Walcha Council

WC - Macdonald River Feasibility Study
Macdonald River Catchment Dam Feasibility Study

July 2019

Executive summary

Walcha Council is intending to augment the bulk water storage for the township of Walcha to ensure its water security is at an appropriate level. Walcha Council has commissioned GHD to perform a feasibility study for a new off-river dam site to be filled by pumping water from the Macdonald River.

This report presents the outcomes of the feasibility study into the provision of additional storage dams to store water pumped from the Macdonald River. The intent of the storage dams is to augment and supplement the existing water storage facilities owned and operated by Walcha Council to improve the reliability of water supplies to the town of Walcha.

This report presents feasibility study layouts for two dams, one located near the Macdonald River (Dam 6) and the other (Dam 4A) at the top of the dividing range between the Macdonald River and the town of Walcha. Based on the results of this feasibility study, Dam 6 is identified as the preferred site for the development of an additional storage dam. However, should it not be possible for any reason to construct the Dam 6 storage, Dam 4A could be developed. Both Dams are expected to result in a total annual yield of close to 300ML from the Macdonald River, based on yield modelling undertaken by NSW Urban Water Services.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.5 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background information

Walcha presently has a town water supply pumped from the Macdonald River (part of the Murray Darling Basin). The current licence is for the abstraction of 379ML/a from the Macdonald River. However, due to limitations on the amount of water available from the River, particularly during droughts, historical abstractions have only amounted to approximately 195 to 220ML/a. Council and residents are concerned about Water security in general and that the low water security is limiting economic development and population growth in the town and surrounds.

Council secured funding to undertake a feasibility study to establish methods to improve the reliability of supply from the Macdonald River (this Feasibility Study). A previous study concluded that water supply from the Apsley River would not provide a reliable source for water supply, hence this present study concentrates solely on the assessment of options to enhance water supplies from the Macdonald River. Enhanced supplies are intended to improve the security of water supplies for Walcha that could also have the potential to drive job opportunities and economic growth for the town in the future.

In accordance with the project brief, the study has concentrated on off-channel storages to store water abstracted from the Macdonald River during wet periods when higher flow occurs in the river, to supplement limited river abstractions during dry periods.

1.2 Purpose of this report

This report presents the outcomes of the feasibility study into the provision of additional storage dams to store water pumped from the Macdonald River. The intent of the storage dams is to augment and supplement the existing water storage facilities owned and operated by Walcha Council to improve the reliability of water supplies to the town of Walcha.

1.3 Scope of study

As per the study Terms of Reference, the Macdonald River Feasibility Study essentially comprised three parts:

1. Preparation of a desktop Assessment locating potential sites for an Off River Dam, situated around the Macdonald River catchment and existing Council infrastructure.
2. Confirmation of dam site suitability and “Secure Yield Modelling”. The secure yield modelling was carried out by NSW Urban Water Services. However, GHD liaised with Council and NSW Urban Water Services in defining the scope of work and interpreting the results of the secure yield analysis, as it impact on the evaluation of the storage dams.
3. Preparation of the Macdonald River Feasibility Study Summary Report (i.e. this report, which collates findings from the above studies).

This report presents feasibility study layouts for two dams, one located near the Macdonald River and the other at the top of the dividing range between the Macdonald River and the town of Walcha. Based on the results of this feasibility study, a preferred site is identified for the development of an additional storage dam.

1.4 Preliminary dam investigations outcomes

GHD and Walcha Council embarked on a collaborative process to shortlist the dam sites that are the subject of this Report.

Full details can be found in the GHD report Dated June 2019 titled “Walcha Council - Macdonald River Feasibility Study - Preliminary Dam Investigations and Options Summary” (Preliminary Options Report)

Based on the details contained within the Preliminary Options Report two sites, namely Site No 6 and Site 4A, were recommended for inclusion in this report.

The number of options identified and the methodology used in the Preliminary Options Report to shortlist to Sites 6 and 4a is summarised below:

- A desktop exercise identified a total of 10 sites for a site inspection.
- Subsequent aerial survey was performed at two selected sites.
- Five potential dam sites were developed within the boundaries of the two surveyed areas, which were subsequently ranked after performing indicative embankment volume calculations.
- High level Dambreak risk and associated consequences and pumping requirements were considered for the 5 proposed (i.e. ranked) locations. An indicative yield analysis previously undertaken by NSW Urban Water Services was also reviewed.
- A weir was also considered during the course of the investigations but was discounted based on several issues. The environmental constraints and the complex and lengthy approval processes associated with this option were the dominant reasons for not pursuing this option further.

Arising from the above study, Walcha Council agreed that off-river storage dams located at Site 4A (at the top of the ridge between the Macdonald River Pump Station and Walcha) and Site 6 (near the Macdonald River Pump Station) be taken forward to the present Feasibility Study. The locations of the sites are shown in Figure 1 below.

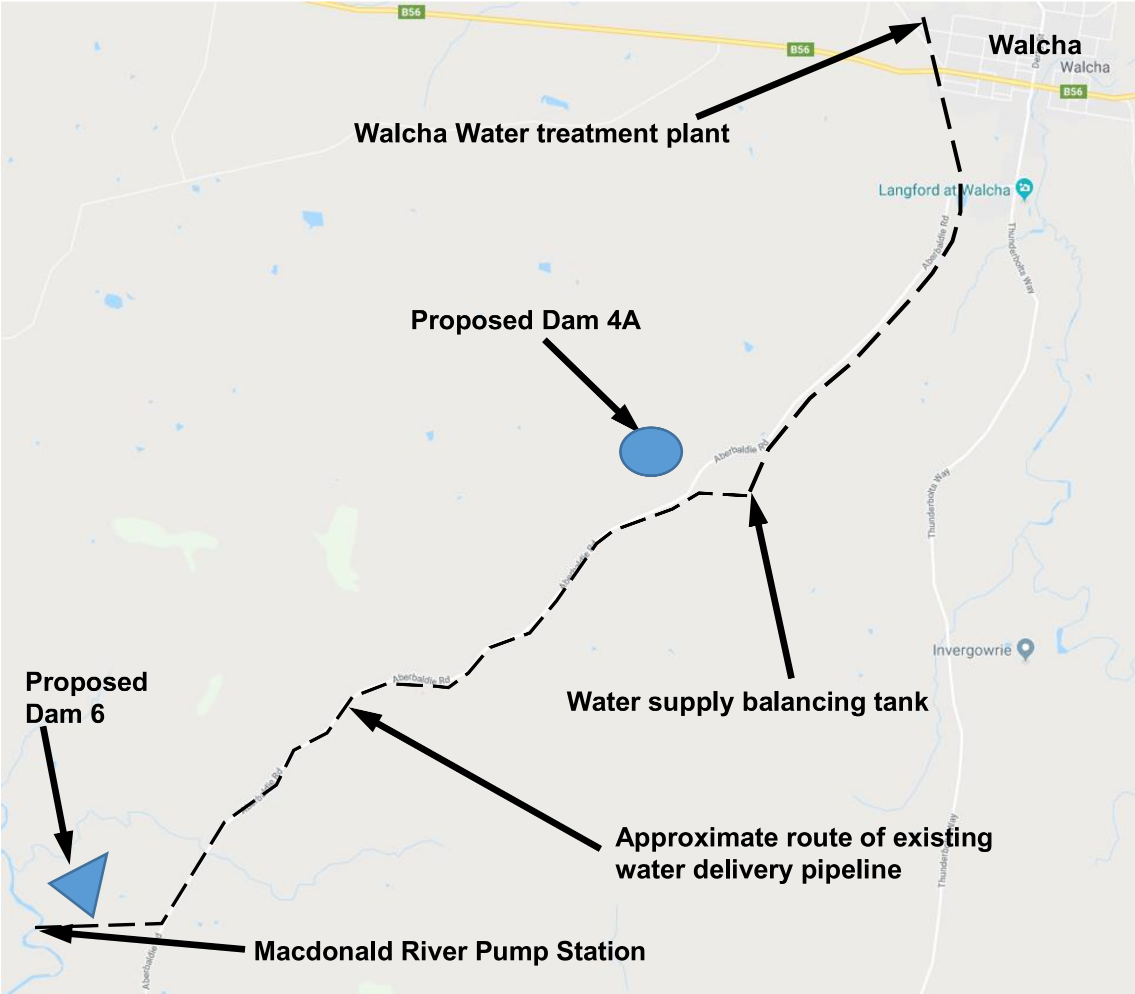


Figure 1 Location of Dam Sites

1.5 Scope and limitations

This report: has been prepared by GHD for Walcha Council and may only be used and relied on by Walcha Council for the purpose agreed between GHD and the Walcha Council as set out in section 1.3 of this report.

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

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

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

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer to Section 1.6 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Walcha Council and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information or incorrect assumptions made based on such reports.

The opinions, conclusions and recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the a limited scope for the site investigations. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

GHD has prepared the preliminary cost estimate set out in Sections 3, 5 and 6 of this report using information reasonably available to GHD and based on assumptions and judgments made by GHD as detailed in the report.

The Cost Estimate has been prepared for the purpose of comparison and evaluation of two sites and must not be used for any other purpose, particularly not for budgeting purposes for future expenditure.

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

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

1.6 Assumptions

While this report discusses pumping systems that may be appropriate for the Dam options presented, the pipeline and pumping system to Walcha has not been addressed in any detail. For the purposes of this study, it has been assumed that the existing pump station and water transfer pipeline to Walcha will be retained.

The storage volumes adopted for this study are based on a Yield study undertaken by NSW Urban Water Services (refer to Section 2) and discussed with Walcha Council.

Appropriate water transfer systems (pumps and pipelines – refer to Section 3) have been evaluated for each dam and, for Dam 4, are based on information provided by Walcha Council.

The use of dam construction materials, principally earthfill, has been based on initial site investigations undertaken (refer to Section 4) as part of the study scope of work (as amended).

Assumptions have been made for the Dam Consequence Category for the design of the dams (refer to Section 5). Dam design assumptions will need to be confirmed for Detailed Design.

2. Hydrology review and yield analysis

In consultation with GHD, Walcha Council instructed NSW Urban Water Services to prepare a high-level comparative yield assessment for Dam 4A and Dam 6 (Yield Study). Please refer to Appendix C for a copy of the Yield Study. In order to facilitate the study, GHD provided the stage-storage characteristics (e.g. area/capacity, volume/water depth) to NSW Urban Water Services so that they could more accurately evaluate the two dam sites.

2.1 Scope of the Yield Study

The Yield Study was to be based on the following assumptions:

For Dam 4A:

- Water abstraction rate from the Macdonald River to be 2.16Ml/Day to account for limitations of the existing delivery pipeline and pump station.
- The licence cap of 379ML/a, excluding environmental flow releases was modelled.
- Demand for the town of Walcha to be gravity fed from Dam 4A.
- A capacity of 300 ML was to be modelled, with no further optimisation required.

For Dam 6:

- Water abstraction rate from the Macdonald River to be 13ML/Day, to account for increased abstraction rates possible for the low pumping head into the dam compared to Dam 4A.
- The licence cap of 379ML/a, both excluding and including environmental flow releases was modelled.
- Water supply for Walcha to be fed from the dam via the existing pump station.
- A capacity of 300 ML was to be modelled initially and thereafter the size of the storage for Dam 6 was to be further optimised.

Note:

The abstraction rate of 13ML/day was adopted for water transfers into Dam 6 based on observations listed within previous hydrology reports regarding the percentile flows.

2.2 Results of the Yield Study

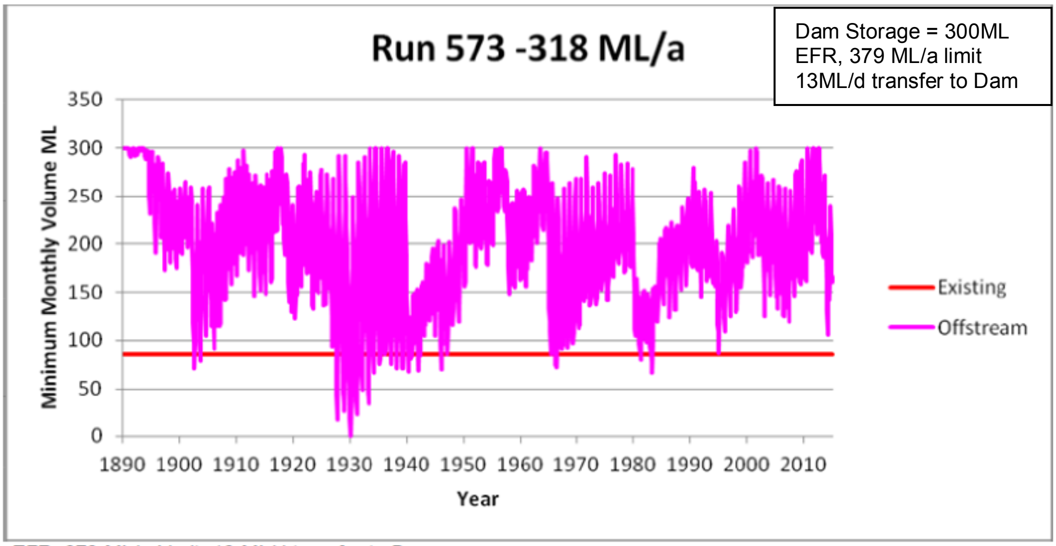
The following results arose out of the Yield Study:

1. Assuming similar climate conditions in the future compared to the period modelled (based on approximately 120 years of climatic data), the yield from the Macdonald River is expected to be close to the target yield of 300ML/a with an additional storage dam of between 200 ML to 300 ML.
2. The yield from a 200 ML size for Dam 6 was not significantly less than that obtained from a 300 ML dam size. Both the 200ML dam and 300ML Dam 6 failed (reached empty) during one year of the modelling run of approximately 120 years. However, the amount of water delivered during the year of failure would have been greater with the 300ML Dam (approx. 250ML versus 200ML).
3. The 300 ML Dam 4A failed in the same year of that Dam 6 failed for the 300 ML (and 200ML) dam options. However, the amount of water delivered from Dam 4A during this year appears to be slightly less than that delivered from Dam 6 (approx. 175ML and 250ML respectively).

4. Reducing the rate of transfer into Dam 6 from 13ML/a to 7.5ML/a results in a very similar yield over the period modelled.
5. On account of the fact that the dam fails at least once during the 120 year period of modelling, there appears to be little difference in yield whether the runs are started with a full dam (as is the case for the modelling undertaken) or empty. In addition, the dams reach full capacity over a number of years, which indicates that there are some years that water transfers were curtailed to a lower rate.

The following figures have been extracted from the Yield Study and provide the basis for the above summary. The Figure numbers are as given in the Yield Study.

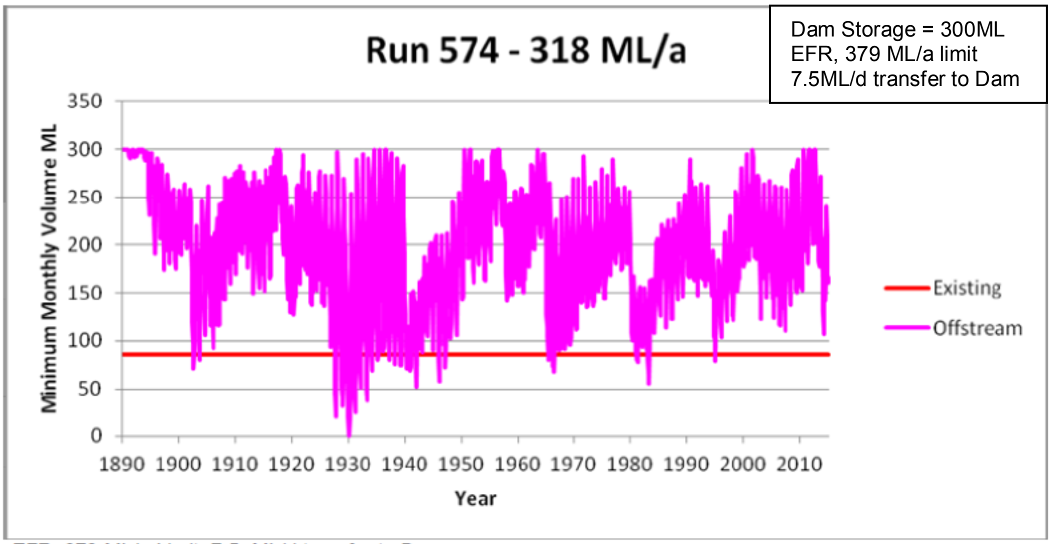
Figure 1 : Site 6 Run 573 Storage Behaviour Diagrams



EFR, 379 ML/a Limit, 13 ML/d transfer to Dam

Figure 2 Figure 1 from the Yield Study – Dam 6

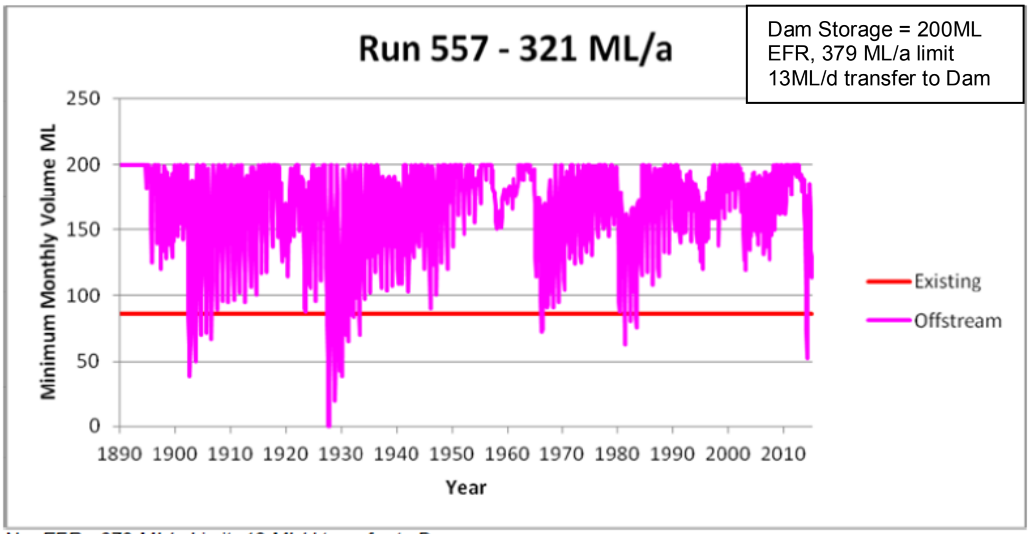
Figure 2: Site 6 Run 574 Storage Behaviour Diagrams



