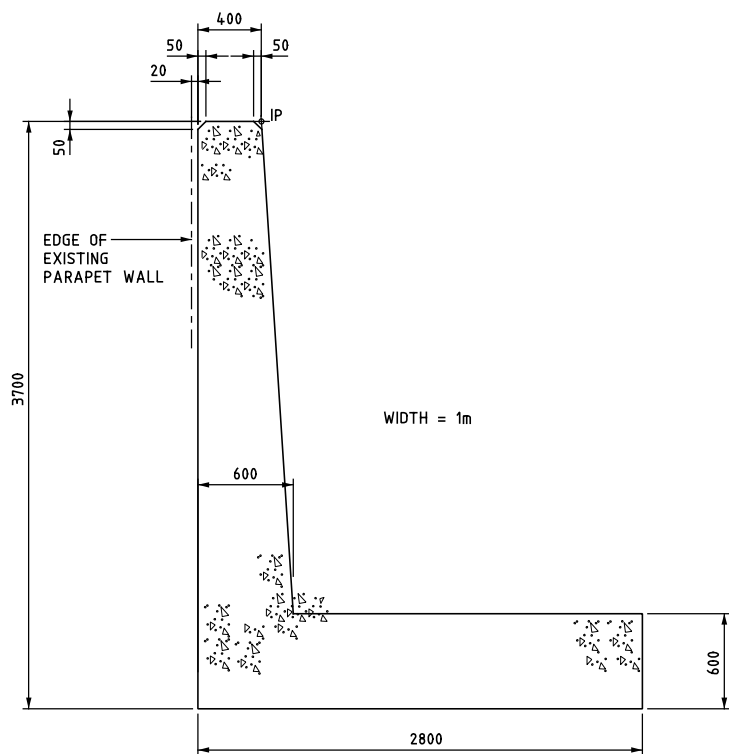
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13/11/2013

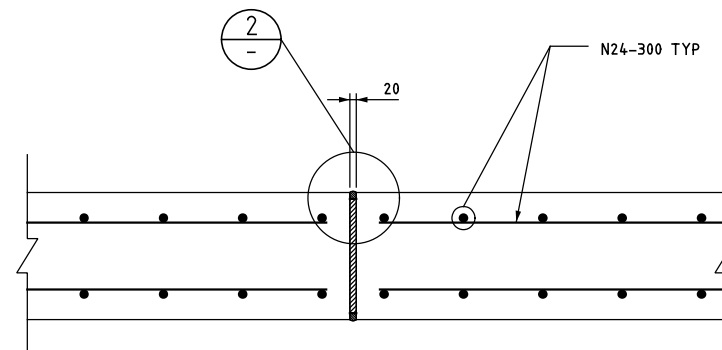
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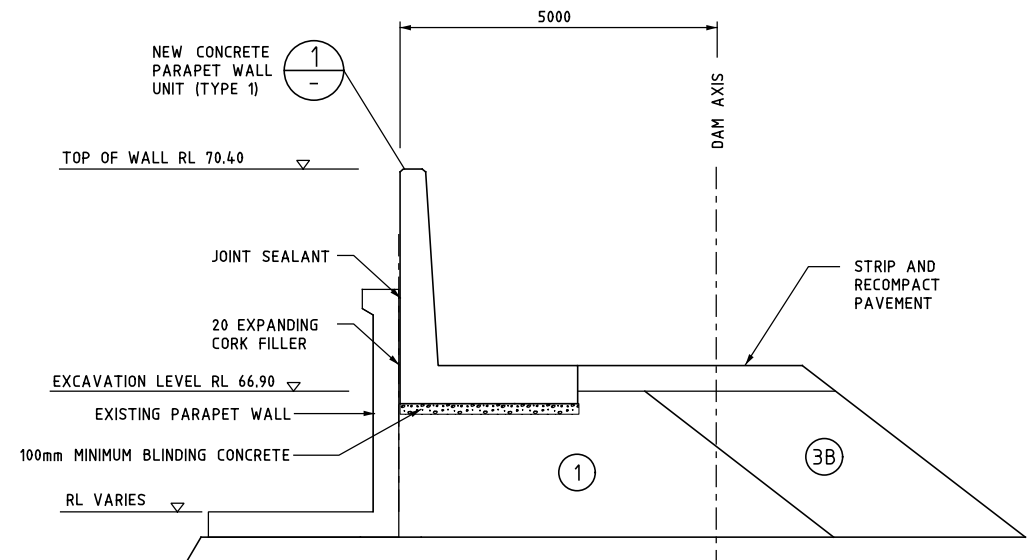
SECTION B
SCALE 1:50
TYPICAL EMBANKMENT SECTION



DETAIL 1
SCALE 1:20
PARAPET WALL UNIT (TYPE 1)



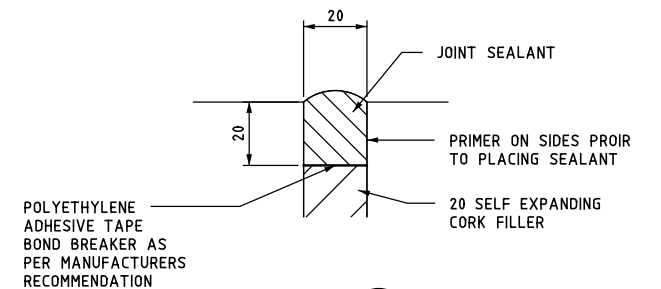
SECTION A
SCALE 1:10
TYPICAL JOINT BETWEEN UNITS



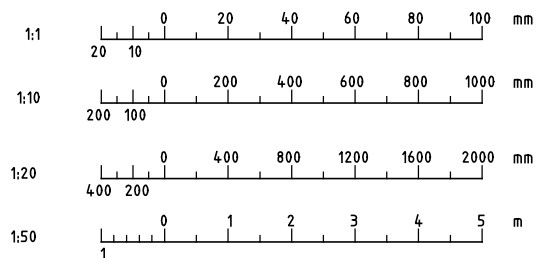
SECTION C
SCALE 1:50
EMBANKMENT RIGHT ABUTMENT SECTION

LEGEND

FUNCTION	DESCRIPTION
1	SEMI-PERMEABLE ZONE MODERATELY WEATHERED RHYOLITE
2	PERMEABLE INTERMEDIATE ZONE SLIGHTLY WEATHERED TO MODERATELY WEATHERED RHYOLITE
3A	FRESH ROCK ZONE FRESH RHYOLITE
3B	MESH ZONE AND FACE ZONE SELECTED FRESH RHYOLITE



DETAIL 2
SCALE 1:1

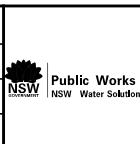


ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013
DETAILS OF AMENDMENTS	APPROVED	DATE

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services
NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, MCKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

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IN THE ADJACENT BLOCK
U. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

DESIGNED	S.P. ENGINEER
DRAFTED	A/P. E. DAMS AND CIVIL
CHECKED	D. JAMIESON
PLANNED	G. SAMIOS



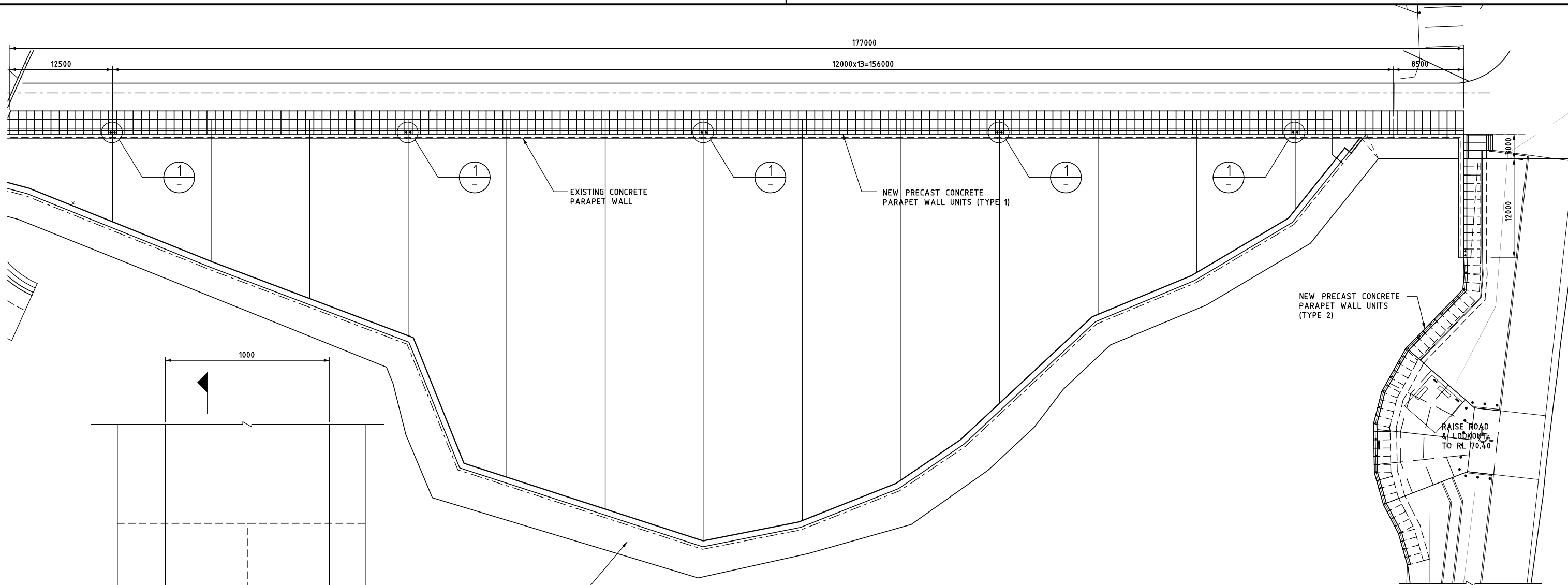
CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY
UPGRADE
PARAPET WALL CROSS SECTIONS

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-22
REVISION A

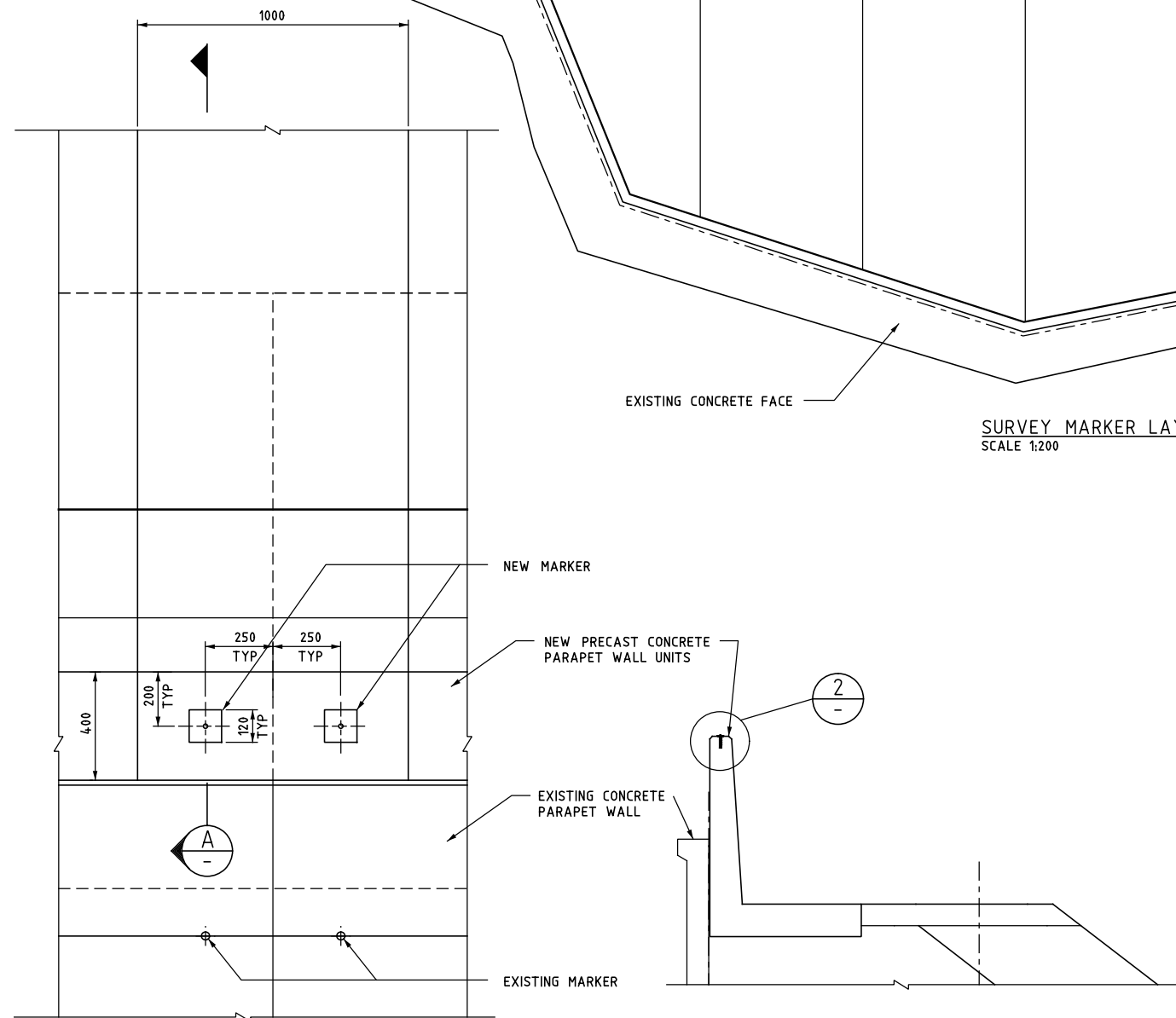
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13/11/2013

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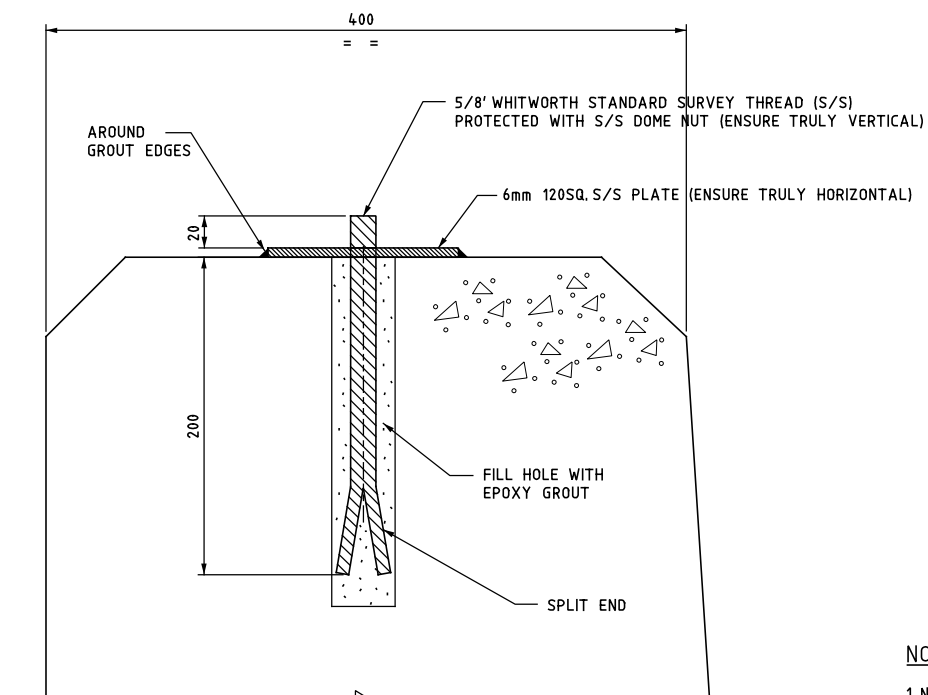


SURVEY MARKER LAYOUT
SCALE 1:200



DETAIL 1
SCALE 1:10

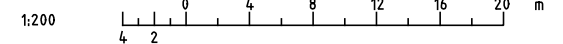
SECTION A
SCALE 1:20



DETAIL 2
SCALE 1:2

NOTE

1. NEW SURVEY MARKERS TO BE INSTALLED IN LINE WITH EXISTING MARKERS.



ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013
DETAILS OF AMENDMENTS	APPROVED	DATE

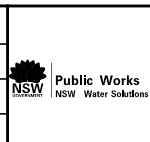
MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

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LEVEL 13, MCKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

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WATER TECHNOLOGIES

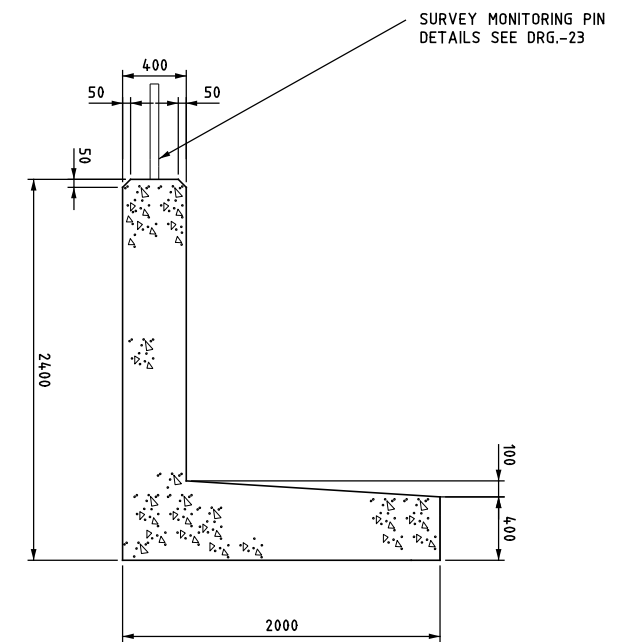
DESIGNED	S.P. ENGINEER
DRAFTED	A/P. E. DAMS AND CIVIL
CHECKED	D. JAMIESON
APPROVED	G. SAMIOS



CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY
UPGRADE

SURVEY MARKER
LAYOUT AND DETAILS

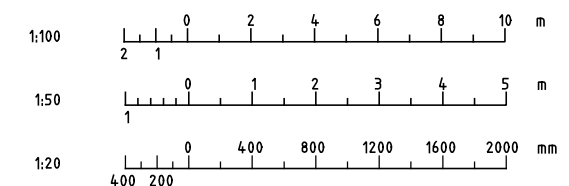
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CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-23
REVISION A



DETAIL 1
SCALE 1:20



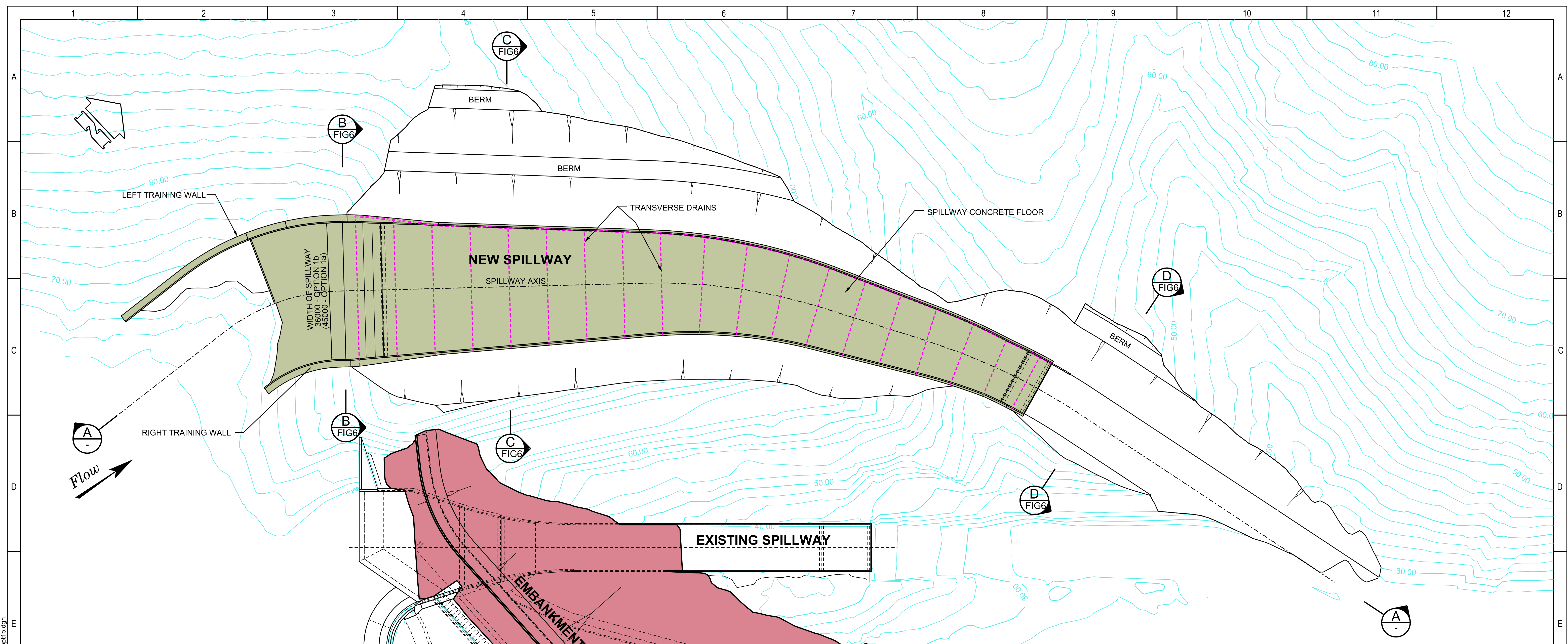
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2. FOR REINFORCEMENT OF WALL UNITS, SEE DRAWING -14.
3. FOR SURVEY MARKER DETAILS REFER TO DRG.-23.



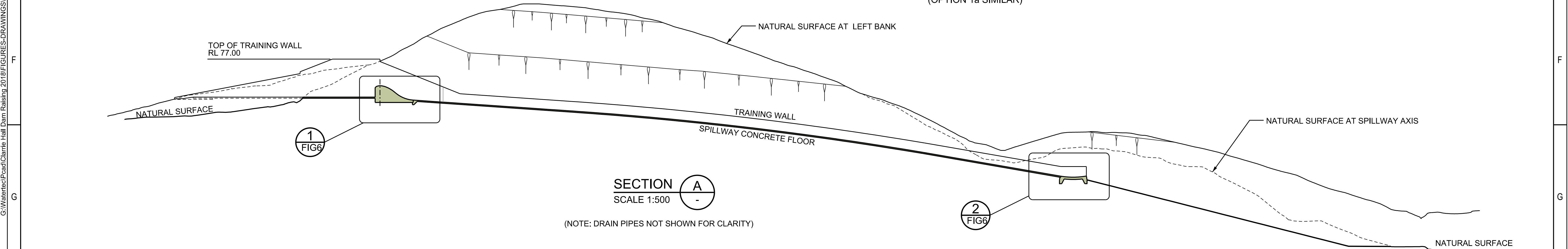
						MICHAEL COUTTS-TROTTER - Director General Department of Finance and Services		THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK  TECHNOLOGY CONTROLLER WATER TECHNOLOGIES		PLAN RM 10 <table><tr><td>DESIGNED G. SAMIOS</td><td>S. P. ENGINEER G. SAMIOS</td></tr><tr><td>DRAFTED G. PANG</td><td>A/P. E. DAMS AND CIVIL D. JAMIESON</td></tr><tr><td>CHECKED G. SAMIOS</td><td></td></tr></table>		DESIGNED G. SAMIOS	S. P. ENGINEER G. SAMIOS	DRAFTED G. PANG	A/P. E. DAMS AND CIVIL D. JAMIESON	CHECKED G. SAMIOS		 Public Works NSW Water Solutions		CLARRIE HALL DAM SPILLWAY FLOOD SAFETY UPGRADE		NO IN SET CONTRACT NO. EC2012-191	
DESIGNED G. SAMIOS	S. P. ENGINEER G. SAMIOS																						
DRAFTED G. PANG	A/P. E. DAMS AND CIVIL D. JAMIESON																						
CHECKED G. SAMIOS																							
A ISSUED FOR CONSTRUCTION.		G.S.		05.03.2013										DRAWING NO. EC2012-191-32		REVISION A							
MK DETAILS OF AMENDMENTS		APPROVED		DATE										RAISED ROAD & LOOKOUT SECTIONS									

APPENDIX B

PROPOSED RAISED DAM DRAWINGS



PLAN (OPTION 1b)
SCALE 1:500
(OPTION 1a SIMILAR)



SECTION A
SCALE 1:500

(NOTE: DRAIN PIPES NOT SHOWN FOR CLARITY)

0	ISSUED FOR REVIEW	XX	XX
REV	AMENDMENT DETAILS	APPROVED	DATE

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GOVERNMENT

PublicWorks
Advisory

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CHECKED	G. SAMIOS
DRAFTED	C. ZHANG
PRINCIPAL ENGINEER	G. SAMIOS

CLARRIE HALL DAM
RAISING OPTIONS

OPTION 1a/1b
SPILLWAY LAYOUT
AND LONG SECTION

PROJECT/CONTRACT No.	?
SCALE @ A1	1:500
DRAWING No.	FIGURE 5
REV	0

1:500

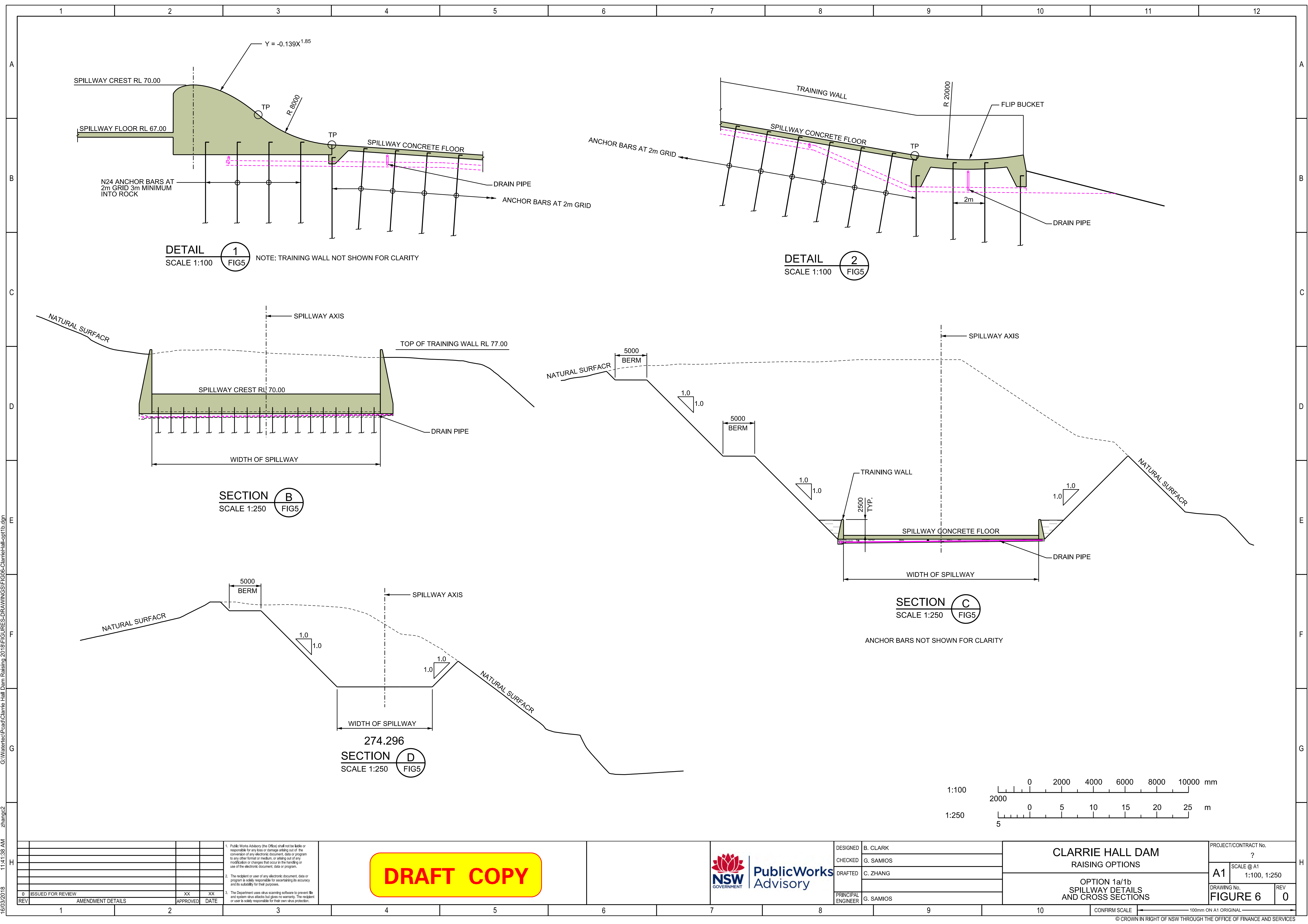
0 10000 20000 30000 40000 50000 mm

10000

CONFIRM SCALE

100mm ON A1 ORIGINAL

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G:\Water\et\Pool\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\SPILLWAY-Details\opt1b.dgn