EFR, 379 ML/a Limit, 7.5 ML/d transfer to Dam

Figure 3 Figure 2 from the Yield Study – Dam 6

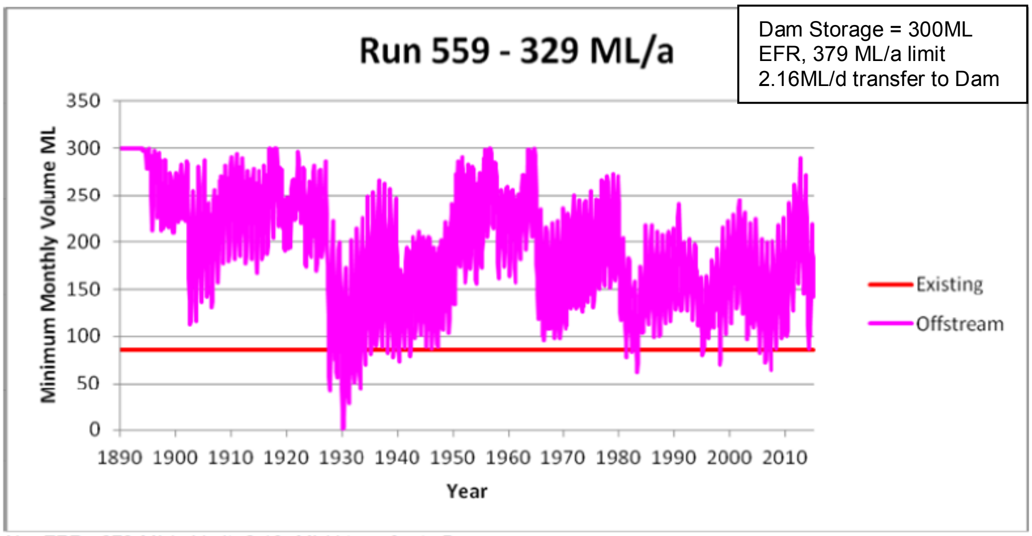
Figure 4 : Site 6 (200 ML) Run 557 Storage Behaviour Diagrams



No EFR, 379 ML/a Limit, 13 ML/d transfer to Dam

Figure 4 Figure 4 from the Yield Study – Dam 6

Figure 6 : Site 4 Run 559 Storage Behaviour Diagrams



No EFR, 379 ML/a Limit, 2.16 ML/d transfer to Dam

Figure 5 Figure 4 from the Yield Study – Dam 4A

The hydrology report from which the above figures have been extracted is included in Appendix C.

3. Pumping system

Indicative conceptual design and costing for two potential pumping systems for storage of water sourced from the Macdonald River to supplement the Walcha water supply are presented in this section.

3.1 Pumping from Macdonald River to Dam 6

The facility involves pumping water at a rate of 13 ML/d (150 L/s) from Macdonald River to the expanded Dam 6 during high water availability in the Macdonald River. The pumping system consists of a new 75 kW vertical turbine pump mounted on the exiting river side pontoon structure and a DN 300 PVC pipeline about 650 m in length from the river to the shore of the proposed expanded dam. An alternative arrangement would be to lay a pipe on the bank of the river into which a submersible borehole pump is placed. This arrangement would be able to safely accommodate fluctuating river water levels. Consideration could also be given to constructing a dry (or wet) well, similar to that for the existing pump station, within the river bank and placing the pump in the well. A pump station building could be placed above the well. Such an arrangement can be expected to increase the cost of the proposed installation by approximately $250,000.

The pipeline discharge into the dam is to be laid below the operating water level to allow water return to the river side pump station by gravity flow. A diversion bypass and valve arrangement is required on the suction intake of the existing town water supply pumps. This allows water to be drawn from Dam 6 instead of the river flow, as required.

An indicative locality is shown in Figure 6 below.

The storage pumping facility includes:

- An upgrade of the existing river structure to accommodate the new pump
- Vertical turbine pump
- Pump discharge piping with check valve and isolation valves
- Flow meter (flow rate and cumulative volume)
- Motor control centre
- Connection to existing electrical switchboard which will require upgrade to include new power terminals
- DN 300 mm x 650 m buried PVC pipeline
- Intake diversion bypass and valves on the existing town water supply pumps suction piping.

This concept design assumes that:

- The existing mainline pumps to the town water balancing tank on the ridge and the new pumping to Dam 6 are not required to operate concurrently, and therefore the existing site power supply is sufficient (the existing Capri and Ritz mainline pumps are rated at 90 kW). If concurrent pumping is required, then the power supply to the Macdonald River pumping site must be reviewed and may potentially require an upgrade and result in additional costs.
- A building or shelter for the pump is not required for security or environmental protection. The pump, motor, control centre and accessories are intended to have appropriate ingress protection rating for unsheltered installation.
- Basic pump stop/start control and protective measures are considered sufficient.

- A single duty pump is provided on the basis that limited downtime for pump maintenance and repair is acceptable, or a temporary rental pump may be used.

The concept design parameters are summarised as follows:

River water level	RL 975 m AHD
Dam discharge point level	RL 999 m AHD
Flow rate	150 L/s
Pump head	33 m (including 3 m margin)
Pump shaft power	75 kW (based on 65% efficiency)
Motor rating	90 kW or 110 kW

The indicative cost of this pumping system is $550,000 and the breakdown is as follows:

Pipeline	$335,000
Pump set and motor control centre	$40,000
River side structure upgrade	$30,000
Discharge and bypass piping, electrical and instruments	$35,000
EPCM	$110,000

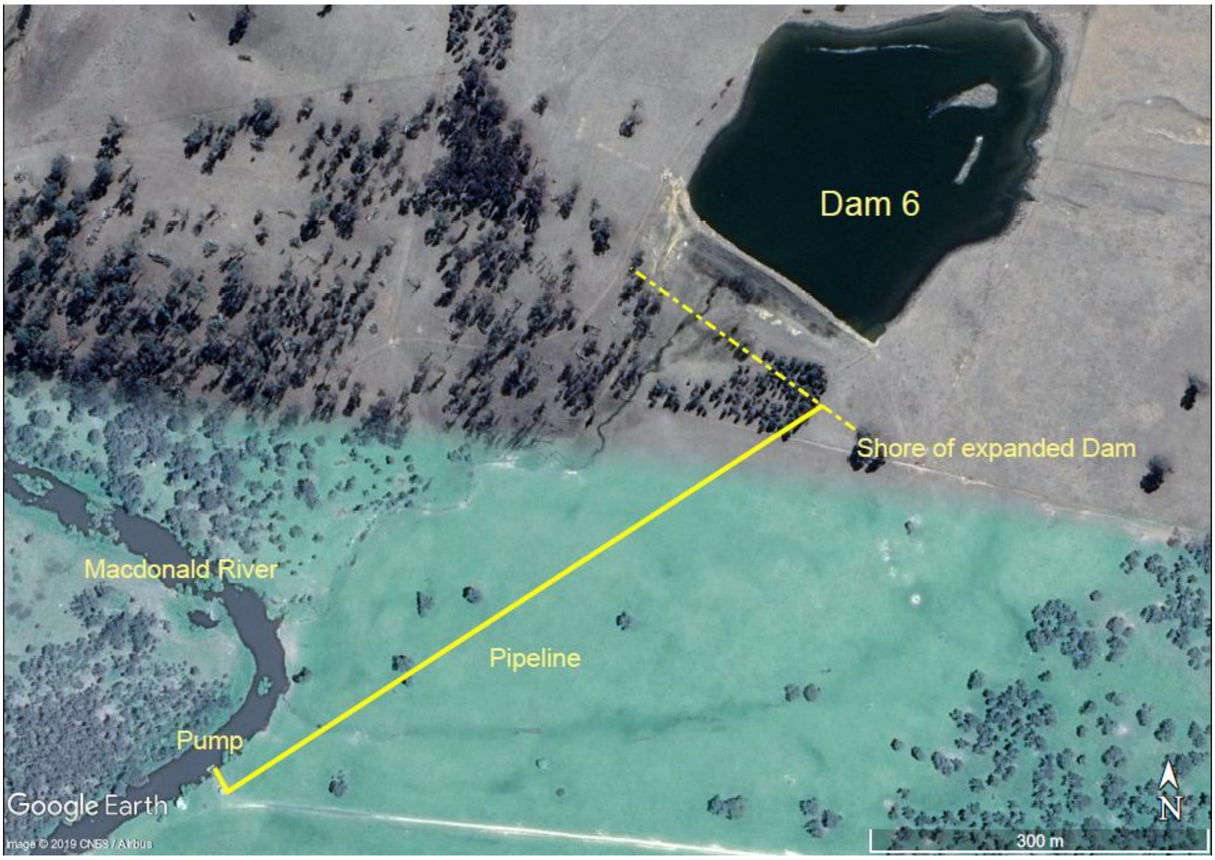


Figure 6 Locality of Pumping System from Macdonald River to Dam 6

3.2 Gravity flow from Walcha balancing tank to Dam 4A

The facility concept is based on continuous operation of the existing town water system to transfer water from the Macdonald River to the Walcha town water balancing tanks during high water availability from the Macdonald River. Water in excess of the town consumption will overflow from the tank into a new DN 150 mm PVC pipeline and flow to the proposed Dam 4A storage located approximately 450m to the west of the tank.

A 7.5 kW pump and suction bypass is required at Dam 4a to return water to the balancing tank using the same pipeline.

An indicative locality is shown in Figure 7 below.

The pipeline crosses the main highway and this may be constructed by either under-bore or open trench as approved by the Road Authority.

The overflow rate will be 2.16 ML/d (25 L/s) which is the normal pumping capacity the existing town water pumping system.

The gravity flow and return water facility will include:

- An upgrade of the existing tanks to include an overflow line and isolation valve,
- Water flow meter (flow rate and cumulative volume),
- DN 165 mm x 450 m buried PVC pipeline.
- Pump and associated bypass piping and electrical supply.

Power is required at the Dam 4A site for the return water pump and is assumed to be locally available is the cost estimate.

Power is not required at the balancing tank site. The flow meter may be battery operated or solar powered, the isolation valve will remain open and water flow control remains as per existing pump station.

The concept design parameters are summarised as follows:

Tank overflow level	RL 1193 m AHD
Pipeline discharge point level	RL 1176 m AHD
Daily overflow rate	2.16 ML less town consumption
Overflow capacity	25 L/s
Return flow rate to balancing tank	25 L/s

The indicative cost of this water transfer system is $220,000 and the breakdown is as follows:

Pipeline	$120,000
Temporary road crossing works	$20,000
Tank overflow line & flow meter	$15,000
Return water pump and piping	$15,000
Power supply and switchboard	$5,000
EPCM	$45,000

The above arrangement does not include a pump building. Should Council prefer that a pump building be provided, this would cost an additional $100,000 to $150,000 to construct.

Figure 7 Locality of Gravity Flow Pipline from Balancing Tank to Dam 4A

4. Geotechnical investigations

Geotechnical investigations, comprising test pitting and sampling for laboratory testing of soil samples were undertaken at a total of 5 sites. Two of the sites were located on the ridge (namely at Dam 4 and Dam 4A) and three sites were located near the Macdonald River (namely at Dam 8, Dam 8A and Dam 6) as shown in Figure 8 and Figure 9, respectively, below.

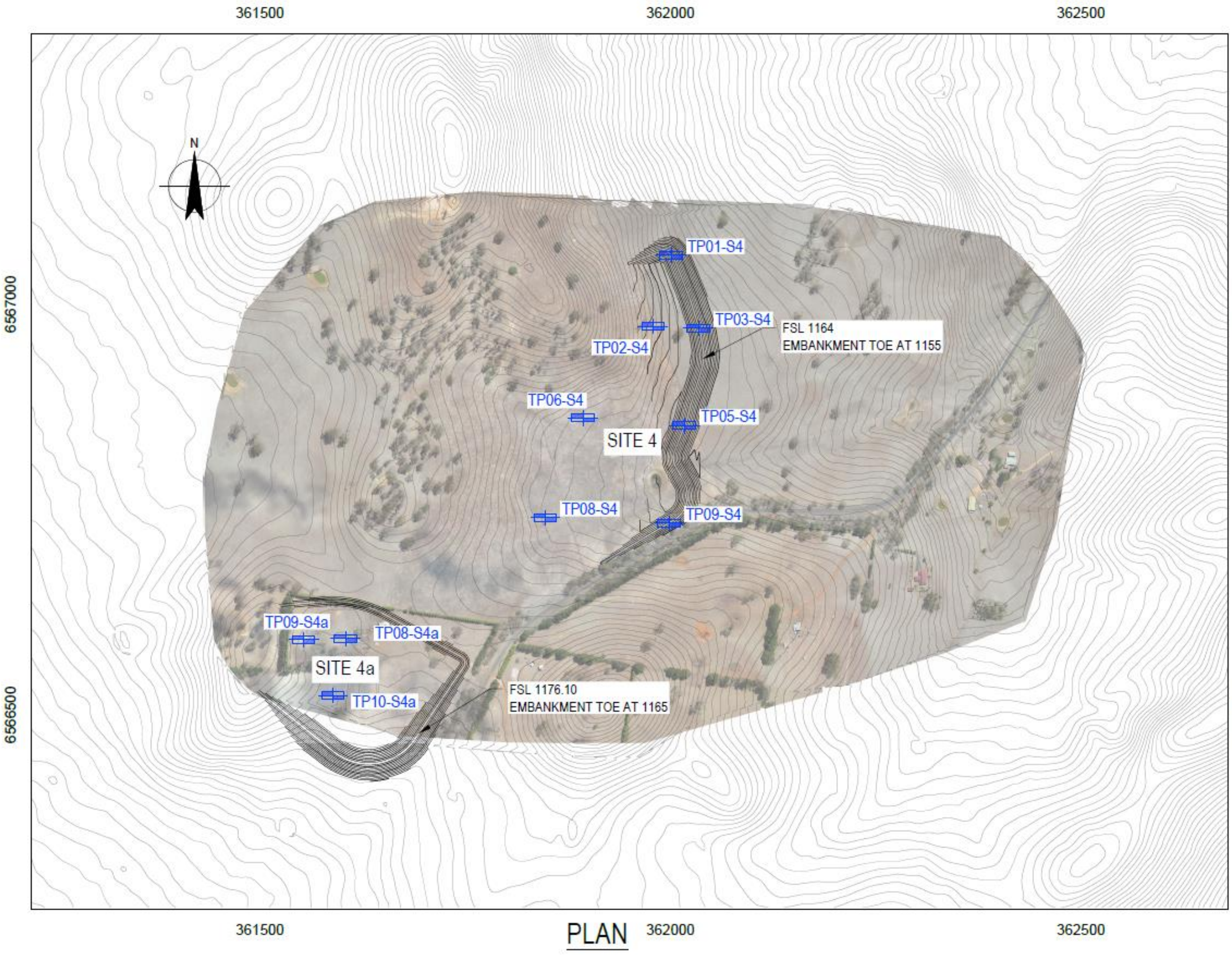


Figure 8 Test Pit Locations at Dam 4 and Dam 4A

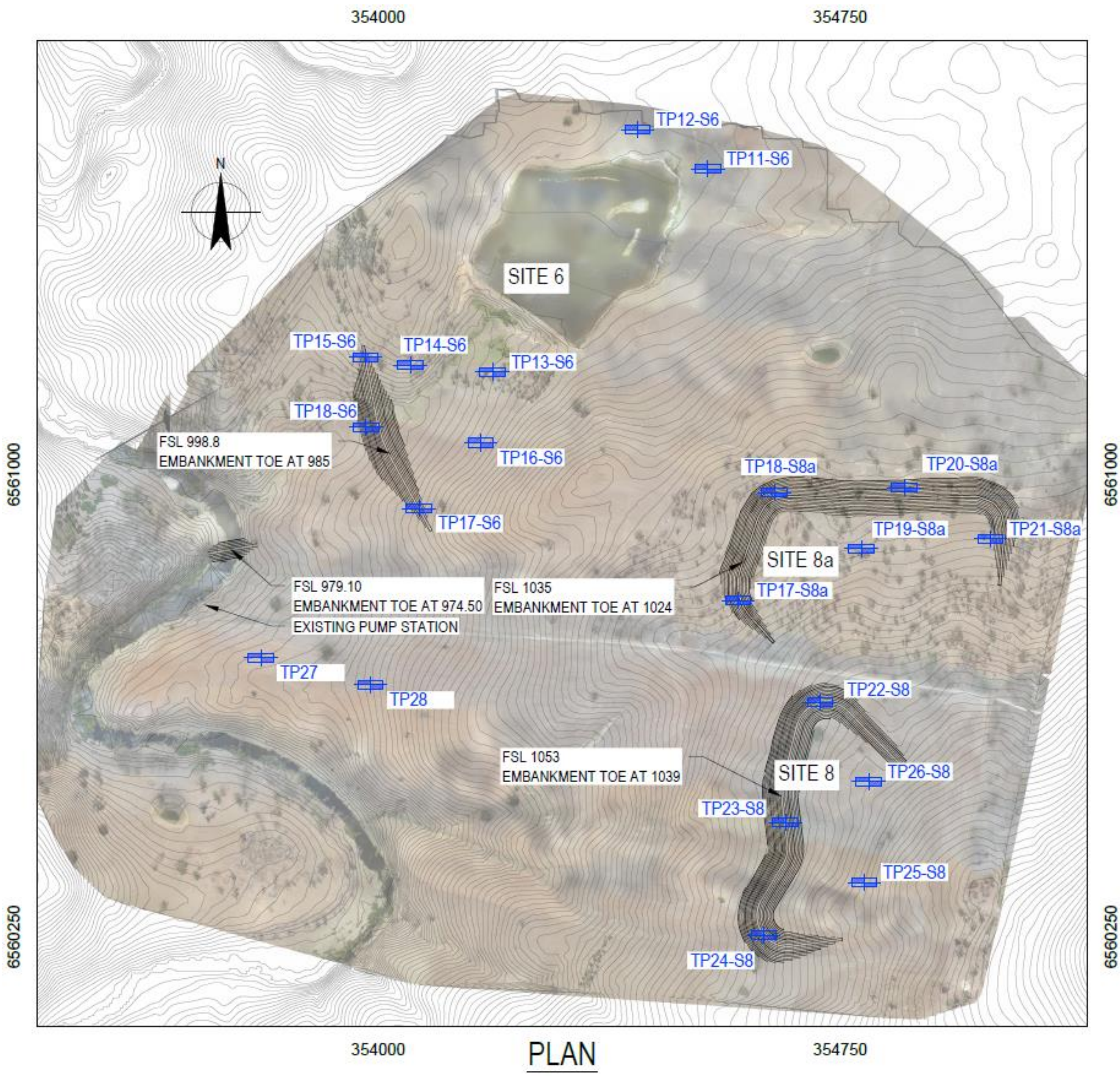


Figure 9 Test Pit Locations at Dam 6, Dam 8 and Dam 8A

4.1 Soil profiles identified

The soil profiles identified at each of the dam sites are summarised as follows:

4.1.1 Site 4

Low plasticity silty topsoil varying in depth between 0.15m to 0.4m, overlying:

- Residual soil (basalt parent rock), in TP01-S4, TP02-S4, TP03-S4 and TP09-S4, comprising medium to high plasticity clay and gravelly clay with occasional cobbles of quartz jasper at a depth of 1.0 m to 2.4 m.
- Residual soil (phyllite parent rock), in TP06-S4 and TP08-S4 comprising medium to high plasticity clay and sandy clay to depth of 1.5m to 2.6m.
- The above sequence overlies basalt (in TP01-S4, TP02-S4, TP03-S4, TP05-S4 and TP09-S4 at a depth of 1.0 m to 2.4 m) comprising extremely to moderately weathered fine grained crystalling basalt, or phyllite (in TP06-S4, TP08-S4) at a depth of 1.5 m and 2.6 m

respectively, described as thinly laminated, extremely to highly weathered and very low strength. The extremely weathered phyllite was recovered as medium plasticity clay and sandy clay.

Based on the above results, it is likely that the cut-off trench for the embankment will be founded at depths of approximately 1.0m to approximately 2.0m and that soil for use in the embankment will be found on the site. However, an evaluation has not been undertaken to confirm that a sufficient quantity of suitable construction soil material will be obtained within the storage area. As discussed in Section 4.3, there may be a need to treat the contact zone between the basalt and phyllite bedrock and/or to treat the storage area to control seepage into the foundations.

4.1.2 Site 4A

In general terms, subsurface conditions encountered in the test locations at Site 4a comprised topsoil and residual clay overlying phyllite bedrock.

- Topsoil, comprising low plasticity sandy clay to between 0.25 m to 0.3 m depth. Basalt cobbles were observed at the surface at TP10-S4a location.
- Residual soil, underlying the topsoil, comprised medium plasticity clay and gravelly clay.
- Phyllite was encountered at 0.6 m depth, comprising very low strength, thinly laminated, highly weathered phyllite with trace quartz.

The residual soil would likely be suitable for embankment construction, albeit that it will likely need to be stabilised to reduce dispersion potential, but is thin and it will be challenging to obtain sufficient material within the footprint of the dam. It is likely that suitable construction soil material for the embankment will need to be sourced from outside of the dam footprint area. The dam footprint and storage area are also likely to require treatment to reduce the risk of seepage through the foundations (refer to Section 4.3).

4.1.3 Site 6

In general terms, subsurface conditions encountered in the test locations at Site 6 comprised a topsoil and/ or residual clay profile overlying phyllite bedrock. Weathered basalt was encountered overlying the phyllite at two test pit locations in the north-eastern portion of the site.

- Topsoil, comprising low plasticity sandy silt and sandy clay, to between 0.15 m to 0.3 m depth. Basalt cobbles were observed at the surface at the location of TP11-S6.
- Residual soil (phyllite parent rock) was encountered in TP13-S6 and TP16-S6 to TP18-S6 and comprised low to high plasticity clay, sandy clay of very stiff to hard consistency.
- Residual soil (basalt parent rock) was encountered in TP11-S6 and TP12-S6 underlying the topsoil, comprising high plasticity clay of very stiff to hard consistency. An exception to the above was noted in TP11-S6 between 1.5 m and 1.9 m depth, where clayey gravel (extremely weathered basalt) was recovered towards the base of the residual soil profile.
- Phyllite was encountered at a depth of between 0.2 m and 2.6 m and comprised very low to medium strength, thinly laminated phyllite. Weathering ranged from extremely weathered to slightly weathered. Bedding appeared sub-vertical with closely spaced defects.

It is expected that a similar soil profile will be found between the existing dam embankment and the proposed Dam 6 embankment. With the exception of localised deposits of sandy material (TP13-S6) and gravel (TP11-S6), the material is likely to be suitable for embankment construction (albeit there is likely to be a need to stabilise the soil to reduce potential dispersion). However, the depth of suitable material will vary from approximately 0.4m to 1.5m and could present challenges for economical and efficient operations. However, the quantity of material required for embankment construction is not great, being of the order of 75,000 m^3. It is possible that the existing embankment could also be used as a source of construction material for the new embankment. Should the sand and gravel deposits traverse across the embankment, localised deeper excavation may be required to provide a suitable cut-off length of imported clay material. The dam footprint and storage area are also likely to require treatment to reduce the risk of seepage through the foundations (refer to Section 4.3).

4.1.4 Site 8

In general terms, subsurface conditions encountered in the test locations at Site 8 comprised topsoil and / or residual clay overlying phyllite bedrock.

- Topsoil, comprising low plasticity clay was encountered to between 0.1 m and 0.2 m depth.
- Residual soil (phyllite parent rock) was encountered in TP22-S8 and TP23-S8 beneath the topsoil. The soil comprised medium to high plasticity clay and sandy clay.
- Phyllite was encountered at depths of between 0.1 m and 0.9 m, comprising thinly laminated, predominantly moderately weathered, low to medium strength phyllite.

While the soils encountered at Dam 8 may be suitable for the construction of an embankment dam, the soil depth is thin and it is unlikely that construction material could economically be obtained from this site.

4.1.5 Site 8a

In general terms, subsurface conditions encountered in the test locations at Site 8a generally comprised topsoil and/ or residual soil and/ or overlying sandstone and siltstone strata overlying phyllite bedrock.

- Topsoil, comprising low plasticity clay, was encountered to 0.1 m to 0.2 m depth.
- Residual soil was encountered in TP17-S8a, TP20-S8a, and TP21-S8a beneath the topsoil. This comprised medium plasticity sandy clay with a honeycombed structure.
- Siltstone and sandstone was encountered in TP18-S8a beneath the topsoil. The material comprised extremely weathered, fine grained, laminated sandstone and siltstone.
- Phyllite was encountered at depths of between 0.2 m and 1.2 m. The material comprised very low to medium strength, thinly laminated to laminated, extremely to moderately weathered phyllite.

The soils encountered at this site are generally unsuitable for construction of an impervious embankment. The soil could potentially be used as shell material. However, the depth of material is insufficient for efficient quarrying operations.

4.1.6 Additional test pits

Two additional test pits (TP27 and TP8) were excavated to the south of Site 6 in an area identified as a potential borrow area. In general terms, these test pits encountered topsoil overlying residual very stiff sandy clay (encountered to 1.6 m depth in TP27 and 0.7 m depth in TP28), in turn underlain by very low to medium strength, thinly laminated to laminated, highly to moderately weathered phyllite bedrock.

Although the depth of suitable material is low, it could be considered as a potential source of construction material should insufficient material be available from within the storage area for Dam 6 (the favoured dam site).

4.2 Discussion of results of field investigations

4.2.1 Topsoil Unit 1

Topsoil should not be used for embankment construction, however it could be spread as a thin layer (100 mm thick) on the downstream surface of the embankment dams to encourage the growth of grass or other suitable erosion resisting vegetation.

4.2.2 Residual soil Unit 2

With reference to the geotechnical site investigation report (GHD, 2019), the following conclusions were identified based on laboratory testing:

- **Unit 2a**: Highly reactive clays were encountered at Dam 4 and Dam 6. These clays exhibit high linear shrinkage values and could pose challenges for embankment construction. These clays were non-dispersive. The plasticity could be reduced by treatment or stabilisation (e.g. mixing with lime)
- **Unit 2b**: Low to medium plasticity residual phyllite indicated the clay and sandy clay to be dispersive (Emerson Class 2 and 3). These clays are likely to have low shrink-swell characteristics. Due to the dispersive nature of these soils they would need to be treated by the addition of 3% gypsum by weight in order to reduce the potential for dispersion.
- **Unit 2c**: The high plasticity residual phyllite were found to be dispersive to slightly dispersive. These soils were encountered at Dam 6 and would need to be stabilised to reduce the potential for dispersion. The samples collected from Dam 8 and the potential borrow area were found to be non dispersive. Linear shrinkage rates were in the low to medium range, indicating a low shrink-swell potential.

4.2.3 Bedrock Unit 3

Unit 3a

Basalt was encountered at Dam 4 and Dam 6. Weathered basalt was recovered as gravel, sand and cobbles with a minor component of clay. Emerson class testing indicated the material to be slightly dispersive. Screening of this material may be required to remove oversize material (>75mm) that does not break down under rolling.

Unit 3b and 3c

Phyllite bedrock is present at all the sites. Samples contained a mixture of clay, silt, sand and gravel. Emerson class testing indicated the material to be dispersive (Emerson class 2 and 3). If this material were to be used as fill material, it would need to be stabilised. Where the material serves as the dam foundation, an insitu layer of material will need to be treated and stabilised with 3% gypsum by weight. It may be necessary to extend the area of foundation stabilisation upstream of the embankment to increase the seepage path length (say, to a depth of 400mm and for a distance of 10m). Alternatively, a clay blanket could be constructed upstream of the embankment, although, considering the likely shortage of construction material, it would be preferable to treat an insitu layer of material.

4.3 Foundation permeability

Based on the results of subsurface investigation, we anticipate that potential embankment dam foundations are likely to comprise phyllite (Unit 3b) in the western portion of Dam 4 and across the sites for Dam 4A, Dam 6, Dam 8 and Dam 8A. Basalt was encountered in the eastern portion of Site 4, but Phyllite may be expected below the Basalt, beyond the depth of the investigations.

Depth to bedrock varied across the investigated locations as follows:

- At Sites 4a, 8 and 8a, shallow bedrock (~1 m) was identified.
- At Site 6, shallow bedrock was identified encountered across the majority of the site, with the exception of two test locations (TP11-S6 and TP13-S6) where depth to bedrock was 1.9 m and 2.6 m respectively.
- At Site 4, a deeper clay profile was encountered, with bedrock identified at depths of between 1.0 m to 2.6 m.

Due to the defect spacing (typically 60 to 200 mm) and laminated nature of the phyllite, the speed of groundwater movement through this unit is expected to be moderate to slow. Typical hydraulic conductivity values in the range of 10^{-7} to 10^{-8} m/s may be expected.

The basalt unit was found to be highly to moderately weathered, primarily recovered as sands and gravels with slightly weathered to fresh cobbles and a minor clay component. The speed of groundwater movement through weathered basalt is expected to be moderate with typical hydraulic conductivity values in the range of 10^{-6} to 10^{-7} m/s may be expected.

As stated previously it may be necessary to treat the insitu dam embankment foundations to a depth of, say, 400mm by the addition of 3% gypsum by weight to counteract dispersion potential and seal potential joints. In addition, it may be necessary to extend the foundation treatment for some distance (say 10m to 20m) upstream of the embankment, either by insitu treatment and stabilisation or by placing a clay blanket. This would extend the seepage path and seal a portion of the foundations.

The presence of permeable foundations may be indicated at the existing embankment dam located upstream of the proposed Dam 6 embankment, where the area downstream of the dam is highly saturated.

5. Dam design and cost estimates

5.1 Feasibility study dam design

The preparatory work leading into the feasibility design stage included the following actions:

- desktop identification of potentially suitable dam sites.
- a site walkover to view the dam sites shortlisted from the above desktop exercise.
- Lidar survey of areas in which dams could potentially be located at the ridge to the west of Aberbaldie Road and near the Macdonald River pump station.

Based on the above actions, it was concluded that Dam 4A and Dam 6 should be evaluated in more detail in this feasibility study. The decision to take forward the two dam sites was principally based on the following:

- Embankment construction quantities for these two sites were less than those for the other dam sites.
- The two sites were at two separate locations that were considered to offer advantages, including:
  - low pumping head to fill Dam 6, which presented the opportunity to cost effectively provide a dedicated pumping system to fill the dam at a more rapid rate, and
  - the utilisation to the maximum extent of the pump station and delivery pipe line already existing for the present water transfer system to fill Dam 4A, albeit at a lower filling rate than would be achieved for Dam 6.

Dam 4A and Dam 6 have both been sized to store 300ML (including dead storage). This size has been chosen in consultation with Walcha Council. It is noted that the Hydrology Yield Study (refer to Section 2 of this report) provided an opinion that the yield from a 200ML Dam 6 would yield marginally less than that of the 300ML Dam 6. A comparative yield assessment was not prepared for Dam 4. The design has assumed earth embankments.

5.1.1 Design of Dam 4A

The following comments apply to the design of Dam 4A:

- It has been assumed that an embankment “turkeys nest” dam will be constructed. Sketch drawing layouts of the dam are included in Appendix A.
- For the purposes of the embankment design, an upstream slope of 3H:1 V and downstream slope of 2.5H:1V have been assumed. These slopes are expected to provide a stable structure, but would need to be confirmed during detailed design. Walcha would need to consider whether the downstream slope should be flattened for purposes of maintenance at the detailed design stage.
- A 5m wide, 0.5m deep reno mattress lined spillway has been sized, principally for overflow of excess pumped flows. The dam has no catchment apart from the surface area of the dam, so a small spillway will be required to cater for rainfall events. Nevertheless, the spillway size would need to be confirmed during detailed design.
- The dam is located on the ridge to the west of the existing balancing tank. In a dam embankment failure event, water could flow either to the north or to the south, depending upon the location of the dam embankment failure. More water could flow to the South than to the north, on account of the higher dam embankment on the south.

- A dam embankment failure to the north would place motorists travelling along Aberbaldie Road at risk near the dam, while motorists travelling on Thunderbolts Way would be placed at risk further from the dam. The water will eventually flow into the Apsley River and flow through Walcha, where it could potentially place road users or walkers at risk, while houses may be inundated depending upon the level that the floodwater would reach. It is therefore conceivable that the dam will have a consequence category of “Significant” or “High C”. This would result in more onerous dam safety and management requirements for Walcha.
- A dam embankment failure to the south would generally flow through farmland and not pass over any arterial roads before flowing into the Macdonald River. Nevertheless, some itinerants (e.g. farmers or their families) could be placed at risk, so the consequence category may bel Low or Significant for this embankment.

- At this stage, no pipework or outlet has been provided to empty the Dam, although provision has been made under Section 3 for pumped abstractions of water from Dam 4A. The dam could therefore be emptied through pumping. The need for a low level outlet should be further evaluated during detailed design.
- Based on the site investigation and materials testing program (reported under the Geotechnical Site Investigation Report, GHD, 2019) the materials could be dispersive, so an allowance has been included in the schedule for gypsum stabilisation of the embankment outer shells, the embankment foundations and a 10m wide footprint upstream of the embankments.
- Based on the findings of the site investigation, the depth of soil or highly weathered material is relatively thin (of the order of 1.0m to 1.5m), so it is unlikely that a sufficient quantity of material will be obtained from the dam storage for construction of the dam. Additional sources of suitable construction material will need to be identified during the detailed design stage.
- A chimney filter has been included in the northern embankment, which has a maximum height of approximately 10m. No chimney filter has been provided for the southern embankment, which has a maximum height of approximately 3m to 4m.
- The crest width of the embankment has been set at 4.0m. This should be sufficiently wide for a utility vehicle to travel, however, there should be little need for a utility vehicle to travel on the embankment. A gravel capping layer has been provided on the crest.

5.1.2 Design of Dam 6

The following comments apply to the design of Dam 6:

- It has been assumed that an embankment will be constructed downstream of the existing dam and that the dam storage will include the existing dam (refer to drawings in Appendix A). The existing dam embankment will be removed. The centreline of the new dam embankment has been set in order to store 300ML of water. With reference to the plan drawing SK030 included under Appendix A, it will be noted that a much narrower section exists approximately 60m upstream of the present dam embankment. Moving the dam to this location would minimise the embankment construction quantity. The location of the dam embankment should be optimised during the detailed design stage.
- For the purposes of the embankment design, an upstream slope of 3H:1 V and downstream slope of 2.5H:1V have been assumed. These slopes are expected to provide a stable structure, but would need to be confirmed during detailed design. Walcha would need to consider whether the downstream slope should be flattened for purposes of maintenance at the detailed design stage.