zhangc2

11:41:38 AM

16/03/2018

REV	ISSUED FOR REVIEW	AMENDMENT DETAILS	APPROVED	DATE
0	ISSUED FOR REVIEW		XX	XX

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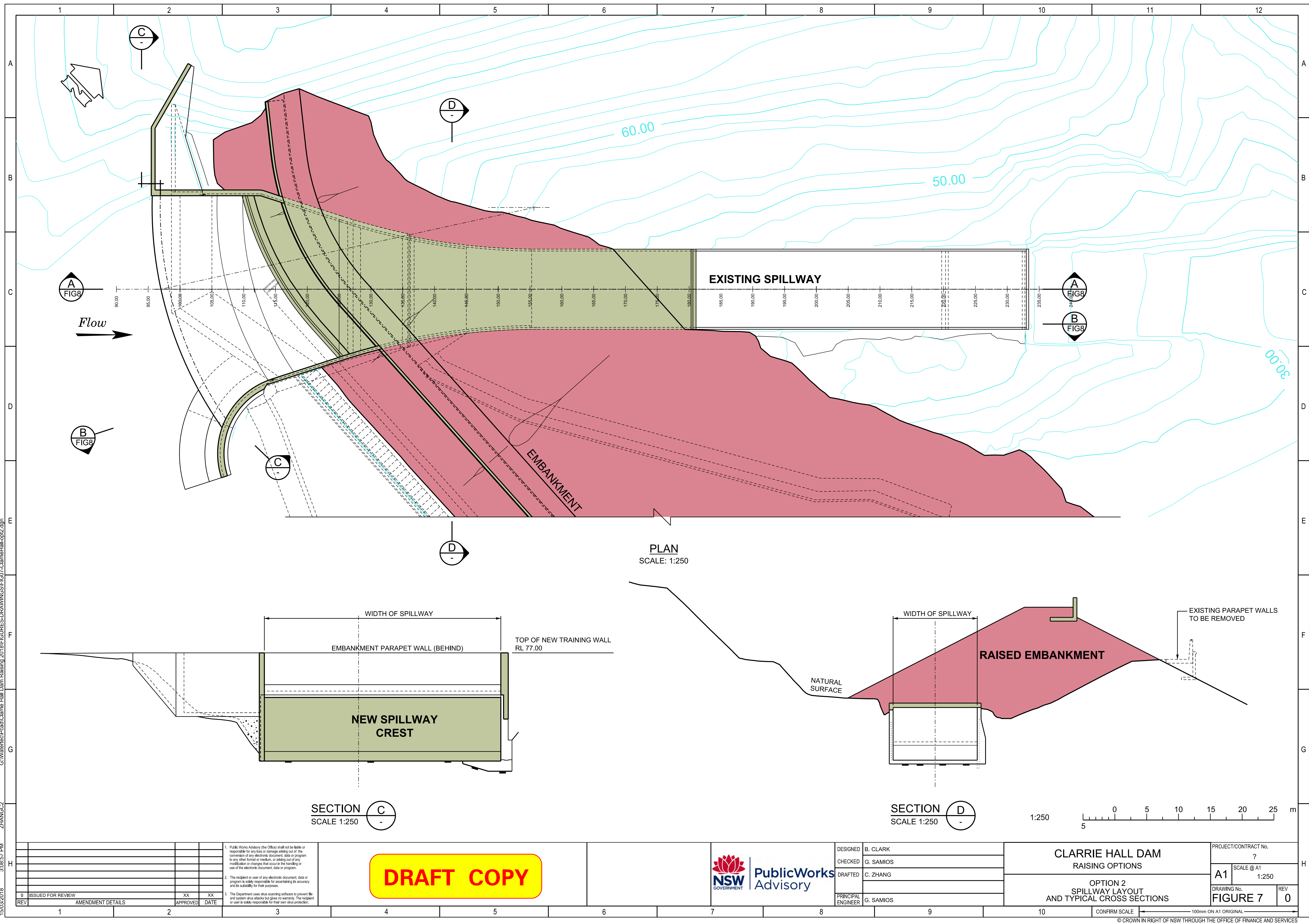
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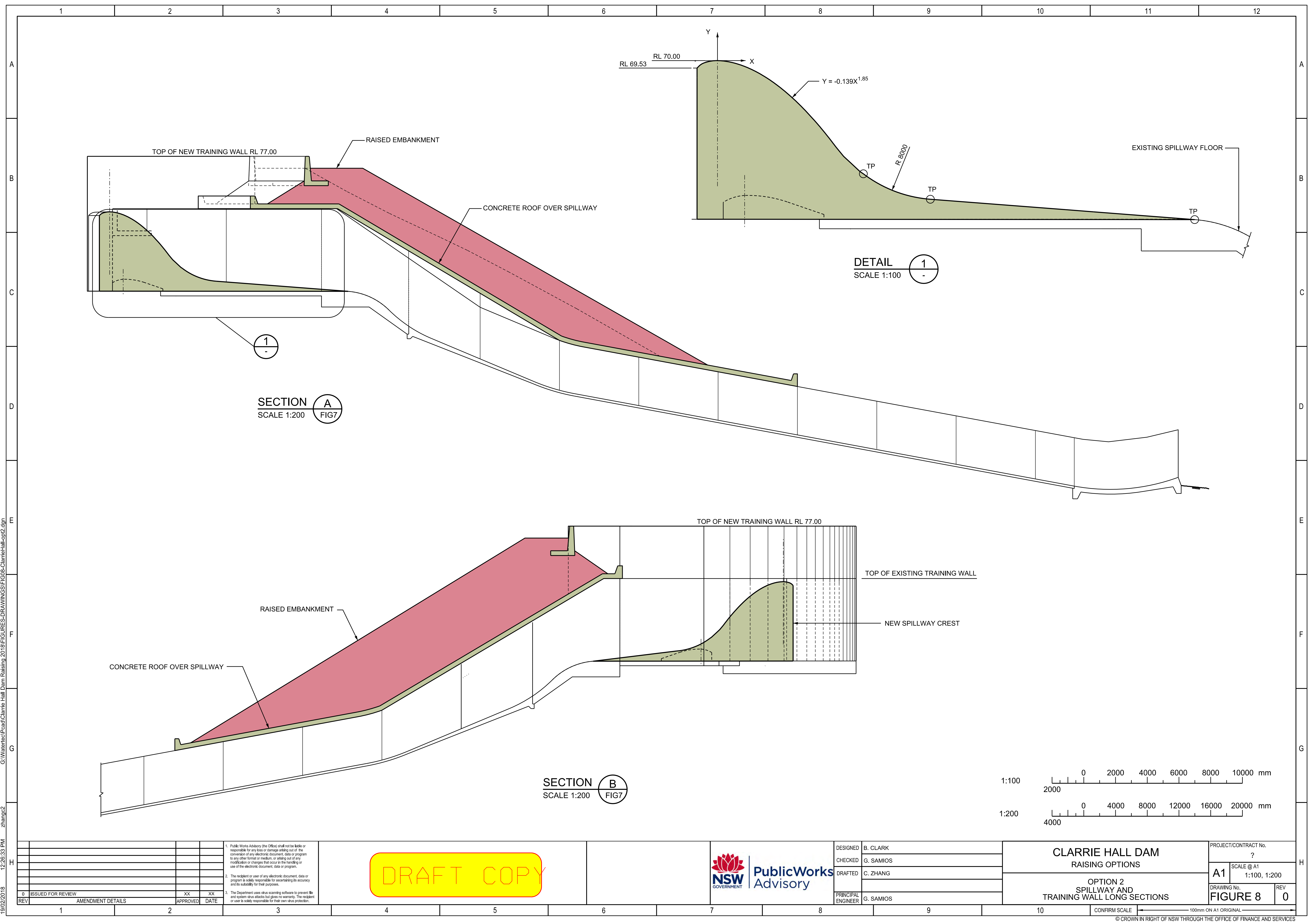


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CHECKED	G. SAMIOS
DRAFTED	C. ZHANG
PRINCIPAL ENGINEER	G. SAMIOS

CLARRIE HALL DAM RAISING OPTIONS	
OPTION 1a/1b SPILLWAY DETAILS AND CROSS SECTIONS	

PROJECT/CONTRACT No. ?	
A1	SCALE @ A1 1:100, 1:250
DRAWING No. FIGURE 6	REV 0





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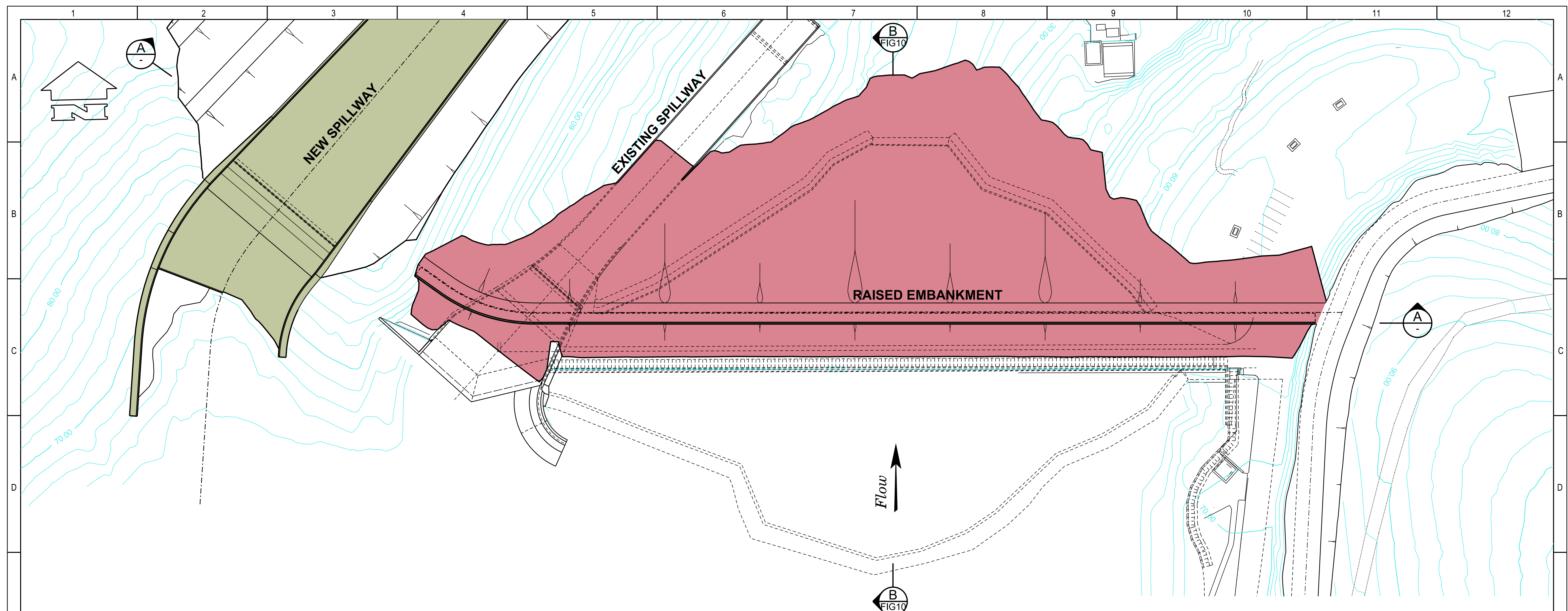
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CLARRIE HALL DAM RAISING OPTIONS	
OPTION 2 SPILLWAY AND TRAINING WALL LONG SECTIONS	

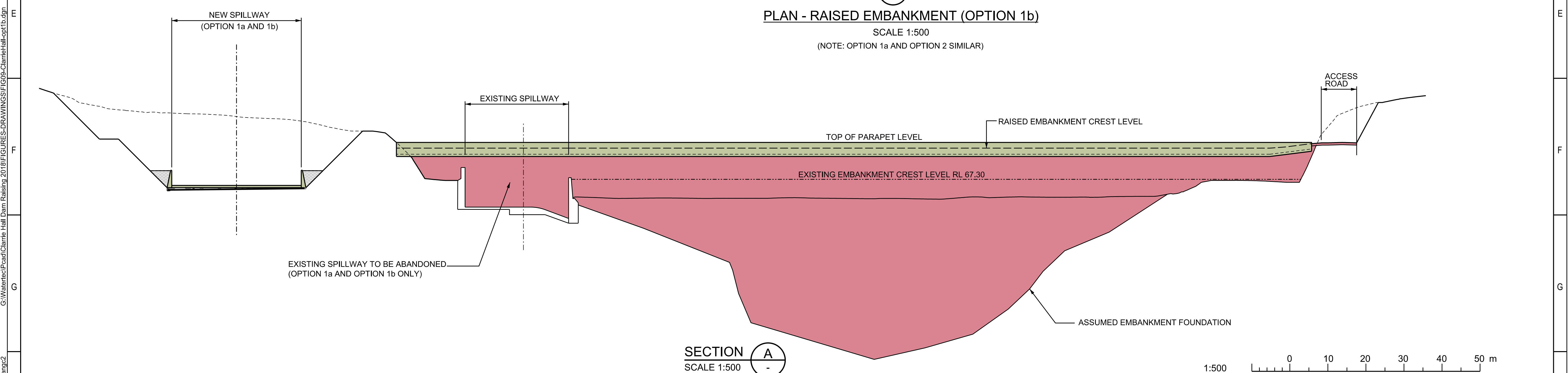
PROJECT/CONTRACT No. ?	
A1	SCALE @ A1 1:100, 1:200
DRAWING No. FIGURE 8	REV 0



PLAN - RAISED EMBANKMENT (OPTION 1b)

SCALE 1:500

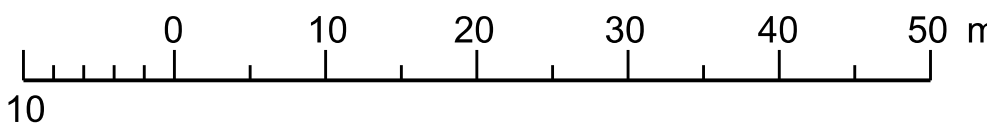
(NOTE: OPTION 1a AND OPTION 2 SIMILAR)



SECTION A

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1:500



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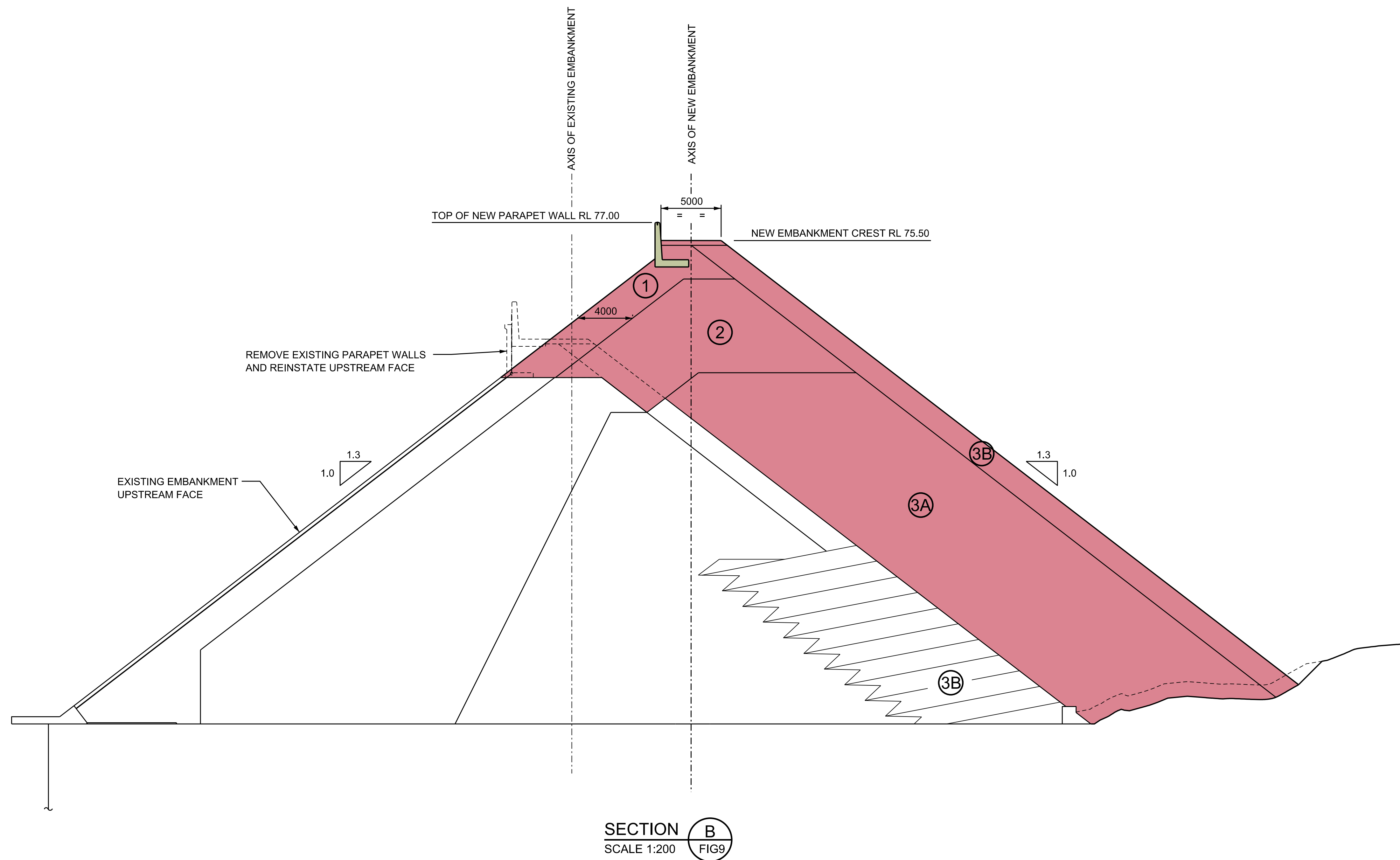
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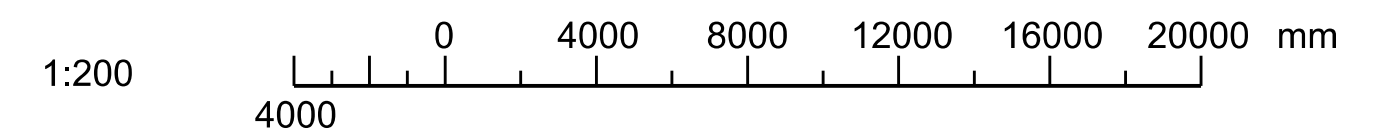
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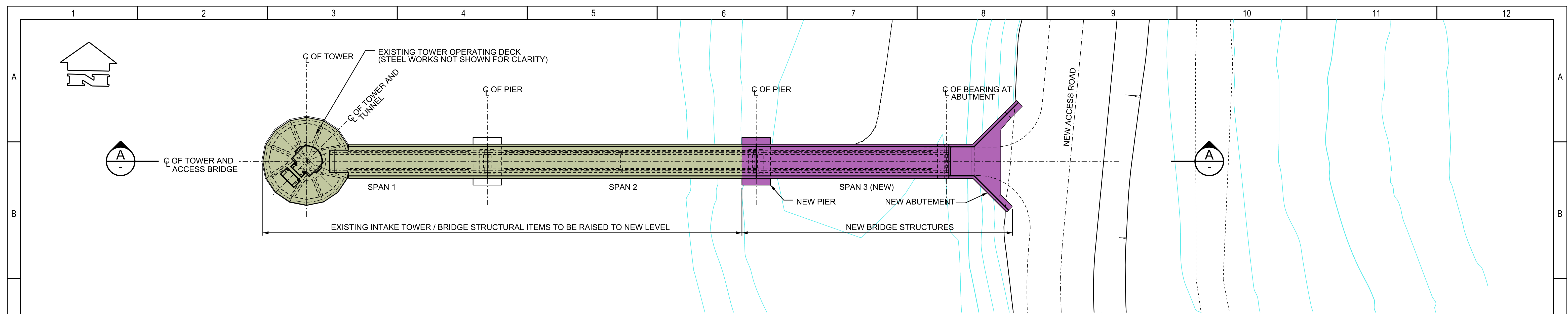
CLARRIE HALL DAM RAISING OPTIONS	
DAM EMBANKMENT RAISING PLAN AND LONG SECTION	

PROJECT/CONTRACT No. ?	
A1	SCALE @ A1 1:500
DRAWING No. FIGURE 9	REV 0

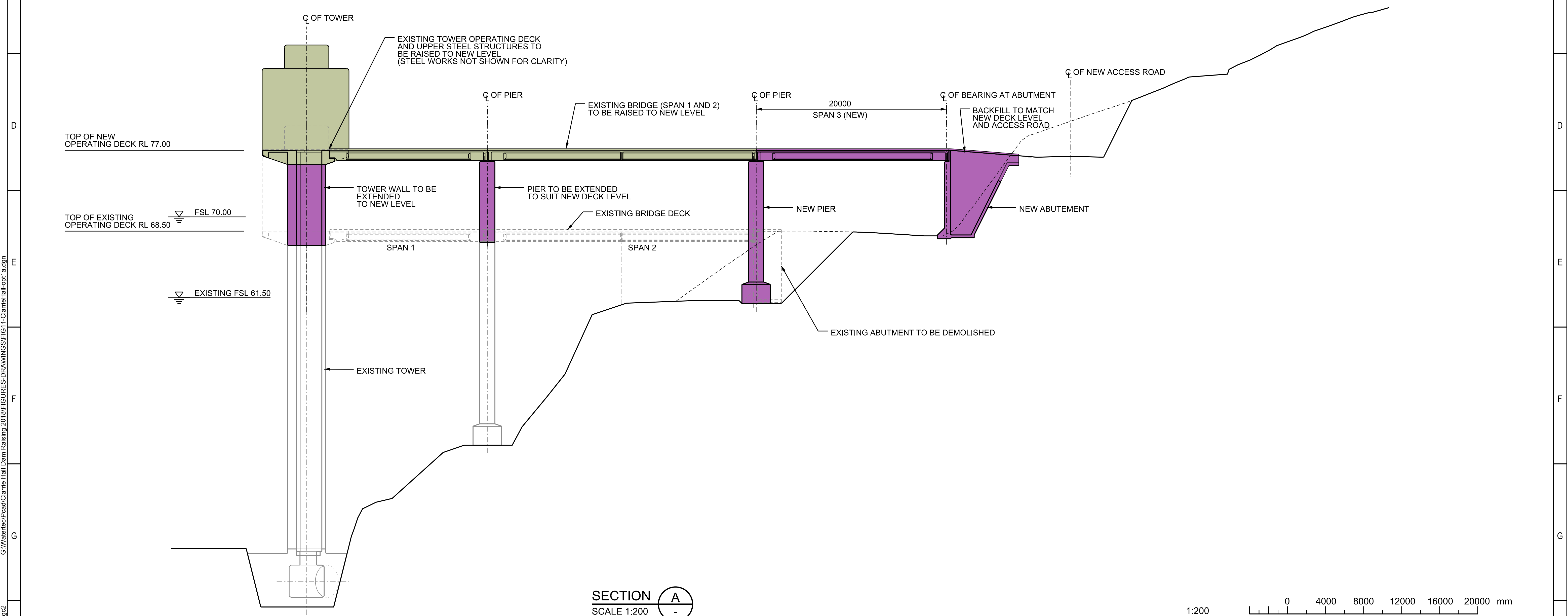


ZONE	FUNCTION	DESCRIPTION
①	SEMI-PERMEABLE ZONE	MODERATELY WEATHERED RHYOLITE
②	PERMEABLE INTERMEDIATE ZONE	SLIGHTLY WEATHERED TO MODERATELY WEATHERED RHYOLITE
③A	FRESH ROCK ZONE	FRESH RHYOLITE
③B	MESH ZONE AND FACE ZONE	SELECTED FRESH RHYOLITE

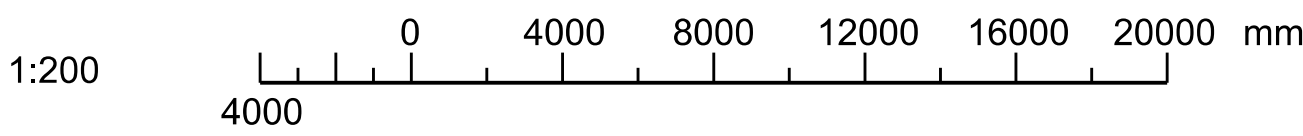
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PLAN
SCALE 1:200



SECTION A
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(NOTE: HANDRAILS AND STEEL WORKS NOT SHOWN FOR CLARITY)



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0 ISSUED FOR REVIEW AMENDMENT DETAILS			XX APPROVED			XX DATE															CONFIRM SCALE 1:200			100mm ON A1 ORIGINAL					

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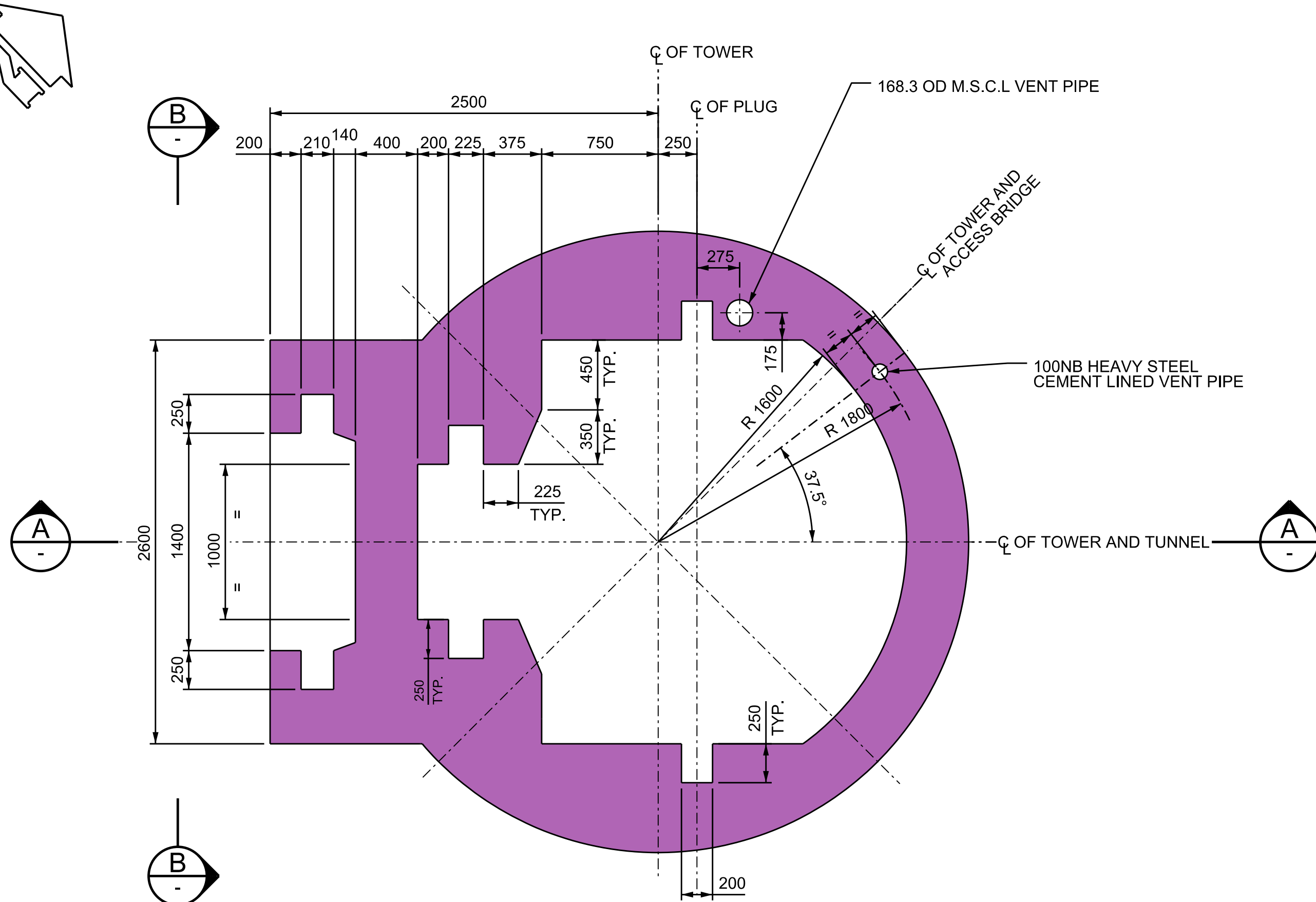
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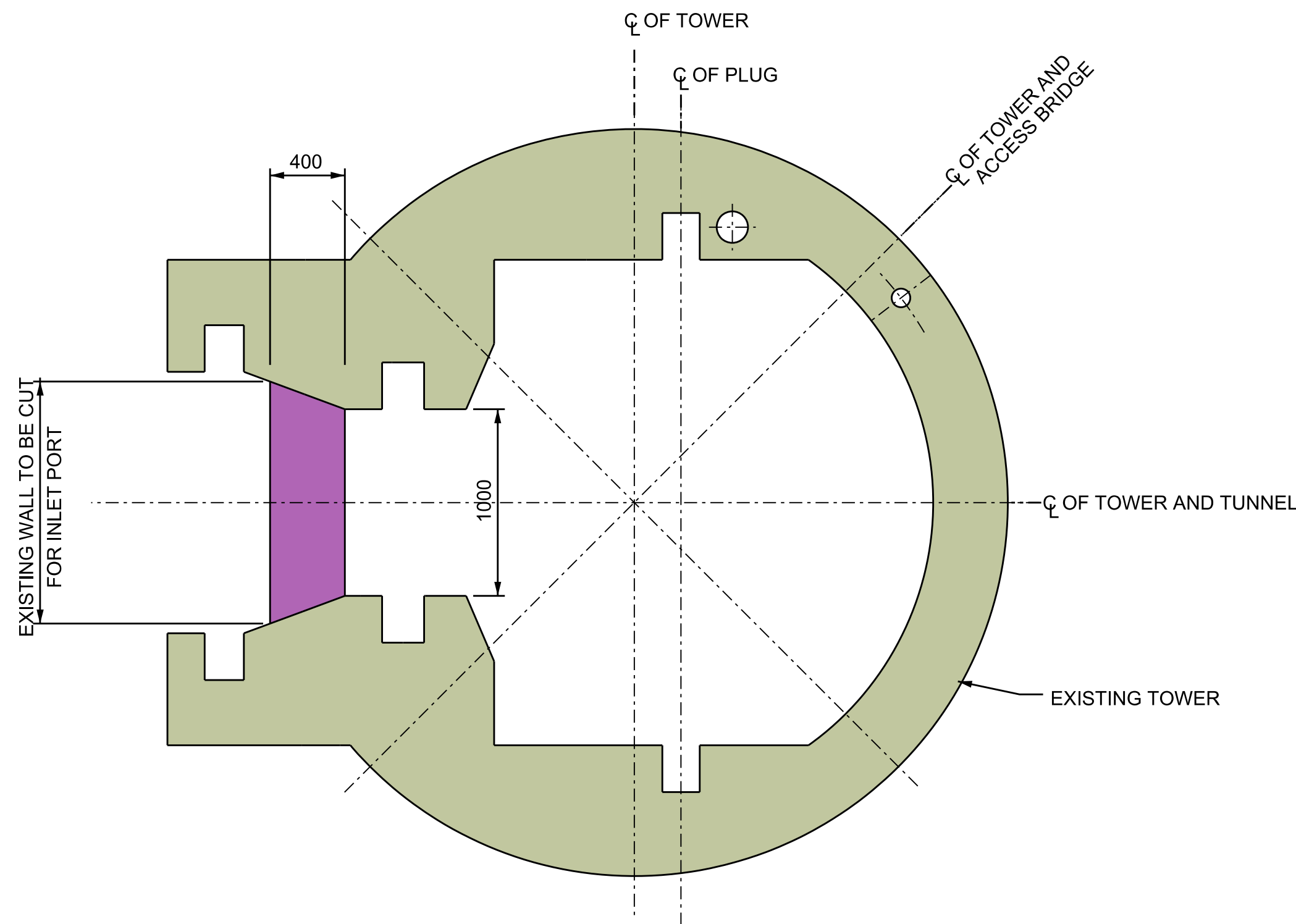
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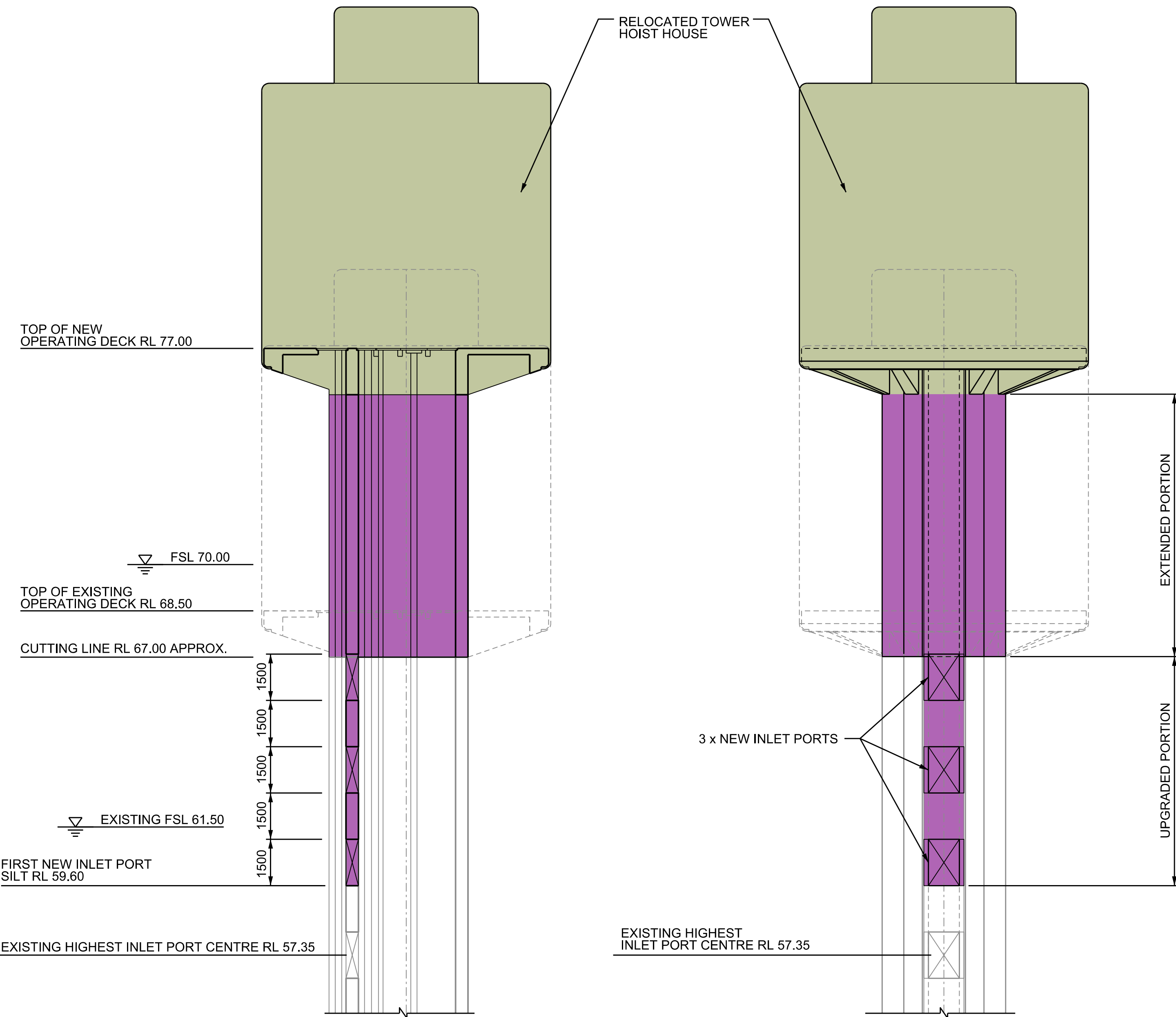
1