- A 10m wide, 0.5m deep reno mattress lined spillway has been provisionally sized, principally to accommodate excess pumped flows and stormwater runoff into the dam. The spillway size will need to be confirmed during detailed design and based on appropriate hydrological stormwater runoff modelling.
- The dam is located near the existing pump station near the Macdonald River. In a dam embankment failure event, water would flow to the south and discharge into the Macdonald River. An assessment of the risks posed by a dambreak flood will need to be made during the detailed design stage to confirm the consequence category for the dam. For the purpose of the present study, it has been assumed that the dam will be a "Low" consequence category structure. However, it is noted that the dam embankment height is marginally less than 15 m and if the dam embankment were to equal or exceed a height of 15m it would automatically become a "Significant" consequence category dam. This should be kept in mind during the detailed design stage.
- At this stage, no pipework or outlet has been provided to empty the Dam, although provision has been made under Section 3 for abstractions of water from Dam 6 to the existing Macdonald River pump station. The dam could therefore be emptied through this outlet. The need for a low level outlet should be further evaluated during detailed design.
- Based on the site investigation and materials testing program (reported under the Geotechnical Site Investigation Report, GHD, 2019) the materials could be dispersive, so an allowance has been included in the schedule for gypsum stabilisation of the embankment outer shells, the embankment foundations and a 10m wide footprint upstream of the embankments.
- Based on the findings of the site investigation, the depth of soil or highly weathered material is limited and obtaining a sufficient quantity of material for embankment construction could present some challenges. However, construction material could be obtained from the area between the existing dam and the new dam and the existing dam embankment could potentially also be utilised as a source of construction material. The site investigation also identified localised zones of permeable sandy material and gravels, which may not be suitable for construction of the dam embankment. Sources of suitable construction material in sufficient quantities will need to be identified during the detailed design stage.
- A chimney filter has been included in the embankment, which has a maximum height of just less than 13.5m.
- The crest width of the embankment has been set at 4.0m. This should be sufficiently wide for a utility vehicle to travel, however, there should be little need for a utility vehicle to travel on the embankment. A gravel capping layer has been provided on the crest.
- No fish ladder has been included in the design of the dam at this stage. The need for a fish ladder will need to be further evaluated during the detailed design stage.

5.2 Cost estimates

Indicative cost estimates have been prepared for Dam 4A and Dam 6 and are included in Appendix B. It should be noted that the cost estimates have been prepared for comparative purposes only, and **cannot be relied on as providing an accurate cost for budgeting purposes for the construction of either dam**. The schedule of quantities upon which the cost estimates have been based on major quantities that have been obtained from the concept design layouts prepared for this Feasibility Study and which are included in Appendix A

The comparative cost estimates are summarised in Table 1 below:

Table 1 Comparative Cost Estimates for Dam Construction

Cost Item	Cost Dam 4A	Cost Dam 6
Embankment and Land Acquisition Cost (including contingency, contractors costs, design fees and Walcha Costs)	**$9,005,000**	**$6,555,000**

6. Cost estimate summary

6.1 Summary of capital costs

A summary of the comparative capital cost estimates is given in Table 2 below.

Table 2 Indicative Comparative Cost Estimates Water Storage Infrastructure

Cost Item	Cost Dam 4A	Cost Dam 6
Embankment and Land Acquisition Cost (including contingency, contractors costs, design fees and Walcha Costs – refer to Section 5)	$9,005,000	$6,555,000
Pump Station, pumps and pipeline (refer to Section 3)	$220,000	$550,000
Allowance for pump buildings (if required)	$100,000	$250,000
Total comparative cost ( )	**$9,325,000**	**$7,355,000**

Note: The cost estimates presented in Table 2 above have been prepared for comparative purposes only, and **cannot be relied on as providing an accurate cost for budgeting purposes for the construction of either dam**. More detailed design is required to determine the likely construction costs more accurately.

6.2 Annual operation and maintenance costs

Table 3 below provides the comparative cost estimates of the annual operating, maintenance and depreciation costs for the two water storage options.

Table 3 Indicative Operation, Maintenance and Depreciation Costs

		Dam 4A			Dam 6		
Item	Description	Base Cost	Rate	Annual Cost	Base Cost	Rate	Annual Cost
1	O&M for Dams	$9,005,000	0.50%	$45,025	$6,555,000	0.50%	$32,775
2	O&M for pumps and electrical	$220,000	2.50%	$5,500	$550,000	2.50%	$13,750
3	Depreciation for Dams	$9,005,000	1.00%	$90,050	$6,555,000	1.00%	$65,550
4	Depreciation for pumps, electrical	$220,000	4.00%	$8,800	$550,000	4.00%	$22,000
	Total annual cost			**$149,375**			**$134,075**

Note: for Table 3 above:

- The above costs are based on the indicative, high-level construction cost estimates prepared for the components associated with each Dam. Additional design effort will be required to establish construction costs for the Dams and associated project components to provide a greater degree of confidence in the actual development costs for the project.
- Personnel Costs are not included as existing personnel will operate and maintain the new works.
- Electricity running costs are not expected to be significantly different for the two Dams and will depend on actual volumes of water transferred to or from each Dam.

7. Conclusions

Based on the results of the feasibility study presented in the foregoing sections, Dam 6 presents the following advantages over Dam 4A:

1. Based on the high-level comparative cost estimates, the capital cost for Dam 6 is of the order of 20% to 25% lower than that for Dam 4A.
2. Based on the high-level comparative cost estimates, the ongoing operational costs (excluding personnel and electricity costs) for Dam 6 is of the order of 15% to 20% lower than that for Dam 4A.
3. The location and associated embankment material quantities can be optimised for Dam 6, particularly if the dam location is moved upstream by approximately 60m. Moving of the dam centreline may be constrained by the need to achieve 300ML storage capacity or saddle embankments may potentially be required.
4. The rate of transfer of water to Dam 6 can be achieved at a faster rate on account that additional pumping infrastructure can be provided relatively cost effectively, since Dam 6 is located close to the Macdonald River. This could potentially provide a slightly improved security of water transfer and storage compared to Dam 4A.
5. Dam 4A is located a significant distance from the Macdonald River and the provision of dedicated pumping equipment will cost a significantly more than the comparative costs developed in this report.
6. It is understood that the landowners may be amenable to the location of Dam 6 on their property on account that a dam already exists within the footprint of the proposed Dam 6 storage area.
7. It is likely that Dam 6 will be associated with less risk to society should the dam embankment fail. Dam 6 is therefore likely to have a lower consequence category than Dam 4A, which will result in lower dam safety monitoring and compliance costs.
8. Both Dam 6 and Dam 4A failed once over a 120 year modelling period in the Yield Study. However, Dam 6 delivered 250 ML and Dam 4A delivered 175 ML as modelled in that particular year.

Appendices

Appendix A - Drawings

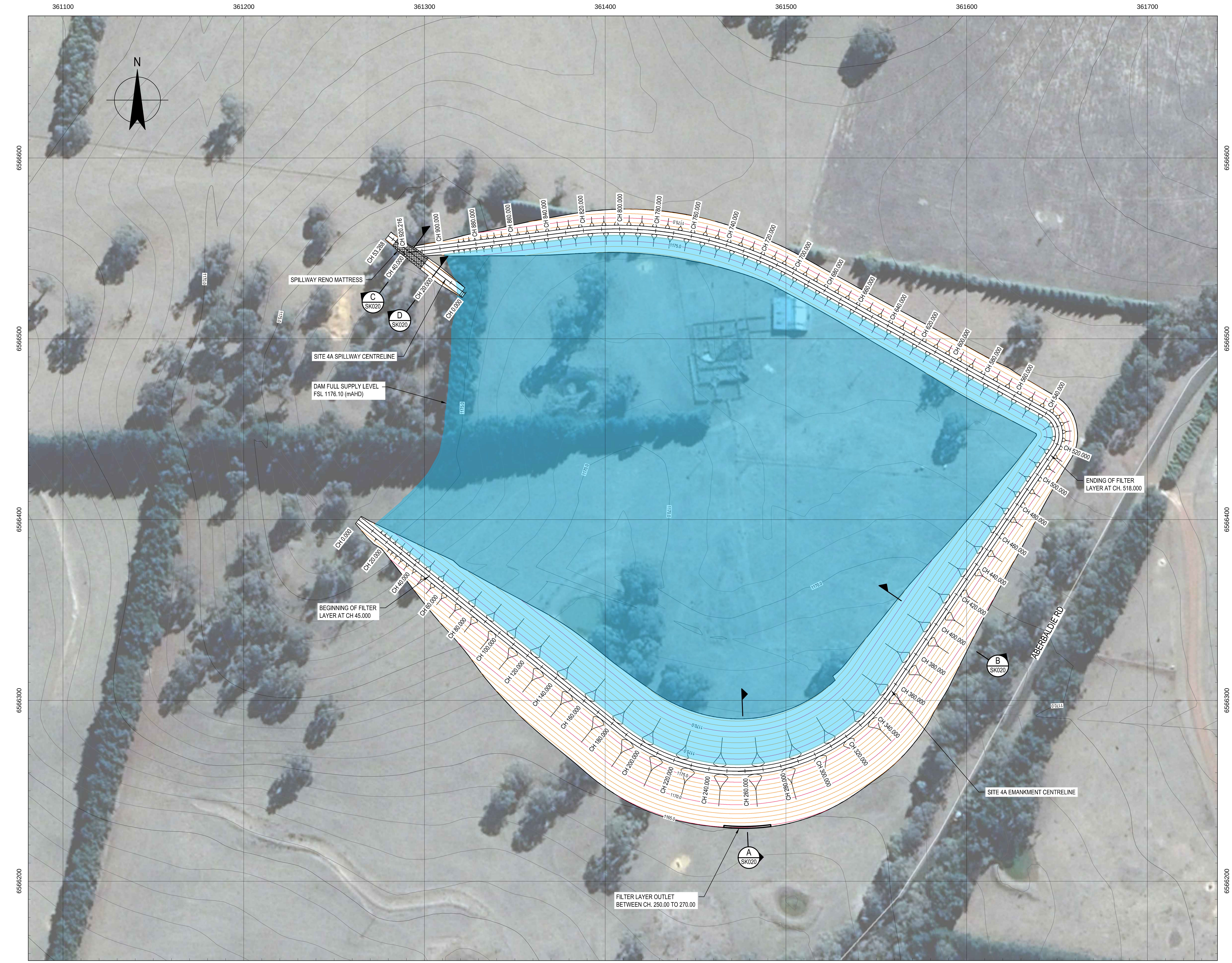


IMAGE SOURCE GOOGLE EARTH 2018

PLAN

SCALE 1 : 1000

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. COORDINATES ARE IN METRES AND TO MAP GRID94 OF AUSTRALIA (MGA56).
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LEGEND:

- PROPOSED CENTRELINE/CONTROL LINE
- PROPOSED CONTOURS @ 0.5m INTERVALS
- EXISTING CONTOURS @ 0.5m INTERVALS
- BASIN FULL SUPPLY LEVEL FSL

0 10 20 30 40 50m

SCALE 1:1000 AT ORIGINAL SIZE

CONCEPT

rev	description	app'd	date
A	ISSUED FOR CONCEPT DESIGN	BB	08.07.19

WALCHA COUNCIL
MACDONALD RIVER FEASIBILITY STUDY

SITE 4A
LAYOUT PLAN

Level 2, 29 Christie Street St Leonards NSW 2065 Australia
Locked Bag 2727 St Leonards NSW 1590
T 61 2 9462 4700 **E** slnmail@ghd.com **W** www.ghd.com

scale	1:1000 for A1	job no.	22-19901
date	JULY 2019	rev no.	A

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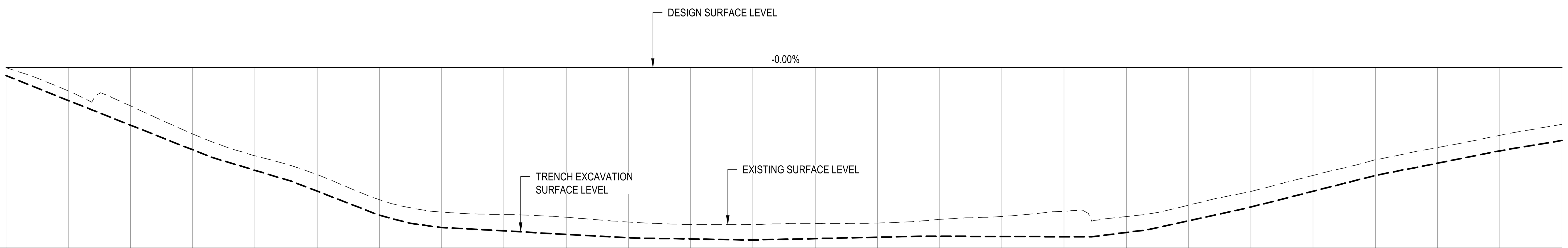
- EXISTING SURFACE LEVEL (light dashed line)



DATUM 1165.000

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20.000	1.478	1176.596	1176.596	1175.118
40.000	2.450	1176.596	1176.596	1174.146
60.000	4.261	1176.596	1176.596	1172.336
80.000	5.657	1176.596	1176.596	1170.940
100.000	6.876	1176.596	1176.596	1169.720
120.000	8.483	1176.596	1176.596	1168.113
140.000	9.278	1176.596	1176.596	1167.319
160.000	9.436	1176.597	1176.597	1167.161
180.000	9.613	1176.597	1176.597	1166.983
200.000	9.921	1176.597	1176.597	1166.676
220.000	10.077	1176.597	1176.597	1166.520
240.000	10.072	1176.597	1176.597	1166.525
260.000	10.008	1176.597	1176.597	1166.589
280.000	9.985	1176.597	1176.597	1166.612
300.000	9.751	1176.597	1176.597	1166.846
320.000	9.566	1176.597	1176.597	1167.030
340.000	9.229	1176.597	1176.597	1167.368
360.000	9.570	1176.597	1176.597	1167.027
380.000	8.835	1176.597	1176.597	1167.762
400.000	7.958	1176.597	1176.597	1168.639
420.000	6.923	1176.597	1176.597	1169.674
440.000	5.924	1176.597	1176.597	1170.673
460.000	5.136	1176.597	1176.597	1171.461
480.000	4.341	1176.597	1176.597	1172.256
500.000	3.632	1176.597	1176.597	1172.965

LONGITUDINAL SECTION - SITE 4A EMBANKMENT CENTRELINE

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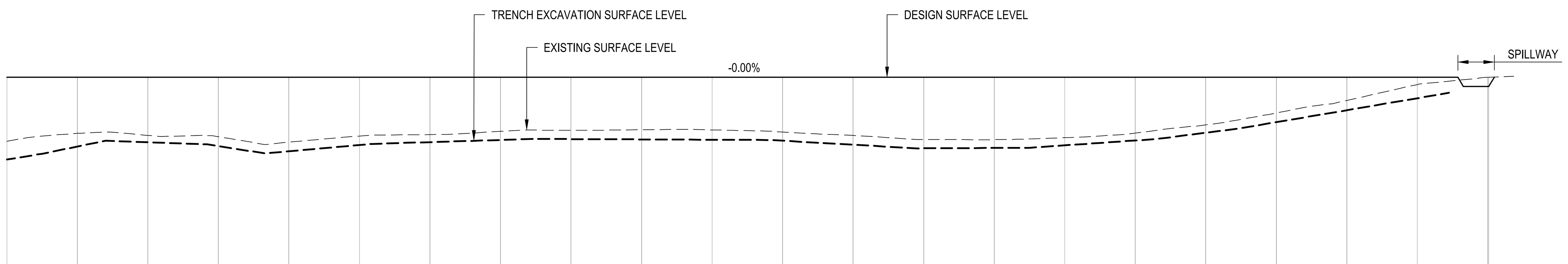

DATUM 1165.000

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520.000	3.185	1176.597	1176.597	1173.412
540.000	3.298	1176.598	1176.598	1173.299
560.000	3.374	1176.598	1176.598	1173.224
580.000	3.682	1176.598	1176.598	1172.915
600.000	3.334	1176.598	1176.598	1173.263
620.000	3.255	1176.598	1176.598	1173.343
640.000	3.070	1176.598	1176.598	1173.527
660.000	3.018	1176.598	1176.598	1173.580
680.000	2.979	1176.598	1176.598	1173.619
700.000	2.988	1176.598	1176.598	1173.610
720.000	3.105	1176.598	1176.598	1173.493
740.000	3.299	1176.598	1176.598	1173.299
760.000	3.539	1176.598	1176.598	1173.059
780.000	3.542	1176.598	1176.598	1173.056
800.000	3.436	1176.598	1176.598	1173.162
820.000	3.170	1176.598	1176.598	1173.429
840.000	2.702	1176.598	1176.598	1173.896
860.000	2.024	1176.598	1176.598	1174.575
880.000	1.316	1176.598	1176.598	1175.282
900.000	0.418	1176.598	1176.598	1176.181
920.000	-0.523	1176.074	1176.074	1176.597
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LONGITUDINAL SECTION - SITE 4A EMBANKMENT CENTRELINE

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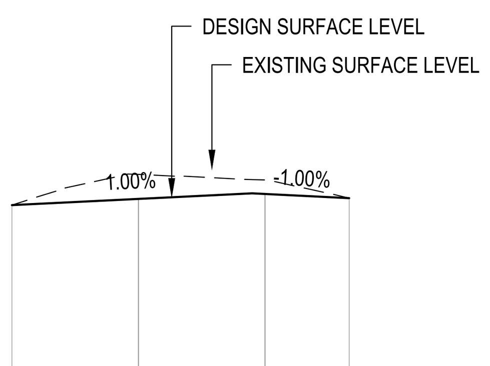