SECTIONAL PLAN - TYPICAL EXTENDED TOWER PORTION (ABOVE RL 67.00)
SCALE 1:25



SECTIONAL PLAN - EXISTING TOWER UPGRADED PORTION (RL 59.60 TO RL 67.00)
SCALE 1:25

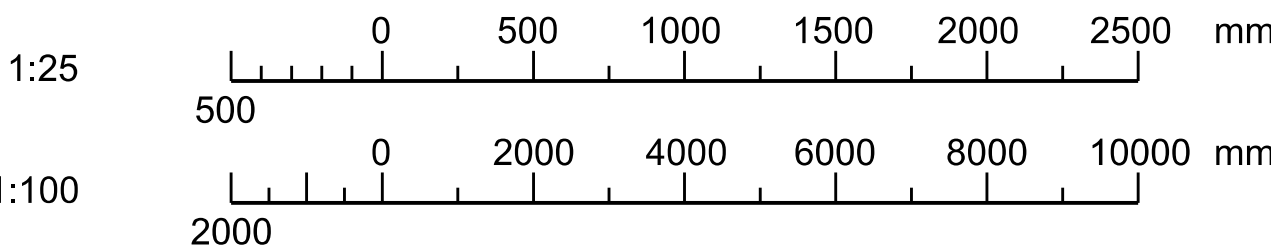


SECTION A
SCALE 1:100

(NOTE: STEEL WORKS NOT SHOWN FOR CLARITY)

VIEW B
SCALE 1:100

(NOTE: STEEL WORKS NOT SHOWN FOR CLARITY)



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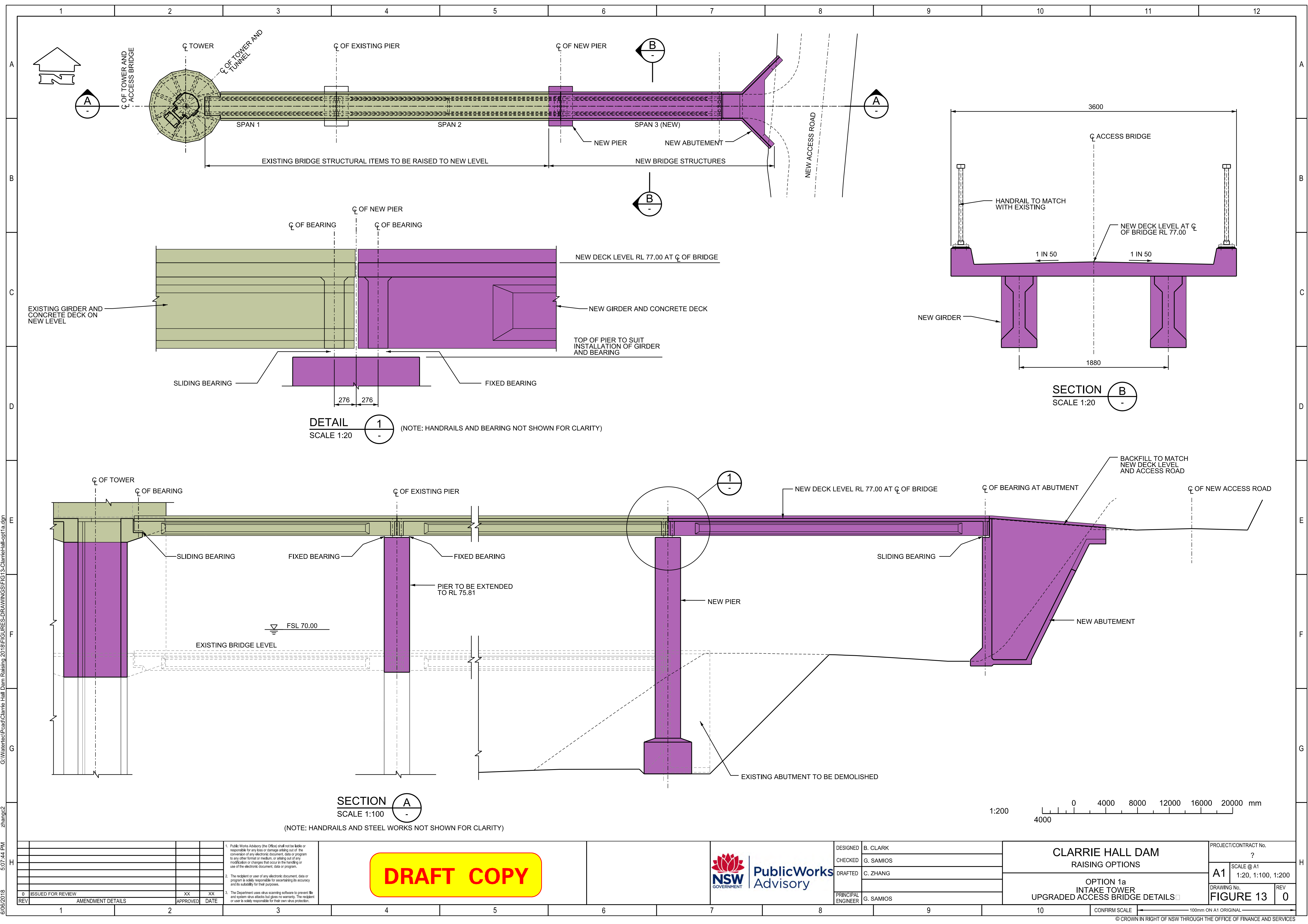
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CLARRIE HALL DAM RAISING OPTIONS	
OPTION 1a INTAKE TOWER UPGRADED WORK DETAILS	

PROJECT/CONTRACT No. ?	
A1	SCALE @ A1 1:25, 1:100
DRAWING No. FIGURE 12	REV 0



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CLARRIE HALL DAM RAISING OPTIONS	
OPTION 1a INTAKE TOWER UPGRADED ACCESS BRIDGE DETAILS	

PROJECT/CONTRACT No. ?	
A1	SCALE @ A1 1:20, 1:100, 1:200
DRAWING No.	REV
FIGURE 13	0

APPENDIX C

RAISED INTAKE TOWER ANALYSIS

C.1 General

The existing intake tower is a vertical reinforced concrete circular shaft 33.65m high with internal diameter of 3.2m. It has eight water inlet ports to facilitate selective water withdrawal.

The existing intake tower is proposed to be raised by 8.5m resulting in the total height of the intake tower to be 42.15m. The raised tower will incorporate two additional water inlet ports.

It is proposed to extend the tower by installing reinforcement bars chemically grouted into the holes drilled at the top of the tower wall. These anchored bars would be installed at spacings to match with the existing reinforcement. The installed anchor bars would then be lapped with reinforcing bars of appropriate length followed by the placement of concrete to the proposed level.

As for the existing arrangement, the raised tower will have radial beams built into the tower wall and a peripheral beam to support the floor slab and the new hoist house super structure. Corbels will be built into the raised tower wall, similar to the existing ones, to support the new access bridge.

C.2 Structural Analysis

Procedure

- Linear static analysis for gravity loads.
- First four natural frequency modes for tower (frequency analysis).
- Spectral response analysis for response accelerations having 10,000, 5,000, 1,000 and 500 year return periods. Response accelerations applied in two directions, orthogonal to each other (X and Y directions) as the tower is not symmetrical.
- Linear combination of results from linear static and spectral analysis.
- Extraction of results to determine demand (base shear and moments) in the X and Y directions using square root of sum of squares (SRSS) method.
- Evaluation of tower capacity and comparison with demand.
- Determination of stresses at the tower/base connection.

Finite Element Model

A 3D model of the raised tower (Figure 1 at **Appendix C**) was developed using the Strand7 finite element computer program. The model was assigned the following parameters:

Material	Concrete
Young's modulus	27460 MPa
Compressive strength	25MPa
Density	2400 kg/m ³

Boundary Conditions

The tower was assumed to be fixed in all directions (translation and rotation) at its connection to the base. The tower was assumed to behave as a cantilever column fixed at the base when subjected to the design loading.

C.3 Loading

Hydrodynamic Loading Determination

As the tower is always likely to be submerged in water, the critical loading would be the hydrodynamic loading being generated onto its inner and outer walls whilst these try to push water as a result of the movement of the tower base caused by an earthquake.

The hydrodynamic loading, caused by the inertia of the water mass, attached to the inside and outside wall faces, was approximated using paper titled "Simplified Evaluation of Added Hydraulic Mass for Intake Towers" by Goyal and Chopra published in ASCE Journal of Engineering Mechanics (1989).

A 1m water differential depth considered between the outside and the inside of the tower ie. water inside the tower 1m below the water outside the tower.

Water level outside the tower was considered at FSL (RL 70.00mAHD).

Gravity Loading

Gravity loading include self-weight of the tower and weight of the hoist house at the top of the tower.

Load Combinations

- Gravity load (Self-weight + Hoist House weight) + Hydrodynamic load

Results

- Base shear and moments for different earthquake return periods are presented at **Table C-1**.
- Maximum tensile stresses at the tower/base connection are presented at **Table C-2**.
- Comparison of section capacity versus demand is presented at **Table C-3**.

Table C-1 Base Shear & Bending Moment about CG of the Section for Different Return Periods

Return Period (yrs)	F _x (kN)	F _y (kN)	M _x (kNm)	M _y (kNm)	Comment
10,000	1130	0	0	18257	Seismic direction vector in X direction
	0	1120	17938	0	Seismic direction vector in Y direction
5,000	780	4	20	12398	Seismic direction vector in X direction
	0	774	12179	0	Seismic direction vector in Y direction
1,000	289	0	0	4435	Seismic direction vector in X direction
	0	286	4348	0	Seismic direction vector in Y direction
500	99	0	0	3037	Seismic direction vector in X direction
	0	103	3155	0	Seismic direction vector in Y direction

Table C-2 Maximum Stresses (MPa) at Tower/Base Connection along the Height of the Section - ZZ axis (Gravity $\pm$ Spectral (SRSS))

Return Period (yrs)	Tensile	Compressive	Comment
10,000	3.70	7.29	Seismic direction vector in X direction
	3.37	6.25	Seismic direction vector in Y direction
5,000	2.07	5.54	Seismic direction vector in X direction
	1.84	4.72	Seismic direction vector in y direction
1,000	0.75	3.16	Seismic direction vector in X direction
	Nil	2.62	Seismic direction vector in Y direction
500	Nil	2.72	Seismic direction vector in X direction
	Nil	2.38	Seismic direction vector in Y direction

Table C-3 Demand Vs Estimated Section Capacity**Bending Moment**

Return Period (yrs)	Demand (kNm)	Estimated Section Capacity - ΦM_u (kNm)	Comment
10,000	18,257	8,835	Section Inadequate - NG
5,000	12,398	8,835	Section Inadequate - NG
1,000	4,420	8,835	Section Adequate - OK
500	3,155	8,835	Section Adequate - OK

Base Shear

Return Period (yrs)	Demand (kN)	Estimated Section Capacity – Φv_{uc} (kN))	Comment
10,000	1130	1022	Section Inadequate - NG
5,000	780	1022	Section Adequate - OK
1,000	289	1022	Section Adequate - OK
500	103	1022	Section Adequate - OK

Findings

Results show that the raised tower section is adequately reinforced to handle the base shear for seismic loading up to the 0.01% AEP (10,000 year) event. However, this is not the case with the moment. It appears that tower section is likely to handle moment resulting from seismic loadings between 0.1% AEP (1,000 year) and 0.05% AEP (2,000 year) events. For the 0.02% AEP (5,000 year) and lower frequency occurrences (but more intense earthquakes), the tower is likely to experience distress and possible structural damage.

APPENDIX D

RAISED INTAKE TOWER BRIDGE PIER ANALYSIS

D.1 General

Access to the intake tower hoist house is from the right side of the dam via a public road leading to an access bridge which connects the public road to the hoist house.

The access bridge consists of two unequal spans supported by a reinforced concrete pier. Short and long spans are 16.5m and 28m long respectively, shorter span being close to the entrance to the hoist house.

The pier supporting the access bridge girders is a rectangle column 1500mm X 2500mm and 19.06m high. The access bridge would need to be raised by 8.5m to match the top of the raised intake tower.

The pier has a base 2m thick, 3m wide and 5m long.

D.2 Structural Analysis

Slenderness Check of Existing and Raised Pier

The access bridge girders sit on the pier through bearing pads and are not structurally connected to the pier. The slenderness of the existing pier was checked assuming it behaved as a cantilever column with built in connection at the base (effective length factor $K_e=2.2$).

The slenderness ratio of the existing pier was estimated to be 93 which satisfied the maximum limit of 120 as per the requirement of AS3600.

However, by increasing the height of the pier, the slenderness ratio increases to 140, exceeding the maximum limit of 120.

It was therefore decided to increase the cross section of the existing column to bring its slenderness ratio less than 120 to comply with AS3600.

The existing column was enlarged in dimensions to 2000mm X 3000mm for the increased height of 27.56m. The slenderness ratio of column with increased dimensions dropped to 101 satisfying the AS3600 limit of not greater than 120.

Procedure

- Linear static analysis for gravity loads.
- First four natural frequency modes for tower (frequency analysis).
- Spectral response analysis for response accelerations having 10,000 year, 5,000 year and 500 year return periods. Response accelerations applied in two directions orthogonal to each other (X and Y directions) as pier is not symmetrical.
- Linear combination of results from linear static and spectral analysis.
- Extraction of results to determine demand (base shear and moments) in X and Y directions using square root of sum of squares (SRSS) method.
- Evaluate capacity of upgraded pier and compare with the demand.
- Determination of stresses at the foundation (concrete base/rock interface).

Finite Element Model

A 3D model of the upgraded and raised pier (Figure 1 at **Appendix D**) was developed using finite element program Strand7. The model was assigned the following parameters:

Material	Concrete
Young's modulus	27460 MPa
Compressive strength	25MPa
Density	2400 kg/m ³

Boundary Conditions

The pier was assumed to be fixed in all directions (translation and rotation) at its connection to the base. The tower was assumed to behave as a cantilever column when subjected to the design loading.

D.3 Loading

Hydrodynamic Loading Determination

As the main pier is always likely to be submerged in water, the critical loading would be the hydrodynamic loading being generated onto its faces whilst these try to push water as a result of the movement of the pier base caused by an earthquake.

The hydrodynamic loading, caused by the inertia of the water mass attached to the pier faces, was approximated using Engineering Manual by USACE, titled "Structural Design and Evaluation of Outlet Works" which, in turn, refers back to the paper titled "Simplified Evaluation of Added Hydraulic Mass for Intake Towers" by Goyal and Chopra published in ASCE Journal of Engineering Mechanics (1989).

Water level around the pier was considered at FSL (RL 70.00 mAHD).

Gravity Loading

Gravity loading include self-weight of the pier and weight of the bridge.

Load Combinations

Gravity load (Self-weight + access bridge weight) + Hydrodynamic load

Results

- Base shear and moments at the column/base connection for different earthquake return periods are presented at **Table D-1**.
- Comparison of section capacity of existing pier versus demand is presented at **Table D-1**.
- Comparison of section capacity of enlarged pier versus demand is presented at **Table D-2**.
- Maximum stresses at the pier base/foundation interface are presented at **Table D-3**.