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40.000	-0.431	1176.080	1176.511
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LONGITUDINAL SECTION - SPILLWAY CENTRELINE

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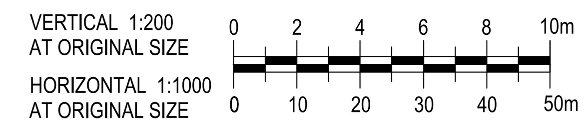

CONCEPT

rev	description	app'd	date
A	ISSUED FOR CONCEPT DESIGN	BB	08.07.19

WALCHA COUNCIL
MACDONALD RIVER FEASIBILITY STUDY

SITE 4A
LONGITUDINAL SECTIONS

GHD
Level 2, 29 Christie Street St Leonards NSW 2065 Australia
Locked Bag 2727 St Leonards NSW 1590
T 61 2 9462 4700 E slnmail@ghd.com W www.ghd.com

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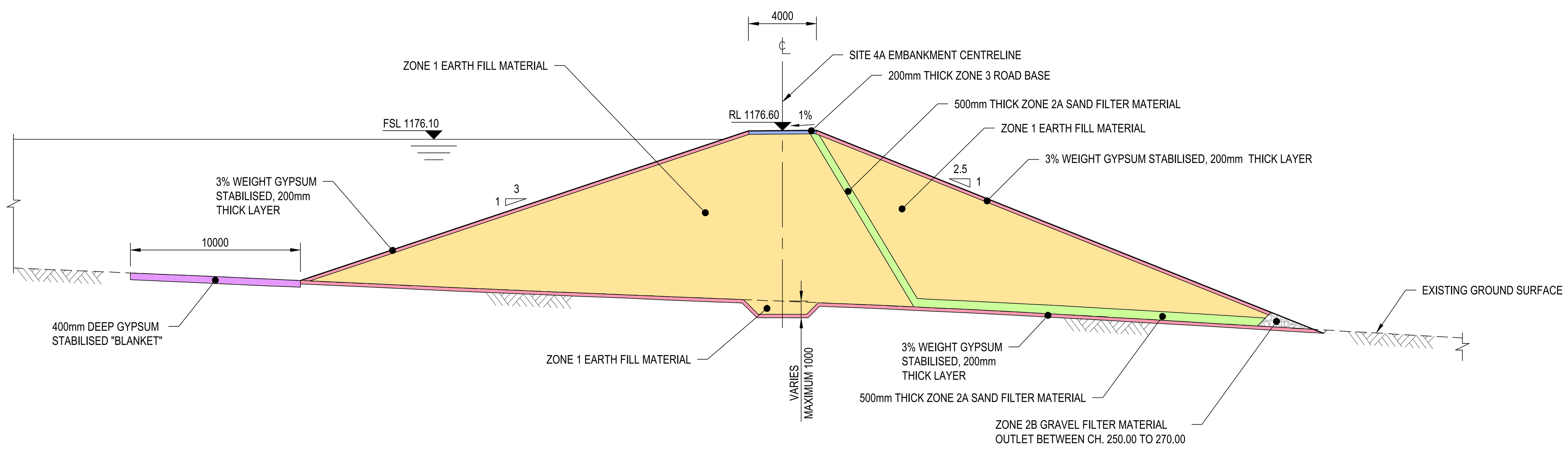
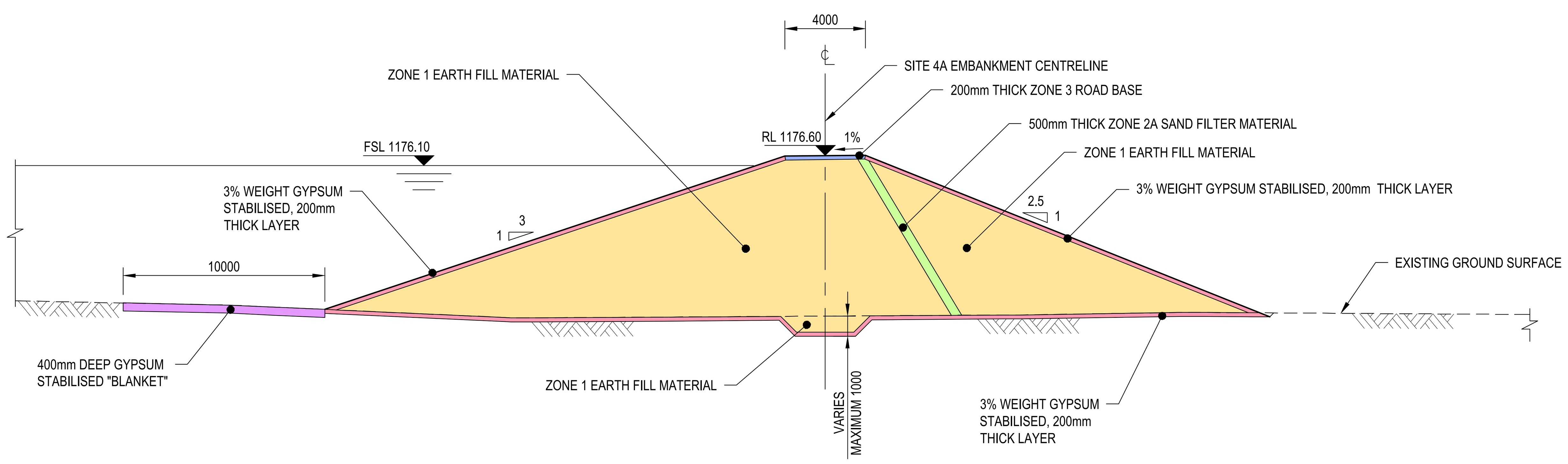


A SECTION THROUGH EMBANKMENT FILTER OUTLET
SK010 SCALE 1 : 200

LEGEND:

- PROPOSED CENTRELINE
- DESIGN SURFACE LEVEL
- EXISTING SURFACE LEVEL
- ZONE 1 EARTH FILL MATERIAL
- ZONE 2A FINE FILTER MATERIAL
- ZONE 3 ROAD BASE
- ZONE 2B GRAVEL FILTER MATERIAL
- ZONE 4 RIPRAP 500mm THICK
- 400mm DEEP GYPSUM STABILISED "BLANKET"
- 3% WEIGHT GYPSUM STABILISED, 200mm THICK LAYER



B SECTION THROUGH EMBANKMENT
SK010 SCALE 1 : 200

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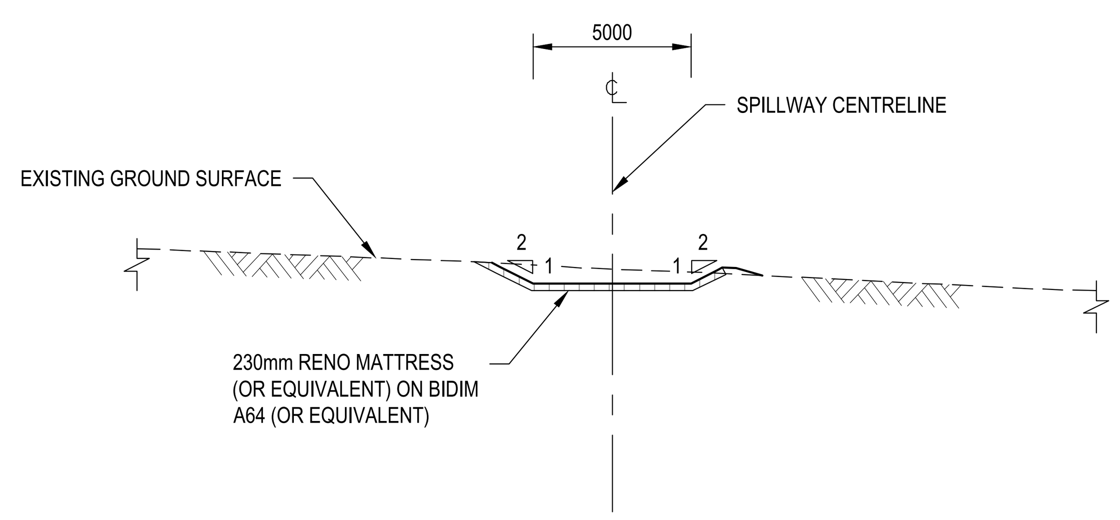
SCALE 1:200 AT ORIGINAL SIZE



C SECTION THROUGH SPILLWAY
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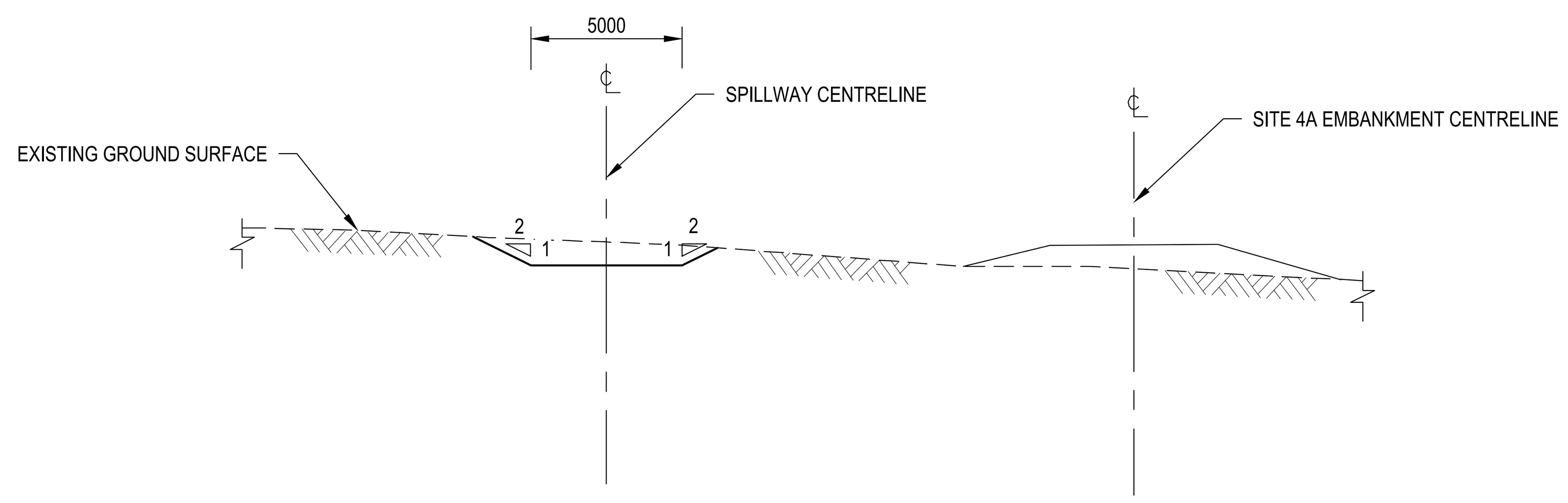

D SECTION THROUGH SPILLWAY
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CONCEPT

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WALCHA COUNCIL
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SITE 4A
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Locked Bag 2727 St Leonards NSW 1590
T 61 2 9462 4700 E slnmail@ghd.com W www.ghd.com

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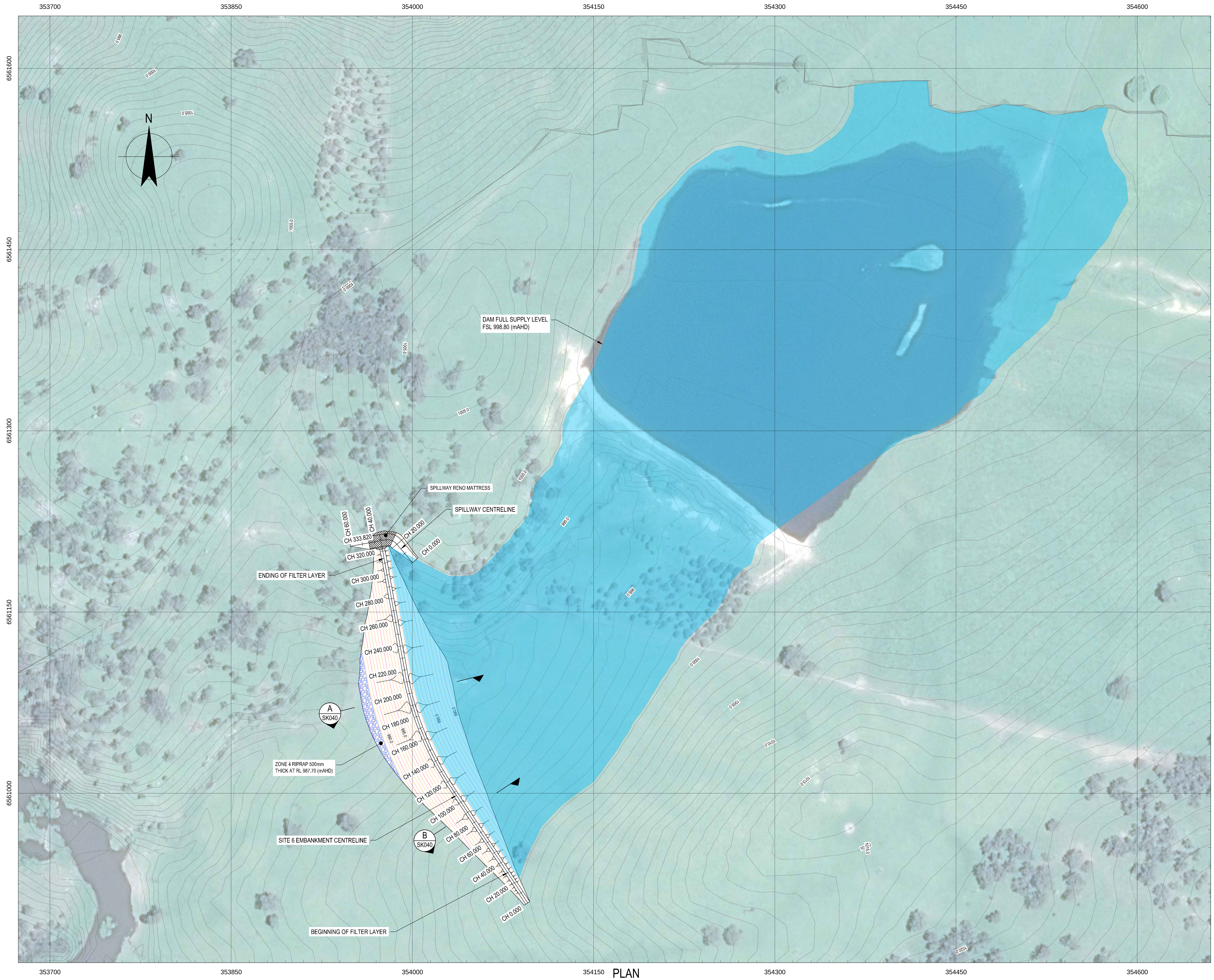
date JULY 2019 rev no. A

approved (PD) SK020



PLAN
SCALE 1 : 1500

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. COORDINATES ARE IN METRES AND TO MAP GRID94 OF AUSTRALIA (MGA56).
3. LEVELS ARE IN METRES RELATED TO AUSTRALIAN HEIGHT DATUM (mAHD).
4. DESIGN BASED ON SURVEY SUPPLIED BY WALCHA COUNCIL AND CARRIED OUT BY CALCO SURVEYORS Pty Ltd.
5. ALL INFORMATION IS INDICATIVE AND SHALL BE VERIFIED DURING THE DETAILED DESIGN STAGE.

LEGEND:

PROPOSED CENTRELINE/CONTROL LINE
PROPOSED CONTOURS @ 0.5m INTERVALS
EXISTING CONTOURS @ 0.5m INTERVALS
BASIN FULL SUPPLY LEVEL FSL

0 15 30 45 60 75m
SCALE 1:1500 AT ORIGINAL SIZE

CONCEPT

rev	description	app'd	date
A	ISSUED FOR CONCEPT DESIGN	BB	08.07.19

WALCHA COUNCIL
MACDONALD RIVER FEASIBILITY STUDY

SITE 6
LAYOUT PLAN

GHD
Level 2, 29 Christie Street St Leonards NSW 2065 Australia
Locked Bag 2727 St Leonards NSW 1590
T 61 2 9462 4700 E slnmail@ghd.com W www.ghd.com

scale 1 : 1500 for A1 job no. 22-19901
date JULY 2019 rev no. A

approved (PD) SK030

Plot Date: 8 July 2019 - 10:28 AM Plotted by: Mohammad Gharib Cad File No: \\ghdnet\ghd\AU\Newcastle\Projects\22\19901\CADD\Drawings\Sketches\22-19901-SK030.dwg

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. LEVELS ARE IN METRES RELATED TO AUSTRALIAN HEIGHT DATUM (mAHD).
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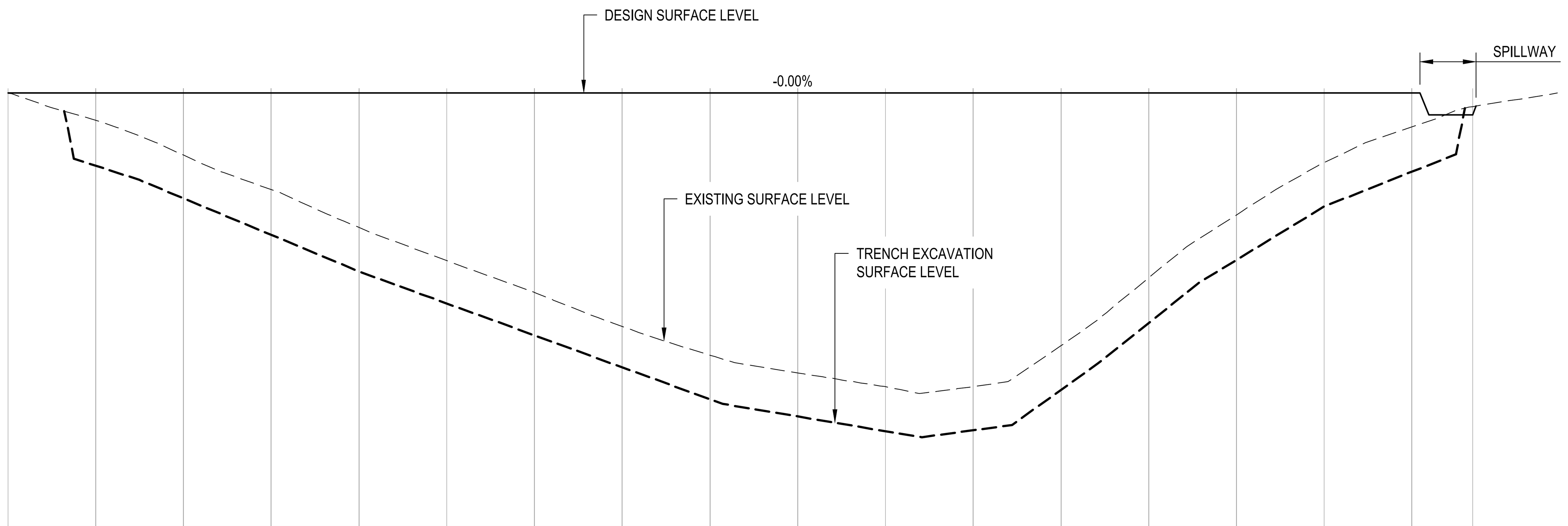
4. ALL INFORMATION IS INDICATIVE AND SHALL BE VERIFIED DURING THE DETAILED DESIGN STAGE.