Table D-1 Base Shear & Bending Moment about CG of the Section

Return Period (yrs)	F _x (kN)	F _y (kN)	M _x (kNm)	M _y (kNm)	Comment
10,000	553	0	0	6561	Seismic direction vector in X direction
	0	638	10472	0	Seismic direction vector in Y direction
5,000	381	0	0	4460	Seismic direction vector in X direction
	0	438	7152	0	Seismic direction vector in Y direction
1,000	140	0	0	1600	Seismic direction vector in X direction
	0	162	2650	0	Seismic direction vector in Y direction
500	85	0	0	965	Seismic direction vector in X direction
	0	98	1604	0	Seismic direction vector in Y direction

Table D-2 Demand Vs Estimated Section Capacity (Existing Pier)**Bending Moment Capacity of Existing Pier Section**M_x (kNm) = 2490M_y (kNm) = 2562

		Return Period (Years)			
		10,000	5,000	1,000	500
Demand (kNm)	M _x (kNm)	10,472	7,152	2,650	1,604
	M _y (kNm)	6,561	4,460	1,600	965
		Section Inadequate	Section Inadequate	Section Inadequate	Section Adequate

Shear Capacity of Existing Pier SectionF_x (kN) = 1059F_y (kN) = 898

		Return Period (Years)			
		10,000	5,000	1,000	500
Demand (kN)	F _x (kN)	553	381	140	85
	F _y (kN)	638	438	162	98
		Section Adequate	Section Adequate	Section Adequate	Section Adequate

Table D-3 Demand Vs Estimated Section Capacity (Enlarged Pier)

Bending Moment Capacity of Enlarged Pier Section

 $M_x \text{ (kNm)} = 5552$ $M_y \text{ (kNm)} = 6263$

Demand (kNm)		Return Period (Years)			
		10,000	5,000	1,000	500
	Mx (kNm)	10,472	7,152	2,650	1,604
	My (kNm)	6,561	4,460	1,600	965
		Section Inadequate	Section Inadequate	Section Adequate	Section Adequate

Table D-4 Max. Stresses (MPa) at Pier Foundation (Gravity + Spectral (SRSS))

Return Period (yrs)	Tensile	Compressive	Comment
10,000	0.75	1.84	Seismic direction vector in X direction
	0.65	1.45	Seismic direction vector in Y direction
5,000	0.34	1.43	Seismic direction vector in X direction
	0.32	1.1	Seismic direction vector in Y direction
1,000	Nil	0.86	Seismic direction vector in X direction
	Nil	0.67	Seismic direction vector in Y direction
500	Nil	0.74	Seismic direction vector in X direction
	Nil	0.58	Seismic direction vector in Y direction

Findings

Results show that the existing access bridge pier section is adequately reinforced to handle the base shear for seismic loading up to the 0.01% AEP (10,000 year) event and bending moment for seismic loading up to the 0.2% AEP (500 year) event. The pier is required to be enlarged in cross section to satisfy code requirements. The enlarged section of the pier improves its bending capacity and the enlarged pier can handle the seismic loading up to the 0.1% AEP (1,000 year) event.

It is also noted that, for seismic loading up to the 0.1% AEP (1,000 year) event, the pier foundation (concrete base/rock interface) remains intact for the full base area as stresses remain in compression.

APPENDIX E

CFD MODELLING OF PREFERRED SPILLWAY OPTION (1B)

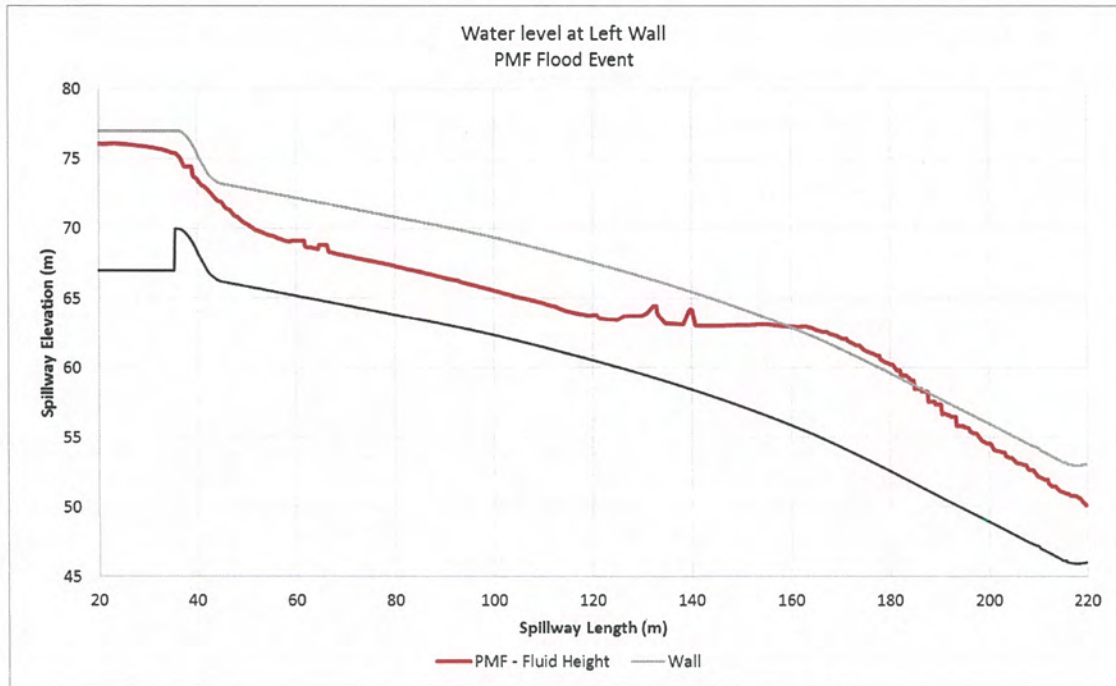


Figure 3-25 Graph showing water level at the Left Wall at PMF event

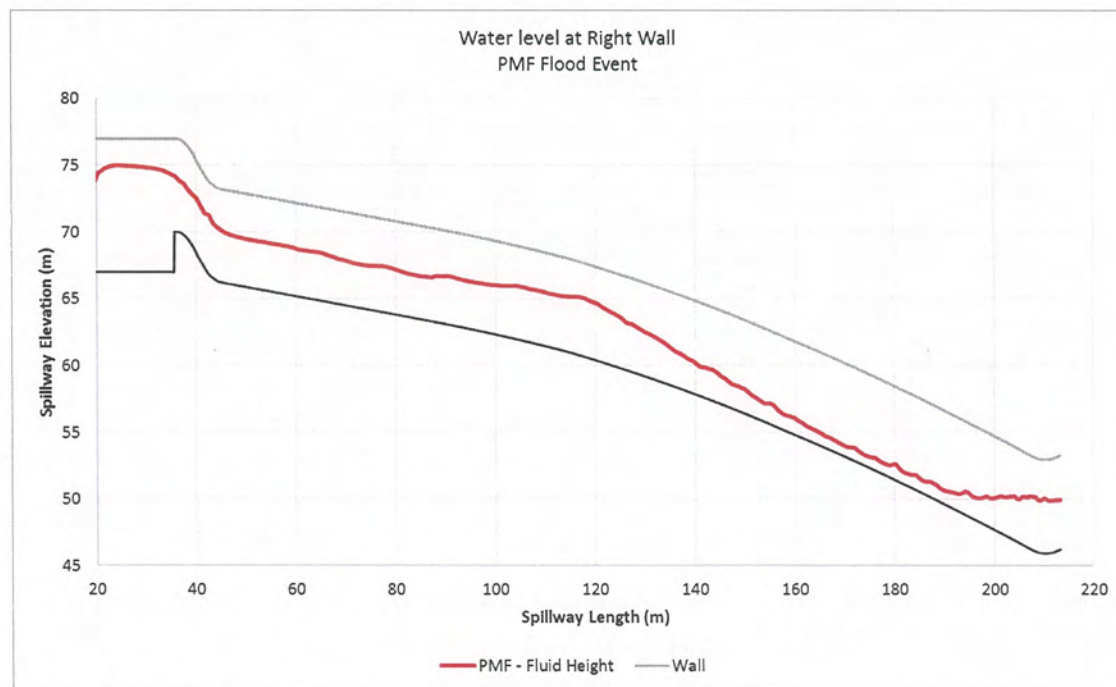


Figure 3-26 Graph showing water level at the Right Wall at PMF event

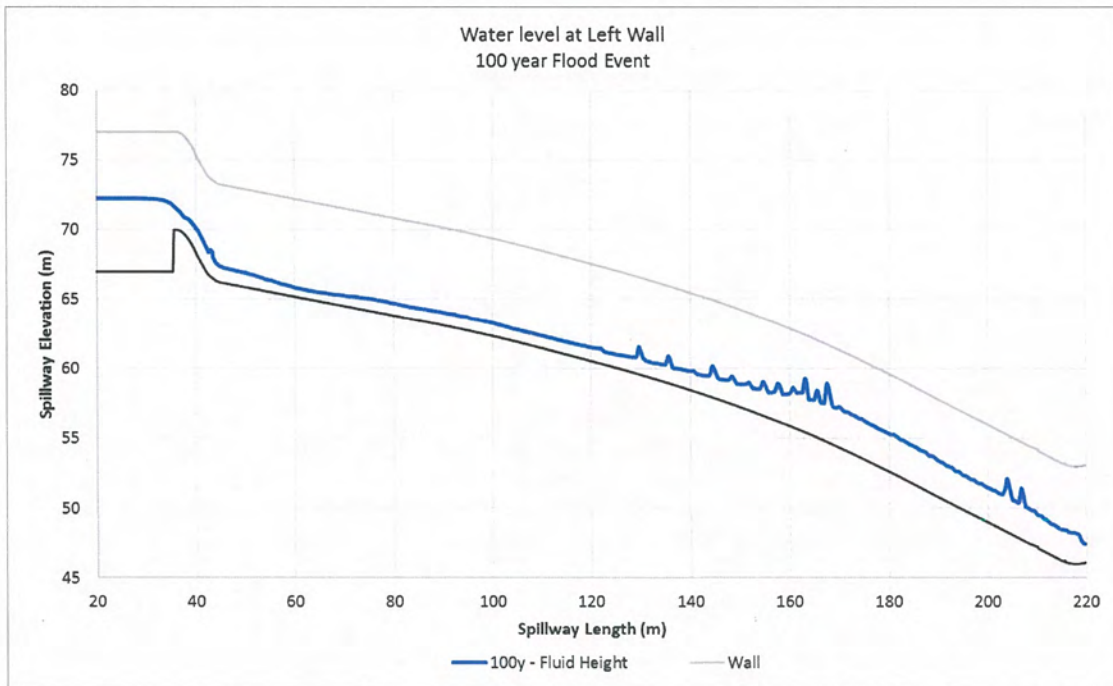


Figure 3-46 Graph showing water level at the Left Wall at 100 year event

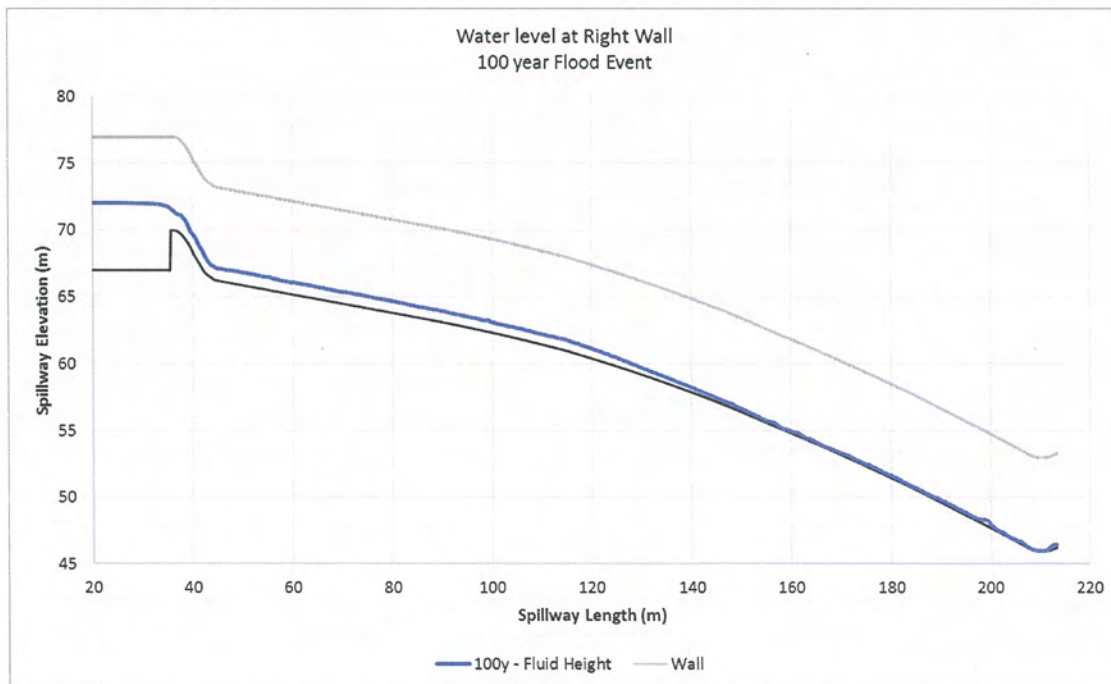
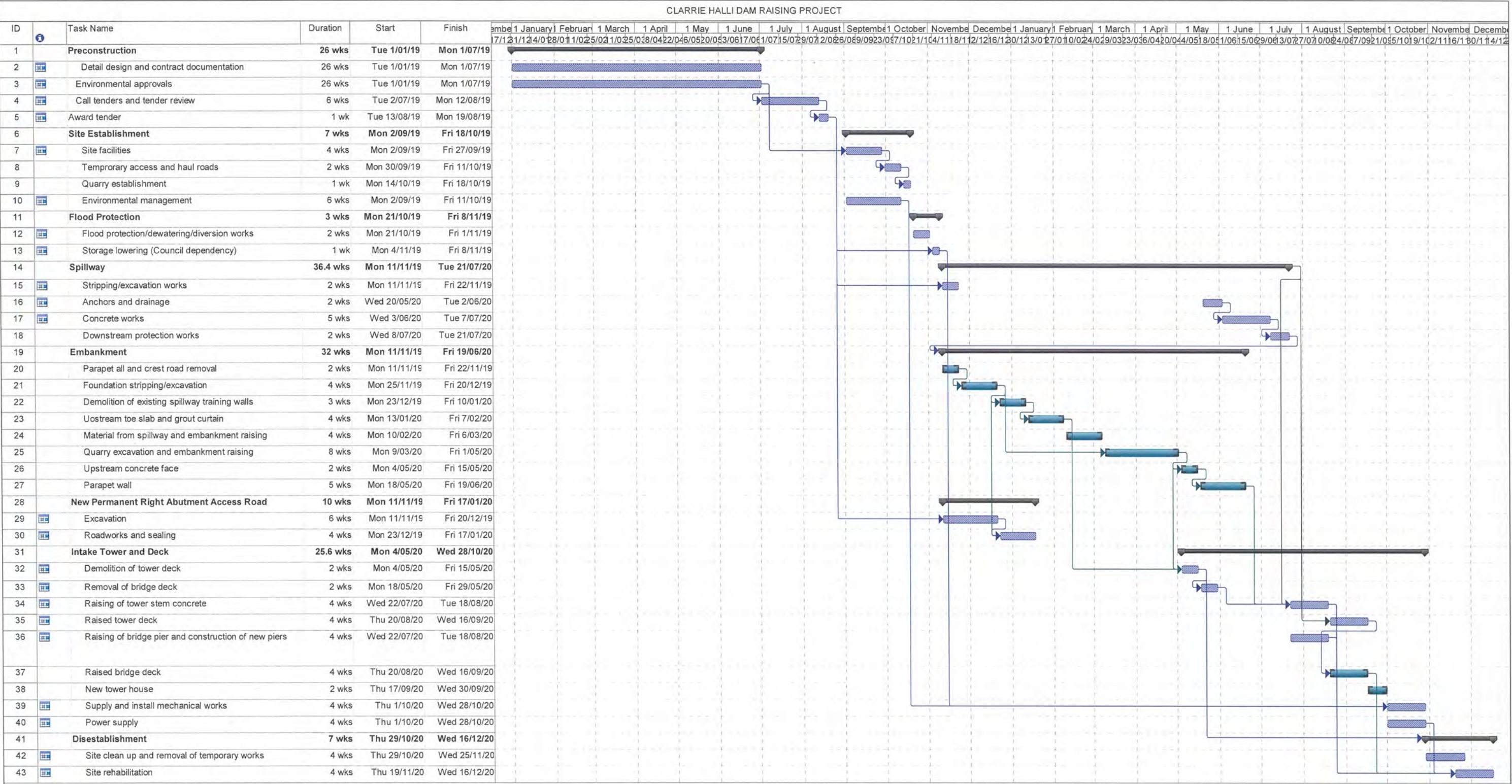


Figure 3-47 Graph showing water level at the Right Wall at 100 year event

APPENDIX F

PROJECT TIME LINE



Project: Revised_Proposal_Program
Date: Thu 5/07/18

- Task
- Split
- Milestone



- Summary
- Project Summary
- External Tasks



- External Milestone
- Inactive Task
- Inactive Milestone



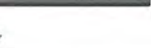
- Inactive Summary
- Manual Task
- Duration-only