DATUM 980.000

LEVEL DIFFERENCE CUT - / FILL +	0.011	1.245	2.831	4.399	6.134	7.639	9.093	10.641	11.952	12.763	13.390	13.383	11.527	8.424	5.553	3.170	1.544	-0.381
DESIGN SURFACE LEVEL	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	999.800	998.800
TRENCH EXCAVATION SURFACE LEVEL		996.487	995.002	993.334	991.666	990.209	988.753	987.297	985.840	985.055	984.385	984.425	986.264	989.319	992.195	994.629	996.213	
EXISTING SURFACE LEVEL	999.789	998.555	996.969	995.401	993.666	992.161	990.707	989.159	987.848	987.037	986.410	986.417	988.273	991.375	994.247	996.629	998.256	999.181
CHAINAGE	0.000	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000	320.000	333.820

LONGITUDINAL SECTION - SITE 6 EMBANKMENT CENTRELINE

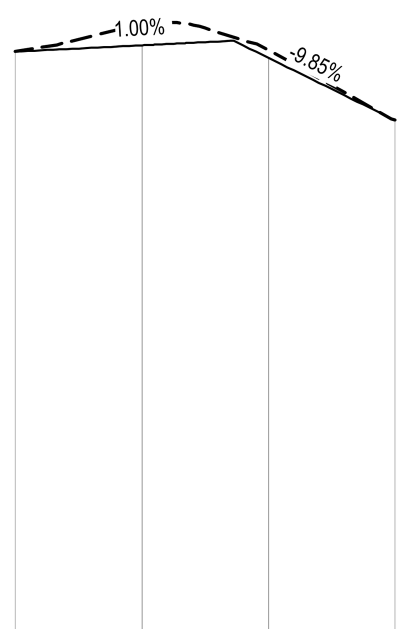
SCALE: H 1:1000 V 1:200

LEGEND:

DESIGN SURFACE LEVEL

EXCAVATION SURFACE LEVEL

EXISTING SURFACE LEVEL



DATUM 980.000

LEVEL DIFFERENCE CUT - / FILL +	0.000	-0.647	-0.247	0.000
DESIGN SURFACE LEVEL	998.455	998.655	998.257	996.287
EXISTING SURFACE LEVEL	998.455	998.655	998.257	996.287
CHAINAGE	0.000	20.000	40.000	60.000

LONGITUDINAL SECTION - SITE 6 SPILLWAY CENTRELINE

SCALE: H 1:1000 V 1:200

VERTICAL 1:200 AT ORIGINAL SIZE 0 2 4 6 8 10m

HORIZONTAL 1:1000 AT ORIGINAL SIZE 0 10 20 30 40 50m

CONCEPT

rev	description	app'd	date
A	ISSUED FOR CONCEPT DESIGN	BB	08.07.19

WALCHA COUNCIL

MACDONALD RIVER FEASIBILITY STUDY

SITE 6
LONGITUDINAL SECTIONS

GHD

Level 2, 29 Christie Street St Leonards NSW 2065 Australia
Locked Bag 2727 St Leonards NSW 1590
T 61 2 9462 4700 E slnmail@ghd.com W www.ghd.com

scale	AS SHOWN for A1	job no.	22-19901
date	JULY 2019	rev no.	A

approved (PD) SK035

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED.
2. LEVELS ARE IN METRES RELATED TO AUSTRALIAN HEIGHT DATUM (mAHD).
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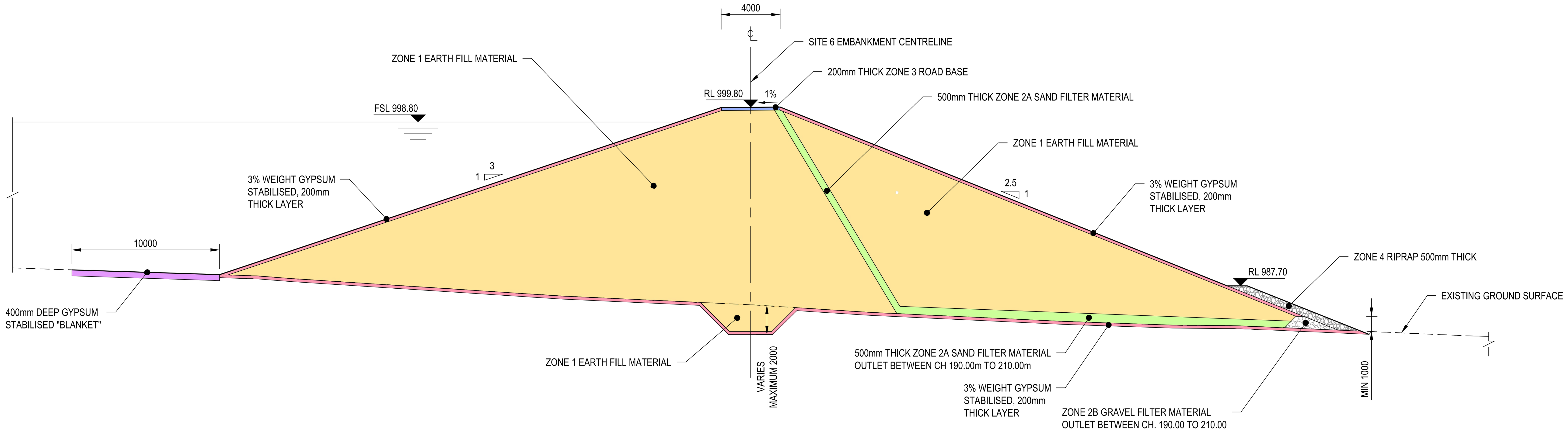
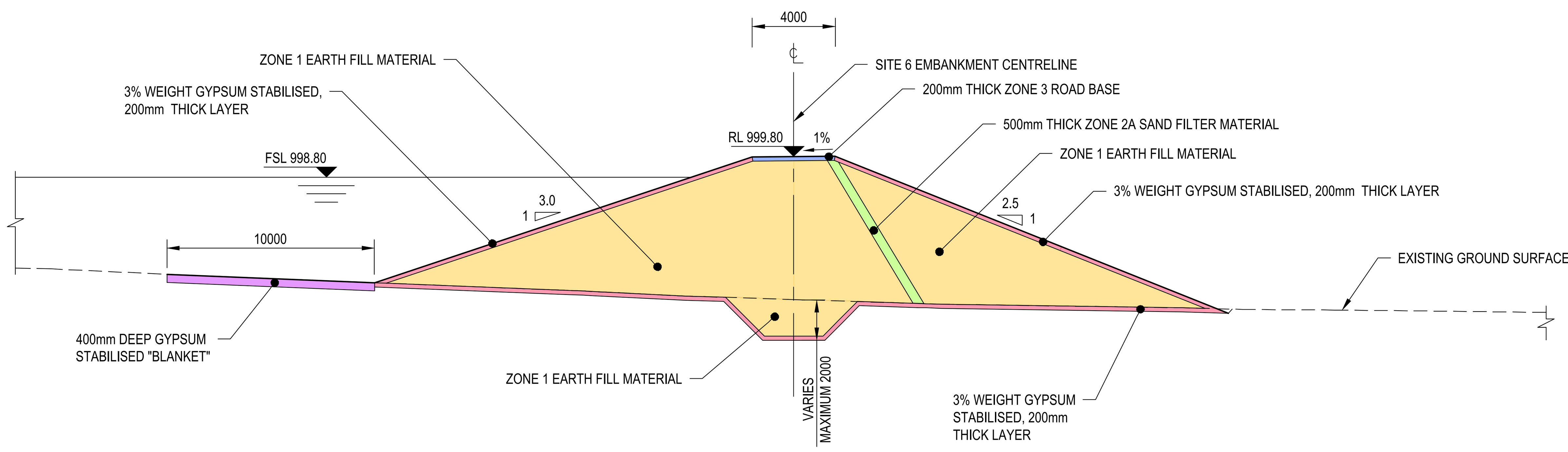
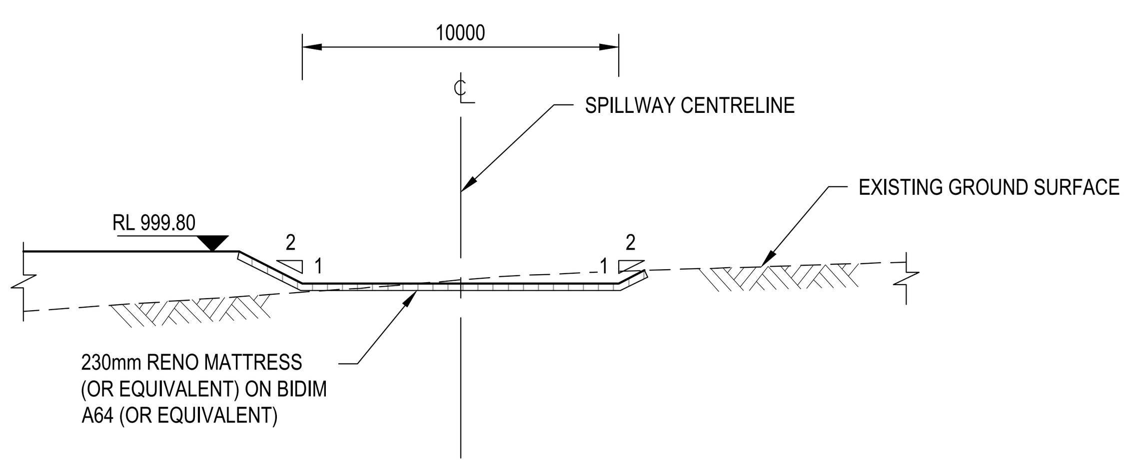
4. ALL INFORMATION IS INDICATIVE AND SHALL BE VERIFIED DURING THE DETAILED DESIGN STAGE.



A SK030 SECTION THROUGH EMBANKMENT FILTER OUTLET
SCALE 1 : 200



B SK030 SECTION THROUGH EMBANKMENT
SCALE 1 : 200



C SK030 SECTION THROUGH SPILLWAY
SCALE 1 : 200

LEGEND:

- PROPOSED CENTRELINE
- DESIGN SURFACE LEVEL
- EXISTING SURFACE LEVEL
- ZONE 1 EARTH FILL MATERIAL
- ZONE 2A FINE FILTER MATERIAL
- ZONE 3 ROAD BASE
- ZONE 2B GRAVEL FILTER MATERIAL
- ZONE 4 RIPRAP 500mm THICK
- 400mm DEEP GYPSUM STABILISED "BLANKET"
- 3% WEIGHT GYPSUM STABILISED, 200mm THICK LAYER

0 2 4 6 8 10m
SCALE 1:200 AT ORIGINAL SIZE

CONCEPT

rev	description	app'd	date
A	ISSUED FOR CONCEPT DESIGN	BB	05.07.19

WALCHA COUNCIL
MACDONALD RIVER FEASIBILITY STUDY

SITE 6
LONGITUDINAL SECTIONS

Level 2, 29 Christie Street St Leonards NSW 2065 Australia
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T 61 2 9462 4700 E slnmail@ghd.com W www.ghd.com

scale 1 : 200 for A1 job no. 22-19901
date JULY 2019 rev no. A

approved (PD) SK040

Appendix B – Cost estimates

Indicative cost estimate for Dam 4A

Item	Description	Quantity	Unit	Rate	Amount
1	**Site Clearing and Excavation**				
1.1	Stipping dam foundation to 200mm depth	6,290	m^3	20	125,800
1.2	Cut-off Trench excavation	2,065	m^3	20	41,300
2	**Gypsum stabilisation**				
2.1	Gypsum stabilised blanket (10 m long x 0.4m deep)	12,310	m^3	50	615,500
2.2	Gypsum stabilised foundation and embankment shell	3,700	m^3	50	185,000
3	**Embankment Construction**				
3.1	Zone 1 earthfill	110,050	m^3	30	3,301,500
3.2	Zone 2A sand filter	2,250	m^3	100	225,000
3.3	Zone 3 roadbase	740	m^3	50	37,000
3.4	Zone 2B gravel filter	60	m^3	100	6,000
3.5	Zone 4 Rip Rap	0	m^3	100	0
4	**Spillway**				
4.1	230mm Reno mattress, 20m long x 10m wide	25	m^3	150	3,750
	Sub Total for measured items				**$4,540,850**
Add:	Contractor's overheads and costs			30%	1,362,255
	Walcha Council Costs			5%	227,043
	Design Fee			5%	227,043
	Contingency			50%	2,270,425
	Sub total for additional items				**$4,086,765**
	Total indicative Dam construction Cost				**$8,627,615**
Add:	Third Party costs				375,000
	Total Indicative construction and third party costs				**$9,002,615**

Notes

1. Intake/outlet pipe indicative cost: provided under mechanical and electrical works (excl. profit and contingency)
2. EIS and other requirements not included
3. Cost estimate is indicative only and is intended to provide a comparative cost for Dam 4A and Dam 6
4. Quantities based on Concept Design only and includes only major items

Indicative cost estimate for Dam 6

Item	Description	Quantity	Unit	Rate	Amount
1	**Site Clearing and Excavation**				
1.1	Stipping dam foundation to 200mm depth	2,980	m^3	20	59,600
1.2	Cut-off Trench excavation	2,750	m^3	20	55,000
2	**Gypsum stabilisation**				
2.1	Gypsum stabilised blanket (10 m long x 0.4m deep)	1,420	m^3	50	71,000
2.2	Gypsum stabilised foundation and embankment shell	6,000	m^3	50	300,000
3	**Embankment Construction**				
3.1	Zone 1 earthfill	73,650	m^3	30	2,209,500
3.2	Zone 2A sand filter	1,660	m^3	100	166,000
3.3	Zone 3 roadbase	285	m^3	50	14,250
3.4	Zone 2B gravel filter	60	m^3	100	6,000
3.5	Zone 4 Rip Rap	340	m^3	100	34,000
4	**Spillway**				
4.1	230mm Reno mattress, 20m long x 10m wide	50	m^3	150	7,500
	Sub Total for measured items				**$2,922,850**
Add:	Contractor's overheads and costs			30%	876,855
	Walcha Council Costs			5%	146,143
	Design Fee			5%	146,143
	Contingency			50%	1,461,425
	Sub total for additional items				**$2,630,565**
	Total indicative Dam construction Cost				**$5,553,415**
Add:	Third party costs				1,000,000
	Total Indicative construction and third party costs				**$6,553,415**

Notes

1. Fish Ladder not included
2. Intake/outlet pipe indicative cost: provided under mechanical and electrical works (excl. profit and contingency)
3. EIS and other requirements not included
4. Cost estimate is indicative only and is intended to provide a comparative cost for Dam 4A and Dam 6
5. Quantities based on Concept Design only and includes only major items

Appendix C – Hydrology Report

working together to ensure water supply security

NUWS

NSW Urban Water Services

377 Sussex Street SYDNEY NSW 2000
PO Box 20078 WORLD SQUARE NSW 2002
T 02 9267 4478 **F** 02 9267 4478
ABN 86 163 223 667 www.nswurbanwaterservices.com.au

WALCHA WATER SUPPLY

Addendum to Yield Study Report

Prepared for
Walcha Council

Report No. 17005 (Addendum)
June 2018
NSW Urban Water Services Pty Ltd

ADDENDUM TO REPORT:

WALCHA WATER SUPPLY, Yield Study Report
Prepared by NSW Urban Water Services for Walcha Council
Report No: 14023, July 2015

Summary

This Addendum provides secure yield estimates from modelling requested augmentation options for Walcha Water Supply headworks system to meet a target future demand of up to 300 ML/a.

The augmentation options focussed on what additional offstream storage was required with different extraction rules for the Macdonald River.

In doing the modelling it was observed that after some point, the larger the offstream storage the *Secure Yield* declined. This was related to the *Secure Yield* being constrained by the 379 ML/a annual extraction limit and the larger storages having larger evaporation losses. For the larger storages while starting full at the start of the model run they never refilled. The offstream storage sizes trialled were selected by trial &error to be the *optimal* size for secure yield for that particular case.

The main informed results are provided in Table 1 and they show:

- While the target demand of 300 ML/a could be met on a secure yield basis for the historic climate it could not be met with 1 ^{o}C climate warming for the cases with the 379 ML/a extraction limit using the lowest GCM (*with 10/15/25 design rule*).

- The target demand of 300 ML/a with 1 ^{o}C climate warming was close to being met in all cases using the median GCM.

- The required additional offstream storage was sensitive to the annual extraction limit as well as whether there was an environmental flow release (EFR).

- While it appears that the results are sensitive to whether an increased annual cap (758 ML/a) is allowed while maintaining an annual average cap over 3 years of 379 ML/a (*compare Case 4 and Case X2 in Table 1*) this is also influenced by selecting the *optimal* size for secure yield for that particular case. If the 243 ML storage used for Case X2 is used for Case 4 the secure yield for historic climate was 316 ML/a (*ie reducing the storage size by some 65 ML only reduced the secure yield by 3 ML/a*).

The results are dependent on the operating rules, data and assumptions as discussed in the previous two NUWS reports:

1. *Walcha Water Supply, Yield Study Report, prepared for Walcha Council, July 2015, Report No.14023.*

2. *Yield Assessment of Apsley River Options, Summary Report, prepared for Walcha Council, December 2017, Report No.17005.*

The yield assessment essentially used the methodology given in NSW Office of Waterõs[1] (NOW) Draft (December 2013) guidelines ñ*Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities.*ò

It should be noted the methodology enables Local Water Utilities to adopt ñ*a capital works program based on the GCM with the median secure yield if the additional cost to move to the GCM with the lowest secure yield is not acceptable*ò

1. *Now Department of Industry Water (DoI Water)*

Table 1: Secure Yield Modelling Results

Case	Model Run No.	Macdonald River Extraction				New Offstream Storage Size ML	Secure Yield ML/a		
		EFR	Limit: Annual Average Over 3 Years ML/a	Limit: Annual Maximum ML/a	Transfer Capacity ML/d		Historic Climate	1 °C Climate Warming	
								Lowest GCM *with 10/15/25*	Median GCM
1	456	n/a	379	379	2.16	**212**	**330**	**265**	**299**
2	473	Case 1	379	379	2.16	**345**	**311**	**223**	**287**
4	472b	Case 1	379	379	13	**309**	**319**	**241**	**302**
X	483	Case 1	n/a	n/a	13	**345**	**494**	**310**	**422**
X2	490	Case 1	379	758	13	**243**	**331**	**209**	**283**
X3	494	n/a	379	758	13	**172**	**340**	**219**	**297**

Other Conditions:

24 hour/7 day pumping from Macdonald River
24 hour/7 day operation for WTP

Offstream Storage Size (*required for modelling evaporation losses*)**:**

Rectangular in shape, 5 m deep
1:3 side slopes , Length of base 2 x width
No Dead Storage

Case 1 (EFR 1):

Only allowed to extract 30% of the daily flow above the cease to pump (CTP) target %ile flow.

For months January to July, CTP when daily flow less than 90% ile daily flow.

For months August to December, CTP when daily flow less than 80% ile daily flow.

If storage at or below 60% full , then for months January to July, CTP relaxed to when daily flow less than 95% ile daily flow.

If storage at or below 60% full , then for months August to December , CTP relaxed to when daily flow less than 90% ile daily flow.

The relevant Macdonald River CTP %ile flows used in the model based on the observed record (1927 to 2015) were:

CTP Target	Woolbrook Gauging Station	Modelled Equivalent at River Offtake
80%ile	31.8 ML/d	24.17 ML/d
90%ile	17.13 ML/d	13.02 ML/d
95%ile	7.34 ML/d	5.58 ML/d

Qualifications

The work contained in this Addendum is considered valid within the context of the study purposes, but caution should be exercised if aspects of this Addendum, 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 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 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.

It is noted that the approach used to develop the required hydrometeorological data was designed to be commensurate with determining Secure Yield (which is a defined term) for feasibility purposes for this Study and thus may not necessarily be appropriate for other models or purposes.

Discussion

In doing the modelling it was observed that after some point, the larger the offstream storage the Secure Yield declined. This was related to the Secure Yield being constrained by the 379 ML/a annual extraction limit and the larger storages having larger evaporation losses. For the larger storages while starting full at the start of the model run they never refilled. The offstream storage sizes trialled were selected by trial &error to be the *optimal* size for secure yield for that particular case.

While the target demand of 300 ML/a could be met on a secure yield basis for the historic climate it could not be met with 1 ^{o}C climate warming for the cases with the 379 ML/a extraction limit . *The procedures resulted in the 1 ^{o}C climate warming being based on the lowest GCM with the 10/15/25 design rule from the NOW guidelines:*

> *"In summary, the NSW Office of Water recommends that utility planning for future water security should be on the following basis where practicable:*
>
> *(a) Where affordable – the GCM with lowest secure yield under 5/10/10 design rule, otherwise,*
>
> *(b) Lesser of: – GCM with median secure yield under 5/10/10 design rule; and*
> *– GCM with lowest secure yield under 10/15/25 design rule."*

Attachment A provides the results of the required model runs for the 15 GCMs and comparable historic data base for assessing 1 ^{o}C climate warming. *Interestingly if the ratio of the median to the historic was to be used to adjust for climate change rather than the procedural lowest ratio of the median to historic and the ratio of the lowest GCM with 10/15/25 to historic then secure yields would only reduce to some 290 to 300 ML/a.*

Table 2 summarises additional model output for the 6 modelled cases that to provide further details in assessing the interactions between the different conditions.

It is noted the transfer rate of 13 ML/d was nominated as it was about the 90% ile flow at the offtake. The pumping results suggest that the Secure Yield may not be that sensitive to whether a transfer rate of 2.17 ML/d or 13 ML/d was used particularly with the 379 ML/a limit and when considering the affects of selecting the *optimal* size for secure yield for that particular case.

Figures 1 to 6 provide storage behaviour diagrams for a repeat of the modelled historic climate while meeting the secure yield demand for the nominated case conditions.

Figures 7 and 8 provide I pumping diagrams from the Macdonald River for the two cases (X2 & X3) with the rolling average cap (*379 ML/a over 3 years with maximum of 758 ML/a*). The diagrams show the amount extracted per financial/water year (*maximum 758 ML/*a) and the amount extracted over 3 years (*maximum 3 x 379 ML/a = 1137 ML/a*).

Table 3 summarises the results from the previous two (2015 & 2018) Yield studies that are relevant to the cases considered herein.

Recommendations

The results presented in this Addendum should be used keeping in mind the assumptions on which the estimates are based.

Until a solution has been selected to meet Walcha's future water supply needs consideration should be given to retaining a rolling average annual extraction cap with a higher annual cap. Conceptually this would allow a higher secure yield than just a rigid annual cap. *Secure Yield* can be sensitive to a particular case and non linear to changes in system constraints.

Table 2: Modelling Results (Historic Climate)

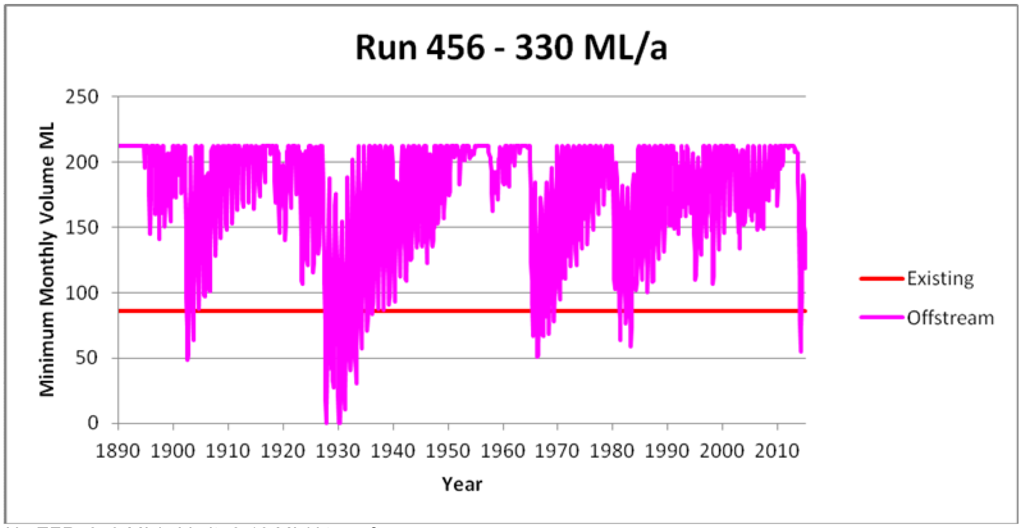
Case	Model Run No.	New Offstream Storage Size ML	Secure Yield (Historic Climate) ML/a	Maximum Daily Pumping Occurred from Macdonald River ML/d	Average Daily Pumping from Macdonald River ML/d	Restrictions			Critical Drought	
						Applied at storage (% full)	Duration (%)	% of Years	From	To
No EFR, 379 ML/a Limit, 2.16 ML/d transfer:										
1	456	**212**	**330**	2.16	1.007816	50	1.72	9.52	29/3/1927	16/3/1930
Case 1 EFR, 379 ML/a Limit, 2.16 ML/d transfer:										
2	473	**345**	**311**	2.16	0.988092	40	1.32	8.73	17/12/1964	30/4/1966
Case 1 EFR, 379 ML/a Limit, 13 ML/d transfer:										
4	472b	**309**	**319**	13	1.002416	40	1.02	8.73	11/4/1929	16/3/1930
Case 1 EFR, No 379 ML/a Limit, 13 ML/d transfer:										
X	483	**345**	**494**	13	1.516478	55	0.76	9.52	25/1/1902	30/8/1902
Case 1 EFR, 379 ML/a Average Over 3 Years Limit,758 ML/a Maximum Limit, 13 ML/d transfer:										
X2	490	**243**	**331**	13	1.022153	50	0.45	7.94	6/2/1902	30/8/1902
No EFR, 379 ML/a Average Over 3 Years Limit,758 ML/a Maximum Limit, 13 ML/d transfer:										
X3	494	**172**	**340**	13	1.026229	60	0.63	8.73	2/3/1902	30/8/1902

Table 3: Summary of Previous Relevant Results

Model Run No	Secure Yield ML/a		Extraction Condition	Eflow Macdonald River	Cap Licence Limit ML/a	Storage Size ML	Macdonald River Transfer Rate ML/d	Apsley River Eflow	WTP Operating Days	WTP Rate ML/d	Macdonald River Pumping Hours/days	Apsley Transfer ML/d
	Historic	1 °C Warming										
From 2015 Walcha Yield Study:												
His72b	**145**	**100**	x	No	Unlimited	**86**	2.16	x	7	2	24/7	x
His74b	**367**	**260**	x	No	Unlimited	**172+86**	2.16	x	7	2	24/7	x
His81	**341**	**230**	x	Case 1	Unlimited	**172+86**	2.16	x	5	2	24/7	x
From 2017 Apsley Yield Study:												
251	**430**	**300**	x	Case 1	Unlimited	**317+86**	2.16	x	5	2	24/7	x
351	**286**	**254**	Rolling Average Max 2 years	Case 1	379	**800+86**	2.16	x	5	2	24/7	x
357	**782**	**575**	Rolling Average Max 2 years	Case 1	379	**800+86**	2.16	30/30	7	Unlimited	24/7	10
151	**469**	**372**	x	Case 1	Unlimited	**800+86**	2.16	x	5	2	24/7	x
154	**544**	**x**	x	Case 1	Unlimited	**800+86**	2.16	x	7	2	24/7	x
153	**469**	**x**	x	Case 1	Unlimited	**800+86**	2.16	Case 1	5	2	24/7	10
156	**669**	**x**	x	Case 1	Unlimited	**800+86**	2.16	Case 1	7	2	24/7	10

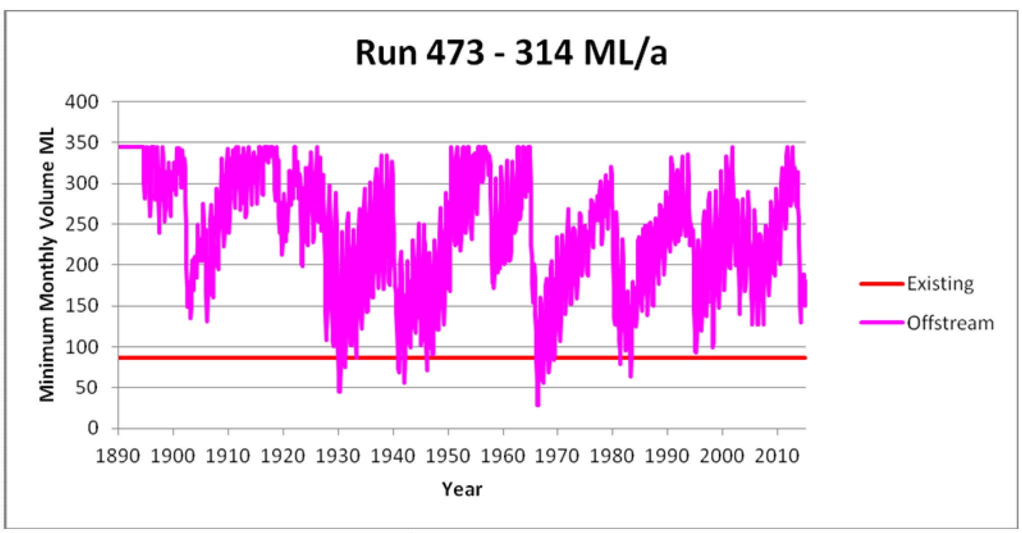
Figures

Figure 1: Case 1 Storage Behaviour Diagrams



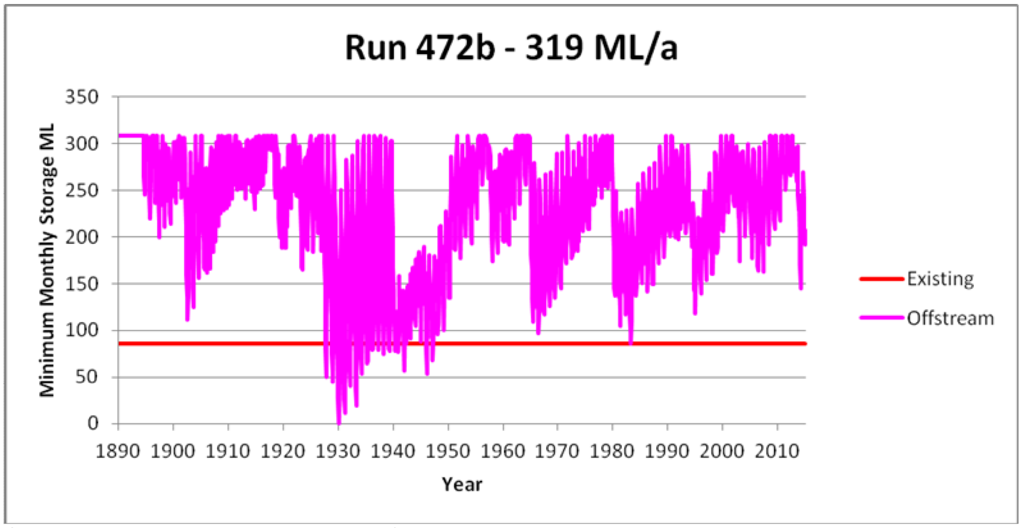
No EFR, 379 ML/a Limit, 2.16 ML/d transfer

Figure 2: Case 2 Storage Behaviour Diagrams



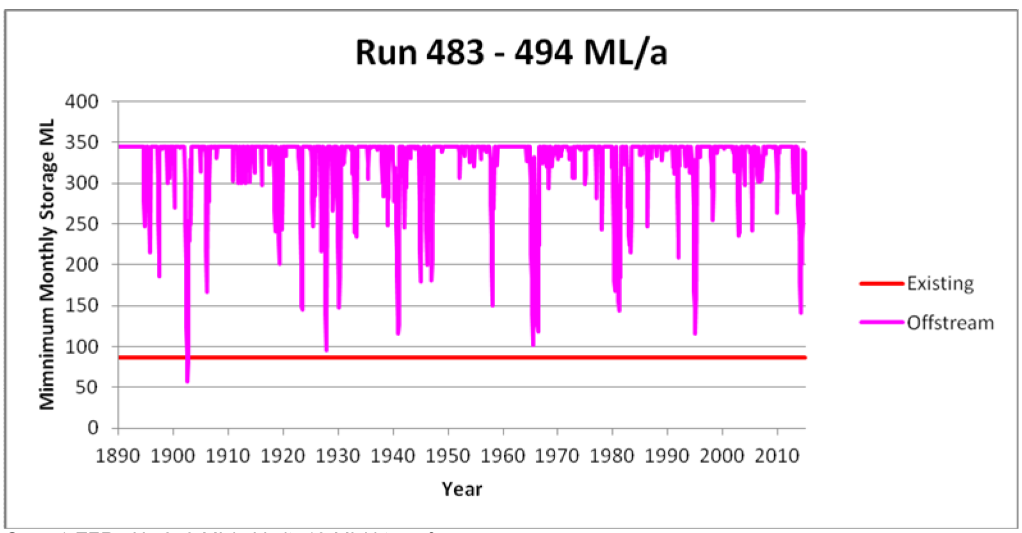
Case 1 EFR, 379 ML/a Limit, 2.16 ML/d transfer