- Manual Summary Rollup
- Manual Summary
- Start-only



- Finish-only
- Progress
- Deadline



APPENDIX G

PROJECT RISK MATRIX

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
	DESIGN RISKS		
D1	Design	Designs will be undertaken fully in accordance with NSW Dams Safety Committee (DSC) requirements, Australian National Committee on Large Dams (ANCOLD) guidelines and all relevant AS standards.	Designs will be in accordance with current best practice and subject to independent peer review.
D2	Items salvageable for reuse	- The crest parapet walls can be reused for the raised embankment crest, however additional walls will be required as the raised dam crest length is longer than existing dam. - It is expected that the existing tower bridge deck and crane support structure can be reused.	- There will be some risk from the time the parapet walls are removed until the embankment is raised about the new spillway. Flood protection during construction needs to be considered carefully. - Car parking and history/aboriginal/learning information to be reinstated. - Areas for storage will be required including storage of the pre-cast parapet walls before reinstatement on the raised crest. - Sequence of construction to keep old spillway operational as long as possible during construction. - Access to site, closed for 2 years – part of contract specification - Existing embankment mesh protection will just be left there and covered over with rock. All agreed.
D3	Construction program and sequencing	The existing dam configuration and constraints around the continued operation of the dam will impact significantly on the construction sequencing and approach. A preliminary construction program will be prepared with input from construction industry specialists. This will be a cost-critical exercise because flood diversion and construction of the embankment and spillway structures in a staged manner at an existing large dam in operation is a complex undertaking.	
D4	Cost estimating	Accurate cost estimates are required to inform Council and other key stakeholders in terms of budget planning. To provide understanding and test uncertainty, a probabilistic risk based cost estimate using analysis using Monte Carlo techniques (@RISK) will be utilised.	
	COMMUNITY CONSULTATION		
C1	Advice to landowners	- Council will need to inform landowners of the works. - The Contractor will be responsible for providing landowners with contact details and of the specific times works will be undertaken that may impact vehicle movement or produce noise/vibrations or other disturbance. - Council will need to inform affected landowners when manual water releases occur from outlet works.	- Need to check downstream users again when we start using automatic valve releases. Ensure we have their mobile numbers to send SMS's to. - Notification of causeways on Tweed River downstream. - Signage at entrance to dam and advertising of dam closure to locals and public in general. - Advice of blasting operation during construction will need to be provided to affected landholders - Temporary flood due to valve opening during construction will need to be communicated to affected residents
C2	Access to site through adjacent landowner	Early consultation with affected landholders will need to be undertaken by Council to ensure that access is granted where necessary	
C3	Land owner access via Clarrie Hall Dam Rd	The Contractor will be responsible for providing landowners with contact details and of the specific times works will be undertaken that may impact vehicle movement or produce noise/vibrations or other disturbance.	
C4	Discovery of an Aboriginal artefact	The Principal assumes the risk if an artefact is found. The Contractor is to notify the Principal and the Principal assumes the risk for any additional costs.	

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
S	SITE AND SERVICES		
S1	Site access and access Roads	• Site access will be via Clarrie Hall Dam Rd from the Kyogle – Murwillumbah Road. • Site is not accessible in times of flood. Non accessibility due to flood will be a risk that the Contractor needs to consider. Flooding of Kyogle – Murwillumbah Road and alternative roads can occur depending on spatial variation of rainfall. The Contractor will need to plan transport and deliveries to avoid delays. • Maintenance of access and all internal roads to be with Contractor. Dilapidation survey's will be required • Traffic control, dust control and speed control will be the responsibility of the Contractor	
S2	Access across dam embankment and spillway walls and intake tower bridge	• Load bearing capacities for embankment, spillway walls and bridge will be calculated by the designers. Design values will be given to the Contractor, but 30yr old structure so the Contractor will need to take this into account. • The Contractor will be responsible for meeting loading requirements and performing ongoing maintenance. Dilapidation surveys will be required	• Confirmation that no Annual or 5 yearly Surveillance inspections required during dam upgrade. Complete one before and one on first fill. • Confirmation of survey requirements just before raising, at end and once filled. • Include Cadastral of existing services in site survey. • The downstream seepage weir will need to be re-instated early after lower embankment placement to enable continued monitoring
S3	Construction impacts on dam wall	• The Principal will need to carry out EPOCH survey and compare data before, during and after construction. • Vibration monitoring will be required • Dilapidation surveys will be required.	• New seepage weir monitoring point required. Pipe from existing location. Do very early in construction to maintain seepage record
S4	Unexpected encounter with existing underground services not shown or incorrectly shown on the design and contract drawings.	• The Contractor must carry out a complete services search prior to commencing excavation works and is responsible to check and confirm the existence and location of any services in the design are correct.	
S5	Encountering materially adverse site conditions	• The Principal bears the risk of materially adverse site conditions. Relevant geological reports will be provided to the Contractor.	
S6	Site services for construction, water supply, sewerage, power	• The Contractor will need to make arrangement for services and ensure appropriate use in consultation with the Principal.	• What is capacity of existing services? – power, no drinking water, no sewerage capacity for construction – very minor public facility only. These aspects need to be considered.
S7	Use of Dam water for construction works	• The Contractor will likely be permitted to use dam water free of charge only for the purpose of carrying out the works (responsible use). The location and method of water extraction must avoid the risk of dam water contamination, and must be approved by the Principal. Dam water is non potable.	
S8	Working in an operational storage Dam	• The Contractor will need to manage this risk and fully understand Council's operational requirements. Daily liaison and regular meetings will be necessary.	• Temporary telemetry provisions need to be made for the construction, once the existing telemetry locations are affected by the raising works. Must maintain seepage monitoring during construction
S9	Construction may limit operational access	• Close coordination between the Contractor and Council operators required to ensure site access restrictions are minimised and managed with adequate notification provided.	
S10	Illegal site access and vandalism	• It will be the Contractor's responsible for securing work site. It is noted that the public have previously accessed the spillway to body board or skate down the cute.	• Video surveillance - could be permanent and handed over to Council at completion of construction. Require monitoring of works, photo, video record by contractor
S11	Site Office Establishment including fenced compound	• The Contractor will need to propose a suitable location for site office with approval from the Principal	• Only limited amenities exist on-site with a pump out tank. Won't be appropriate for larger workforce.

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy		Comments
		It will be the Contractor’s responsibility to provide and maintain site office for Council staff.		Accommodation. Contractor may approach Council to have a person(s) housed onsite for security. We may support for mutual benefits.
S12	Delivery, storage and protection of materials	The Contractor will need to ensure adequate processes for delivery, storage and protection of materials are implemented		
WORK HEALTH AND SAFETY				
W1	Identified WHS Construction Risks	- Working at Heights - Working over and near water - Flooding - Excavation works - Drilling works - Grouting works - Concrete works - Rockfill haulage, placement and compaction - Overhead Electricity - Scaffolds and work platforms - Hazardous substances - Moving Plant - Hazardous Equipment - Traffic and vehicular movement - Access and egress	- Public access - Demolition activity - Formwork - Vibration - Hydraulic pressure - Power tools - Manual handling - Underground services - Confined Spaces - Solar radiation - Dust - Noise - Bushfires	- Public access restricted for entire period of construction - FCD Valve will letting water through the site most of the time. This flow will need to be allowed to flow through. - Large snakes are regularly found in the vicinity of the dam. - FCD Valve is remotely operated and warning needed for opening, ALARM. - Biggest risk for us is walking around the rocky areas – Slippery and uneven surfaces. - Operational access to all parts of the new dam need to be thought of in the design. Including both sides of spillway for inspection and viewing spillway from certain points. - Rock falling is a risk to workers. - Blasting - alarm and notification to landholders. Consider use of Non-Explosive Controlled Demolition Agent for rock excavation if geotechnical conditions are suitable. - Security cameras required - Communication during construction needs to be adequate
W3	Management of WHS on site during construction	- The principal Contractor will be responsible for the management of WHS for themselves, subContractors and all associated construction personnel, including any Council personnel. - Council’s operations staff will be inducted into and work under the Contractor’s WHS system - Coordination will be needed to ensure the Contractor’s site procedures and Council adopted procedures do not contradict. - Council’s dam management operations and emergency procedures will need to be provided for inclusion in the principal Contractor’s safety management plan.		
W4	Falls from height / Working over water	It will be the Contractor’s responsibility to comply with all WHS requirements. Selection of appropriate subbies, implementation of appropriate management plans and SWMS.		
W5	Bushfires	The Contractor will need to prepare evacuation plans to ensure that adequate procedures are in place in case of bushfires		
W6	Working below a coffer dam or water retaining structure, and working within a stream bed / flood prone area	It will be the Contractor’s responsibility to comply with all WHS requirements. Selection of appropriate subbies, equipment, construction techniques, implementation of appropriate management plans, SWMS, early warning and evacuation.		

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
W7	Control of jointly occupied site with Contractor/s and Council.	The Contractor will need to manage entry of all personnel to site. (Site control system for all people entering/leaving/transiting site will need to be developed). This should include allowance for emergency night time entry by Council staff.	
W8	Control of landholders with access via Clarrie Hall Dam Rd	The Contractor will need to manage safe access for all landholders.	
W9	Remotely activated outlet valve	The Principal will need to ensure audible and visual alarm prior to release and the Contractor will need to consider valve operation in its safety management plan	
W10	Presence of H ₂ S gas adjacent to outlet works when water is discharged.	It is unclear whether construction personnel stationed on site would be at risk. It is currently not an issue since Council staff are not stationed at the dam. Gas released disperses but is not measured and smell is present. The Contractor will need to account for the presence of H₂S gas in its safety management plan.	
W11	Presence of asbestos during construction.	The intake tower contains asbestos and therefore the contractor will need to manage the risk and use appropriate methods of removing the asbestos as required for the raising works.	
W12	Independent certification for coffer dams or other flood mitigation constructions with a structural component or potential impact on water flows to or through the spillway	The Contractor will need to engage an independent certifier for coffer dams or other flood mitigation constructions. The Contractor will need to arrange, provide and pay all costs for certification.	
W13	Independent certification for formwork	The Contractor will need to engage an independent certifier for the formwork. The Contractor will need to arrange, provide and pay all costs for certification.	
ENVIRONMENTAL AND SITE CONDITIONS			
E1	Identified Environmental Risks	- Dewatering Management - Erosion and sediment control - Contamination of dam water - Contamination of Doon Doon Ck - Effects of flooding events and potential for pollution storage of fuels and oils, and other hazardous substances - Flora and Fauna - Cultural and Heritage Issues e.g. Indigenous items found during excavation - Impact of Construction Traffic - Weed Control - Mitigation Measures identified in Review of Environmental Factors - Contractors risk (except for Indigenous items found during construction)	- Particularly in dam and downstream - Blasting dust, noise, vibration to be considered. - Construction noise and dust. - Waste materials need adequate management of disposal - Tree clearing? V's Water quality – generally Council to determine through Environmental Assessment phase - Water turn over in dam risk increased if lowering dam and no flow through. - Sediment from upstream clearing etc. entering Tweed River. Need to stage the catchment clearing so large areas are not left bare when dam fills. - Can the storage filling be controlled to any extent to allow fauna to migrate – consider. - Raised storage rim - can there be some shallow areas at the back of the storage but steeper slopes elsewhere to limit weed growth - De-stratification needs to be determined, current project to speed-up to get results that can be included in the environmental assessment.
E2	Contamination of water / management of runoff Protection of Dam, Doon Doon Ck and groundwater water	- Contractor will need to address in Construction Environmental Management Plan (CEMP) - Contamination of water could result significant impact of flora and fauna in Doon Doon Creek - which is an unacceptable outcome.	If there is low water level there is an increased risk of turn-over

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
		- The Contractor will need to use appropriate controls and systems to ensure no issues and will need to manage risk of pollution from the works due to flooding events also. - Work methods, materials and sequencing to allow for effects of flooding events and potential for pollution. Appropriate storage / treatment of runoff	
E3	Noise and Vibrations	- The Contractor will need to comply with Environmental Assessment/Approval (EA) requirements and consult with affected residents. - Vibration monitoring will be required on dam during the construction period	
E4	Disposal of surplus material	The Contractor in consultation with the principal will need to undertake appropriate disposal of surplus materials, identifying item for salvage.	
E5	Discharge of dewatering water (and treatment)	The Contractor will need to obtain approvals for discharge to receiving waters and outlined in CEMP	
E6	Management of Acid Sulfate Soils & Groundwater	ASS risk is considered unlikely, however the Contractor will need to abide by the EA and geotechnical provisions and obtain approvals for discharge to receiving waters as required.	
E7	Upstream inundation areas	Environmental assessment will need to be undertaken on new upstream inundation areas, including for flood surcharge inundation e.g impact on significant vegetation may influence raising height decision	Council's flora and fauna study to consider further with some additional research.
E8	Tree clearing	Areas subject to inundation that were previously unaffected will need to be assessed for tree removal and the associated environmental impact.	- Trees on the rim of the new dam catchment. Desire to have deeper drop-off but retain dedicated flat areas for lilies and bird habitat. Need to sort this out soon so we can complete clearing in areas needed. - We don't want too many trees dead in water - Consider water quality risk in terms of leaving trees in the storage, as part of Environmental Assessment
E9	Early identification of ancillary sites	Design stage to identify all potential ancillary works areas (including rock borrow areas, materials set down areas etc.) that need to be assessed and included into project environmental assessment and approval	PWA to provide construction disturbance footprints for flora and fauna assessments as soon as they are available
E10	Breach of Project condition of approvals	- Contractor will need to ensure all project approvals, commitments, and monitoring requirements are included into CEMP - Environmental reporting during construction (including management of complaints / incident register) - Auditing of environmental compliance during construction	
E11	Vegetation clearing	- Early initiation of environmental monitoring commitments - Pre-clearing (inundation) surveys and flora/fauna translocation activities	What areas are to be cleared? This needs to be provided by PWA as input for environmental assessment.
CONSTRUCTION and PROGRAMMING			
CP1	Time Period for Construction and Working Hours	An estimate construction schedule will be developed with input from a construction Contractor.	

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
		- Considering of seasonal rainfall valuations to be considered regarding proposed commencement date for construction works - Council to decide acceptable working hours so that estimated construction program can be developed. (For the spillway upgrade project the following working hours applied: Monday – Friday 7am – 6pm. Saturday 8am – 1pm. No work on Sundays or Public Holidays) - The Contractor may need to operate temporary works such as dewatering equipment outside normal working hours but pumps will need to meet EA noise restrictions.	
CP2	Lowering of the Storage During Construction	- Council need to make a decision on whether any storage lowering during the construction is acceptable and if so to what extent. The timing of the construction may influence the requirements set across the construction period. i.e. lowering may be permitted during “wet season” for example. - Implications to threatened species needs to be considered when determining the timing of any water lowering activities. This needs to be assessed early in the design stage to mitigate an impact at construction stage.	- Expected that lowering of storage by approximately 1m will be required during construction works for a period of approximately 3 months. Levels to be detailed in design and these progressed through ETI and Tender process. - There is threatened water birds (Jacana) that need to be considered in relation to storage lowering.
CP3	Damage to/ loss of works/equipment occurring from flooding and overtopping of spillway or other construction areas.	- The Contractor is responsible for all personnel and equipment and should have insurance for flooding events. - Council consider lowering the storage during the works (to say RL61.30m AHD, as was adopted for the spillway upgrade project) and control flooding from minor inflows via releases through the outlet works. This will not in any way absolve the Contractor from full responsibility for the impacts of flooding. - The Contractor will need to demonstrate how it will manage flooding risks and recover from events. (eg. nightly removal of equipment with hazardous substance or large enough to cause damage, no instream temporary works components that could get caught in spillway etc.)	
CP4	Construction sequence / scheduling of works	- The Contractor is best placed to determine the construction sequence and will be responsible for all construction sequence risks. - The construction of works will need to be sequenced such that there is no increased risk of damage to overall dam structure as a result of flooding during the construction works (in accordance with NSW Dam Safety Requirements) - The works sequence will need to be agreed with by the designers - The Contractor will need to show how they will control risks through sequencing.	Provide justification for the sequencing of works in the concept design report
CP5	Potential site isolation due to flooding	- The Contractor must plan for flooding events that can isolate the site and ensure that their equipment can be quickly and safety removed from flood areas, as necessary - There will be a time delay associated with such an event and the Contractor can request an extension of time, but there will be no price variation for such a delay. Contractor's insurance should cover for such eventuality.	
CP6	Damage to Dam's structural integrity during flooding	- The construction of works will need to be undertaken and sequenced such that there is no increased risk of damage to overall dam structure as a result of flooding during the construction works (in accordance with NSW Dam Safety Requirements) - Temporary structures must be able to be removed quickly to ensure they do not restrict spillway flow capacity in-situ or through failure, if flooding occurs	