Figure 3: Case 4 Storage Behaviour Diagrams



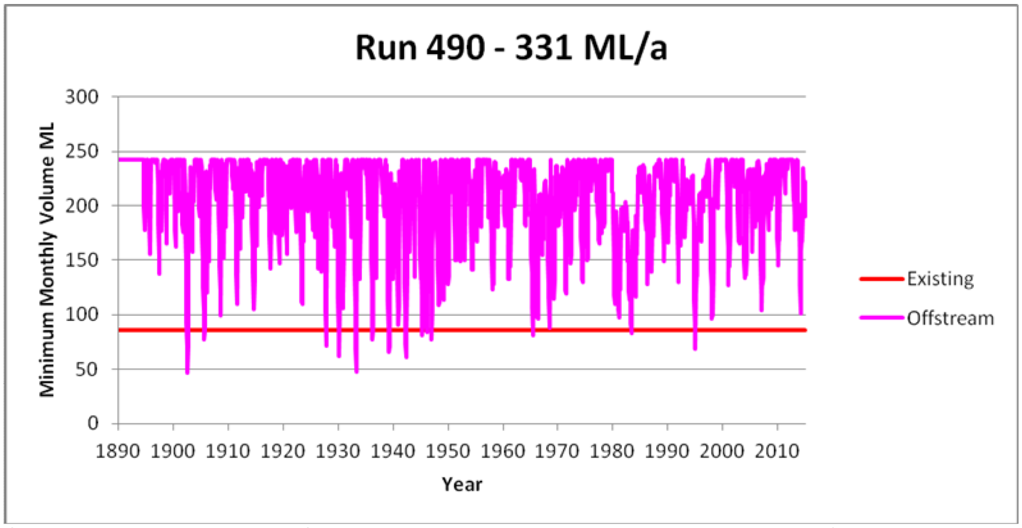
Case 1 EFR, 379 ML/a Limit, 13 ML/d transfer

Figure 4: Case X Storage Behaviour Diagrams



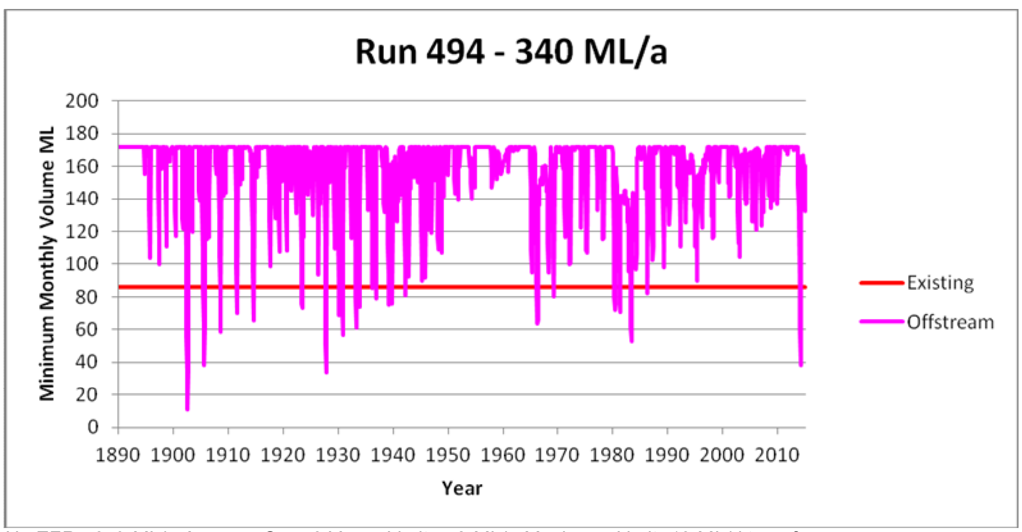
Case 1 EFR, No 379 ML/a Limit, 13 ML/d transfer

Figure 5: Case X2 Storage Behaviour Diagrams



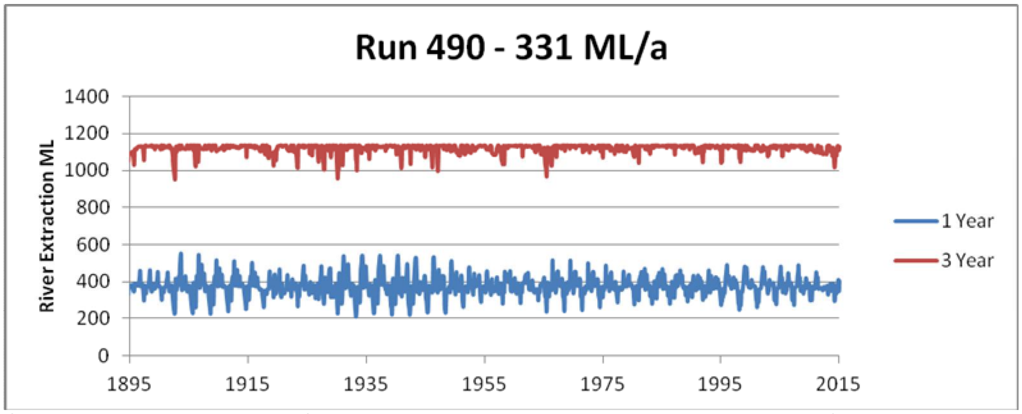
Case 1 EFR, 379 ML/a Average Over 3 Years Limit,758 ML/a Maximum Limit, 13 ML/d transfer

Figure 6: Case X3 Storage Behaviour Diagrams



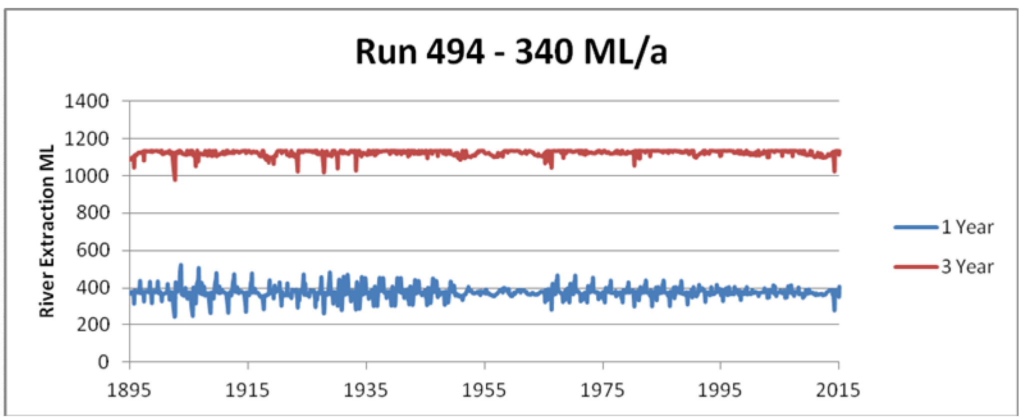
No EFR, 379 ML/a Average Over 3 Years Limit,758 ML/a Maximum Limit, 13 ML/d transfer

Figure 7: Case X2 Pumping Diagram



Case 1 EFR, 379 ML/a Average Over 3 Years Limit,758 ML/a Maximum Limit, 13 ML/d transfer

Figure 8: Case X3 Pumping Diagram



No EFR, 379 ML/a Average Over 3 Years Limit,758 ML/a Maximum Limit, 13 ML/d transfer

ATTACHMENT A

Model Results for 15 GCMs and corresponding Historic Base

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 using observed flow data and a longer period was modelled previously (refer to Section 5 of the 2015 Yield report) and the following data has been adjusted in Table 1 in accordance with the NOW Guidelines to reflect these differences.

Case 1- Run 456: No EFR, 379 ML/a LIMIT, 2.16 ML/d Transfer (refer Table 1)

Walcha2, Run 456CC F:\Results\Walcha\Data\Climate\Walcha_

Time: 1/06/2018 8:53:36 AM

					Restricted		Critical Drought	
		Storage	Secure	% Restricted	% of	% of		
	Run	Capacity	Yield	at	duration	years	Start	End
HISTORICAL	1	298.27	283	60	1.44	6.09	21/03/1994	24/12/1994
	2	298.27	256	70	2.11	9.57	15/02/1902	16/12/1902
MEDIAN	3	298.27	256	70	2.11	9.57	10/02/1902	16/12/1902
	4	298.27	204	65	2.21	9.57	22/01/1902	16/12/1902
LOWEST	5	298.27	172	60	2.20	8.70	05/01/1902	16/12/1902
	6	298.27	257	65	1.99	9.57	13/02/1902	16/12/1902
	7	298.27	183	70	1.85	9.57	18/02/1902	24/03/1903
	8	298.27	268	60	2.09	9.57	21/03/1994	18/01/1995
	9	298.27	195	65	2.03	8.70	30/01/1902	16/12/1902
	10	298.27	253	70	2.06	9.57	17/02/1902	16/12/1902
	11	298.27	279	65	1.61	9.57	17/02/1902	16/12/1902
	12	298.27	277	65	1.72	9.57	12/02/1902	16/12/1902
	13	298.27	224	65	1.87	8.70	09/02/1902	16/12/1902
	14	298.27	232	65	1.95	9.57	23/02/1994	24/12/1994
	15	298.27	280	60	1.92	8.70	24/03/1994	24/12/1994
	16	298.27	294	60	1.32	8.70	26/04/1994	24/12/1994
10/15/25	5	298.27	206	60	3.27	11.30	05/01/1902	16/12/1902

Case 2 - Run 473: Case 1 EFR, 379 ML/a LIMIT, 2.16 ML/d Transfer (refer Table 1)

Walcha2, Run 473CC F:\Results\Walcha\Data\Climate\Walcha_

Time: 1/06/2018 9:51:37 AM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	430.77	276	50	2.39	6.96	18/09/1992	18/01/1995
	2	430.77	271	55	2.67	8.70	19/01/1902	16/12/1902
	3	430.77	270	55	2.27	7.83	13/01/1902	16/12/1902
	4	430.77	211	50	2.47	8.70	06/12/1901	16/12/1902
LOWEST	5	430.77	165	55	2.53	9.57	18/11/1901	24/03/1903
	6	430.77	255	55	3.23	7.83	03/07/1992	18/01/1995
	7	430.77	201	60	2.09	6.09	19/01/1902	24/03/1903
	8	430.77	247	55	3.68	9.57	24/11/1993	18/01/1995
	9	430.77	213	55	3.46	9.57	09/12/1901	24/03/1903
	10	430.77	271	60	2.53	7.83	19/01/1902	16/12/1902
	11	430.77	291	55	2.82	8.70	27/11/1901	16/12/1902
	12	430.77	283	55	2.52	6.96	19/10/1993	24/12/1994
	13	430.77	228	55	2.92	8.70	24/11/1993	18/01/1995
	14	430.77	241	60	3.70	8.70	26/11/1993	24/12/1994
MEDIAN	15	430.77	255	55	3.26	8.70	15/11/1993	18/01/1995
	16	430.77	293	50	2.43	8.70	23/11/1901	28/02/1906
10/15/25	5	430.77	198	55	4.22	13.04	13/11/1901	24/03/1903

Case 4 - Run 472b: Case 1 EFR, 379 ML/a LIMIT, 13 ML/d Transfer (refer Table 1)

Walcha2, Run 472bCC F:\Results\Walcha\Data\Climate\Walcha_

Time: 1/06/2018 12:58:22 PM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	394.645	287	55	1.30	6.09	26/10/1993	24/12/1994
	2	394.645	275	60	1.44	8.70	19/01/1902	16/12/1902
	3	394.645	275	60	1.27	9.57	13/01/1902	16/12/1902
	4	394.645	217	55	1.12	6.09	06/12/1901	16/12/1902
LOWEST	5	394.645	189	60	2.12	9.57	18/11/1901	16/12/1902
	6	394.645	281	55	1.92	9.57	30/09/1993	24/12/1994
	7	394.645	221	60	1.60	8.70	23/12/1993	18/01/1995
	8	394.645	271	55	1.91	9.57	21/12/1993	24/12/1994
	9	394.645	223	55	1.39	6.09	09/12/1901	16/12/1902
MEDIAN	10	394.645	272	60	1.13	8.70	19/01/1902	16/12/1902
	11	394.645	304	50	1.75	8.70	13/10/1901	16/12/1902
	12	394.645	301	50	1.78	9.57	19/10/1901	16/12/1902
	13	394.645	241	60	1.81	9.57	29/12/1993	24/12/1994
	14	394.645	244	60	1.74	8.70	23/11/1993	24/12/1994
	15	394.645	279	55	1.55	8.70	22/12/1993	24/12/1994
	16	394.645	301	50	1.39	8.70	02/03/1905	28/02/1906
10/15/25	5	394.645	217	55	2.19	11.30	15/11/1901	16/12/1902

Case X - Run 483: Case 1 EFR, No 379 ML/a LIMIT, 13 ML/d Transfer (refer Table 1)

Walcha2, Run 483CC F:\Results\Walcha\Data\Climate\Walcha_

Time: 6/06/2018 11:52:31 AM

	Run	Storage Capacity	Secure Yield	% Restricted at	Restricted % of duration	Restricted % of years	Critical Drought Start	Critical Drought End
HISTORICAL	1	430.77	373	55	1.11	9.57	13/04/1994	24/12/1994
	2	430.77	319	60	1.16	9.57	14/01/1902	16/12/1902
	3	430.77	319	60	1.02	7.83	20/12/1901	16/12/1902
	4	430.77	241	60	1.84	9.57	06/12/1901	16/12/1902
LOWEST	5	430.77	200	60	1.93	9.57	15/11/1901	24/03/1903
	6	430.77	331	55	1.12	7.83	13/01/1902	16/12/1902
	7	430.77	232	65	1.60	9.57	19/01/1902	24/03/1903
MEDIAN	8	430.77	319	55	1.49	9.57	13/01/1902	16/12/1902
	9	430.77	241	55	1.25	6.09	09/12/1901	16/12/1902
	10	430.77	298	65	1.34	9.57	19/01/1902	16/12/1902
	11	430.77	389	60	1.36	9.57	15/01/1902	16/12/1902
	12	430.77	385	60	1.41	9.57	13/01/1902	16/12/1902
	13	430.77	273	60	1.52	9.57	17/12/1901	16/12/1902
	14	430.77	291	60	1.46	8.70	19/12/1901	16/12/1902
	15	430.77	344	55	1.35	9.57	18/12/1901	16/12/1902
	16	430.77	406	60	1.58	9.57	06/04/1994	24/12/1994
10/15/25	5	430.77	234	55	1.95	10.43	15/11/1901	16/12/1902

Case X2 - Run 490: Case 1 EFR, 379 ML/a Average Over 3 Years Limit, 758 ML/a Maximum Limit, 13 ML/d Transfer (refer Table 1)

Walcha2, Run 490CC F:\Results\Walcha\Data\Climate\Walcha_

Time: 22-Jun-18 10:10:15 AM

	Run	Storage Capacity	Secure Yield	% Restricted at	Restricted % of duration	Restricted % of years	Critical Drought Start	Critical Drought End
HISTORICAL	1	328.395	290	55	1.07	8.70	13/04/1994	24/12/1994
	2	328.395	249	60	1.09	9.57	19/01/1902	16/12/1902
	3	328.395	256	0	0.00	0.00	13/01/1902	16/12/1902
	4	328.395	185	60	1.39	9.57	06/12/1901	16/12/1902
LOWEST	5	328.395	159	60	1.94	9.57	18/11/1901	16/12/1902
	6	328.395	273	55	1.29	9.57	15/01/1902	16/12/1902
	7	328.395	196	60	1.23	6.09	22/01/1902	24/03/1903
MEDIAN	8	328.395	248	50	0.80	5.22	16/01/1902	16/12/1902
	9	328.395	188	55	1.08	5.22	10/12/1901	16/12/1902
	10	328.395	231	65	1.27	9.57	19/01/1902	16/12/1902
	11	328.395	306	55	1.30	9.57	14/11/1901	16/12/1902
	12	328.395	307	55	1.55	9.57	30/10/1901	16/12/1902
	13	328.395	218	60	1.47	9.57	13/01/1902	16/12/1902
	14	328.395	228	60	1.36	8.70	13/01/1902	16/12/1902
	15	328.395	268	55	1.17	9.57	13/01/1902	16/12/1902
	16	328.395	296	60	1.47	9.57	09/05/1905	28/02/1906
10/15/25	5	328.395	183	60	2.59	13.91	18/11/1901	16/12/1902

Case X3 - Run 494: No EFR, 379 ML/a Average Over 3 Years Limit, 758 ML/a Maximum Limit, 13 ML/d Transfer (refer Table 1)

Walcha2, Run 494CC F:\Results\Walcha\Data\Climate\Walcha_

Time: 22-Jun-18 11:05:55 AM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	258.145	278	65	1.14	9.57	10/05/1994	25/12/1994
	2	258.145	257	65	1.18	7.83	15/02/1902	16/12/1902
	3	258.145	268	70	1.53	9.57	10/02/1902	16/12/1902
	4	258.145	179	65	0.91	8.70	24/01/1902	16/12/1902
LOWEST	5	258.145	151	65	1.32	9.57	06/01/1902	16/12/1902
	6	258.145	254	65	1.31	9.57	08/05/1994	24/12/1994
	7	258.145	203	65	1.53	9.57	18/02/1902	24/03/1903
	8	258.145	248	60	0.84	7.83	03/05/1994	24/12/1994
	9	258.145	171	65	0.85	9.57	30/01/1902	16/12/1902
	10	258.145	220	70	1.27	8.70	17/02/1902	16/12/1902
	11	258.145	307	70	1.61	9.57	29/05/1994	24/12/1994
	12	258.145	306	70	1.62	9.57	27/05/1994	25/12/1994
	13	258.145	194	65	0.92	8.70	09/02/1902	16/12/1902
	14	258.145	223	65	1.12	8.70	10/02/1902	16/12/1902
MEDIAN	15	258.145	243	60	0.69	6.09	04/05/1994	24/12/1994
	16	258.145	302	70	1.47	9.57	10/05/1994	25/12/1994
10/15/25	5	258.145	179	60	1.32	9.57	05/01/1902	16/12/1902

GHD

Suite 8 Atrium Business Centre
345 Peel Street Tamworth NSW 2340
T: 61 2 4979 9900   F: 61 2 4979 9988   E: ntlmail@ghd.com

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