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
		Independent certification of coffer dam and instream structures will be required	
CP7	Dam Safety Procedures	- There will need to be an interim Dam Safety Emergency Plan (approved by the NSW DSC) for the construction period taking into account the changed conditions and operation of the dam during the works. - The Contractor will need to comply with DSEP requirements and the Principal will be in charge of DSEP activities.	Interim DSEP to be prepared by PWA at conclusion of design
CP8	Water Release	- Contractor will need to be conscious of resulting sprays, odours and other associated consequences. - Releases may occur with limited warning.	
CP9	Contamination of water	- Contamination of water could result in the Principal being unable to continue to provide water supply to the Shire - which is an unacceptable outcome. - The Contractor will need to use appropriate controls and systems to ensure no issues and will need to manage risk of pollution from the works due to flooding events also.	
ADDITIONAL RISKS IDENTIFIED			
A1	Hydrographic Survey		Council considering getting a hydrographic survey now to determine silt build-up because it will be harder to do when dam is deeper.
A2	Existing Concrete Face Condition		Concrete face wall detailed inspection – Considering doing this now to determine useful life of concrete, condition and alignment. It will be harder to do when deeper and we won't see this concrete anymore. PWA to provide details of suggested diving consultant. Suggest using remotely operated vehicle (ROV).
A3	Concrete Admixtures		Concrete specification needs to ensure cheaper additives do not compromise the quality of the concrete. Need to let contractor know early about % of additives etc. allowed.
A4	Fish Passage		Design options to mitigate fish passage will need to be included in environmental assessments if they have construction elements that are outside current study footprints
A5	Operational water quality management		Flooding of vegetation has the potential to impact on water quality associated with rotting vegetation.
A6	De-stratification		De-stratification requirements post-construction need further assessment and investigation.
A7	Flooding of aquatic vegetation		- Further exploration of opportunities such as habitat translocation, manipulating filling rates of dam post construction (if possible), construction of temporary farm dams for supplementary habitat. Action: - David Hannah to explore opportunities as part of flora and fauna assessment
A8	Flora and fauna study area		Flora and fauna study will need to assess areas associated with extended embankments, new spillway, new access road and boat ramp design, construction ancillary areas etc. Public Works to provide general footprint of extent of works. David Hannah to provide scope of additional flora fauna assessment to Rob Siebert

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
A9	EIS requirements		Additional requirements not planned or expected may have implications to project programming. e.g. biodiversity pathway may change
A10	Brief for site survey		PWA to provide to Council. Survey plans to include property boundaries and existing services
A11	Communications on-site		Ensure adequate communications on-site during the works - site has poor mobile phone coverage in certain locations at certain times
A12	Photography and videography		Construction works should be recorded using photography and videography
A13	Amenities		The contractor will need to provide own amenities as existing site amenities will be insufficient
A14	Site offices on adjoining land		Contractor will need to identify early if site offices are required on adjoining land. Discuss with contractors at ETI stage
A15	Storage during construction		Areas for storage will be required including storage of the pre-cast parapet walls before reinstatement on the raised crest.
A16	Filling rate after construction		Filling rate will impact upon flora and fauna. Likely that storage will fill rapidly after raising. Valve releases will have little impact on storage if high flood inflows.
A17	Consultation with Lot 1 DP118944		This land owner is not to be approached. Current ongoing issue. Owners: Brian and Lesley Hill. Property on western side of CHD Road
A18	Blasting of rock		- Consider use of Non-Explosive Controlled Demolition Agent for rock excavation if geotechnical conditions are suitable. - Consider impact on existing adjacent structure - Vibration limits
A19	Stockpiling of materials		Location, management, haul roads - needs to be determined early
A20	Concrete batching plant		Location and approach needs to be determined early
A21	Existing rock cores		PWA can view the old rock cores as part of their geotechnical assessments. Peter Haywood can arrange viewing at Bray Park.
A22	Loss of survey infrastructure surrounding the dam and the monitoring pins in the existing dam		Many marks as possible need to be preserved to allow the existing survey control to be adequately connected to the new structure
A23	Changes in PWA staff on this project		PWA staff has specialist knowledge of Clarrie Hall Dam due to involvement from the original and design and construction and in the spillway upgrade project. This experience should be retained on the project.

APPENDIX H

PROJECT COST ESTIMATE AND COST RISK ASSESSMENT

Clarrie Hall Dam Raising to RL70.0m (42,300ML)

Item	Description	P10	P50	P90	Risk Distribution	Expected Price	Comments
	Preconstruction						
1	Flood Hydrology	\$48,620	\$48,620	\$48,620	Pert	\$48,620	Completed
2	Survey	\$70,103	\$70,103	\$70,103	Pert	\$70,103	Completed
3	Flora and Fauna Studies	\$190,000	\$190,000	\$190,000	Pert	\$190,000	Engagement
4	Cultural Heritage	\$128,000	\$160,000	\$240,000	Pert	\$168,000	Engagement but will be subject to additional costs
5	Environmental Flows	\$152,000	\$190,000	\$210,000	Pert	\$187,000	Engagement of K Bishop, P Cloke and EcoLogical. May go to \$210,000
6	Concept Design	\$794,000	\$794,000	\$794,000	Pert	\$794,000	NSW PW engagement
7	Preliminary Environmental Assessment	\$80,000	\$100,000	\$100,000	Pert	\$96,667	To be done internally. Cost not expected to exceed \$100,000
8	Application for SEARS	\$16,000	\$20,000	\$20,000	Pert	\$19,333	To be done internally. Cost not expected to exceed \$20,000
9	Agency Consultation	\$16,000	\$20,000	\$20,000	Pert	\$19,333	To be done internally. Cost not expected to exceed \$20,000
10	EIS Consultant	\$640,000	\$800,000	\$1,200,000	Pert	\$840,000	Engagement of consultant to do the EIS incl of further studies beyond those above if needed
11	Exhibition and Workshops	\$16,000	\$20,000	\$30,000	Pert	\$21,000	Public advertisement, production of documents etc
12	Response to Submissions Report	\$48,000	\$60,000	\$90,000	Pert	\$63,000	Engagement of consultant to prepare the Response to Submissions
13	Determination	\$16,000	\$20,000	\$30,000	Pert	\$21,000	Admin costs for sending to Minister etc
14	Planning Approvals	\$32,000	\$40,000	\$60,000	Pert	\$42,000	To be completed by Designer
15	Detailed Design	\$960,000	\$1,200,000	\$1,800,000	Pert	\$1,260,000	PWA Assessment (would include some further geoech) NSW PWA can provide estimates
16	Project Management	\$320,672	\$373,272	\$490,272	Pert	\$384,006	Assume 10%
17	Contingency	\$320,672	\$746,545	\$1,470,817	Pert	\$796,278	Range of contingency assumed; 10% - 20% - 30%
	Total Pre Construction	\$3,848,068	\$4,852,540	\$6,863,812		\$5,020,340	
	Construction						
18	Establishment	\$725,000	\$1,450,000	\$2,900,000	Pert	\$1,570,833	Includes Site Estab, disestablishment, flood protection, dewatering, Env mngt during construction
19	Clearing, Diversion and foundations	\$500,000	\$1,000,000	\$2,000,000	Pert	\$1,083,333	included in items 42 and 43 based on PWA estimate
20	Embankment construction	\$5,600,250	\$7,467,000	\$8,960,400	Pert	\$7,404,775	from PWA estimate
21	Spillway and outlet works	\$12,000,000	\$16,400,000	\$20,000,000	Pert	\$16,266,667	\$16,400,000 (spillway) + \$1,800,000 (intake tower) from PWA estimate
22	Intake Tower	\$1,600,000	\$1,800,000	\$2,200,000	Pert	\$1,833,333	from PWA estimate
23	Fish Elevator	\$0	\$0	\$0	N/A	\$0	As per page 18 of the Fine Screen Report, it is assumed that is is unlikely that a fishway would be required.
24	Dam Services	\$400,000	\$600,000	\$1,000,000	Pert	\$633,333	Ok. This cost may include any adjustment to current outlet valves operation and power requirements
25	Relocation of services/roads etc	\$1,200,000	\$1,600,000	\$2,000,000	Pert	\$1,600,000	Suggest allow new right abutment road cost \$1,400,000 from PWA estimate + say \$200,000 for general services relocation
26	Contact Administration	\$2,202,525	\$3,031,700	\$3,906,040	Pert	\$3,039,228	from PWA estimate (10%)
27	Contingency	\$4,845,555	\$10,004,610	\$21,483,220	Pert	\$11,057,869	Range of contingency assumed; 20% - 30% - 50%
	Total Construction	\$29,073,330	\$43,353,310	\$64,449,660		\$44,489,371	
	Total Project	\$32,921,398	\$48,205,850	\$71,313,472		\$49,509,712	



Level 4, 66 Harrington Street
SYDNEY NSW 2000

www.publicworksadvisory.nsw.gov.au

APPENDIX E

EPBC Referral Variation Determination





Notification of

VARIATION OF PROPOSAL TO TAKE ACTION

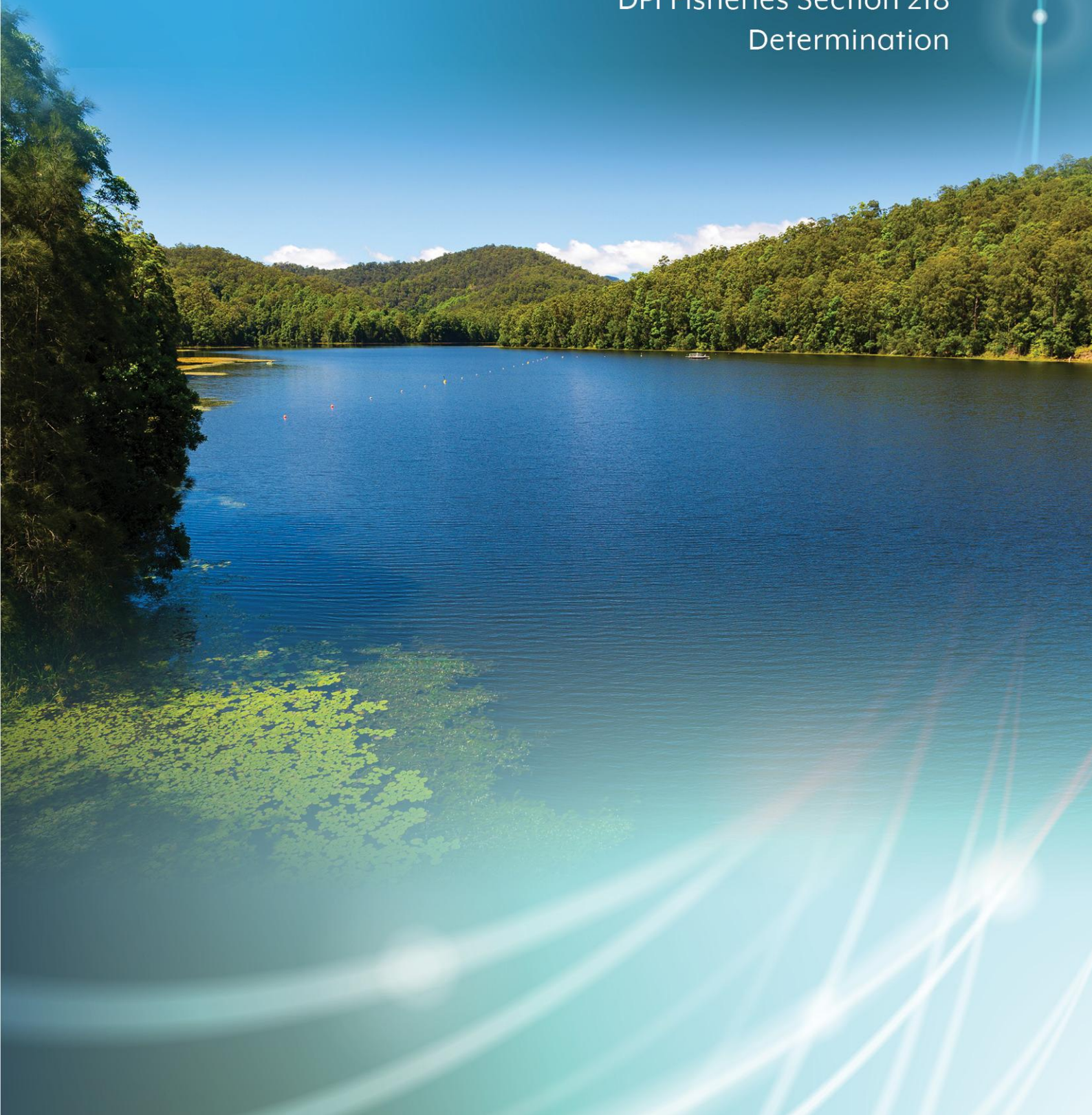
Clarrie Hall Dam Raising Project, Doon Doon, NSW (EPBC 2018/8339)

This variation to the proposal has been accepted in accordance with section 156B of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

proposed action	To raise the Clarrie Hall Dam wall and construct associated infrastructure at Doon Doon, NSW. [See EPBC Act referral 2018/8339].
varied proposed action	To raise the Clarrie Hall Dam wall and construct associated infrastructure at Doon Doon, NSW [See EPBC Act referral 2018/8339 and request for variation of the proposed action dated 22 May 2023].
person proposing to take the action	Tweed Shire Council ABN 90 178 732 496
variation	The proposed action remains the raising of Clarrie Hall Dam wall. Variations include increasing the disturbance footprint by 3.5 ha to facilitate upgrading the intersection of Clarrie Hall Dam Road and Kyogle Road and the realignment of Commissioners Creek Road, including replacement of McCabe's Bridge.
Decision-maker	
Name and position	Jennifer Pearson Acting Branch Head Environment Assessments NSW and ACT
Signature	
date of decision	30 June 2023

APPENDIX F

DPI Fisheries Section 218
Determination



OUT23/10933
14 July 2023

Mr Rob Siebert
Coordinator Strategy and Business Management
Water and Wastewater Unit
Tweed Shire Council
PO Box 816
MURWILLUMBAH NSW 2484
Via email: wateradmin@tweed.nsw.gov.au

Re: Notification of Section 218 Determination for Clarrie Hall Dam

Dear Mr Siebert,

Re: Notification of Section 218 Determination for Proposed Raising of Clarrie Hall Dam

Tweed Shire Council notified the NSW Department of Primary Industries (DPI Fisheries) of the Raising of the Clarrie Hall Dam project (Reference SSI-9548) on the 28 October 2021.

The Raising of the Clarrie Hall Dam project triggers Section 218 (Fishways to be provided in construction of dams and weirs) of the *Fisheries Management Act 1994* (FM Act) which states:

(5) a public authority that proposes to construct, alter or modify a dam, weir or reservoir on a waterway –

(a) must notify the Minister of the proposal, and

(b) must, if the Minister so requests, include as part of the works for the dam, weir or reservoir, or for its alteration or medication, a suitable fishway or fish by-pass.

Please be advised that DPI Fisheries has assessed the scope of the Raising of the Clarrie Hall Dam Project and has recommended the application of S.218 which requires the provision of suitable fish passage.

Section 4.8 (Fish Passage Trade-offs) of the *NSW Policy and guidelines for fish habitat conservation and management* (2013) provides provisions for transferring S.218 fish passage requirements to alternative high priority sites. DPI Fisheries proposes that S.218 fish passage requirements for Clarrie Hall Dam be transferred to the construction of suitable fish passage at Bray Park Weir.

I understand that Department officers have consulted Tweed Shire Council regarding this fish passage trade off proposal and that these discussions have been constructive and positive. To ensure both parties agree with respect to the trade-off proposal, DPI Fisheries is now seeking written confirmation of Tweed Shire Council's endorsement of the proposed Bray Park Weir fishway offset. Please note that fish passage offset activities at Bray Park Weir must be completed prior to the completion of Clarrie Hall Dam raising.

DPI Fisheries notes that habitat-related offsets may also be requested to compensate additional fish habitat-related impacts of the dam raising proposal beyond the FM Act fish passage provisions. DPI Fisheries understands that further studies will be undertaken by Council to better understand the extent of impacts to fish habitats and that this information will assist in determining suitable habitat offsets.

For further information on this fish passage trade-off determination, please contact Luke Pitman, Program Leader, Freshwater Environment, 0439 458 900.

Yours sincerely,

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Anthony Townsend'.

Anthony Townsend

A/Director Freshwater Environment
DPI Fisheries