yass valley council

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Ordinary Meeting of Council

Wednesday 24 March 2021
4.00pm
Council Chambers
209 Comur Street, Yass

ATTACHMENTS TO REPORTS
ITEMS UNDER SEPARATE COVER

Ordinary Meeting of Council

Attachments to Reports
Items Under Separate Cover

Page No.

APPENDIX A

GULLY REHABILITATION PLAN

66 BROOKLANDS ROAD
WALLAROO NSW 2618

Version 1
03 June 2020

SOILANDWATER

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PURPOSE AND SCOPE OF THIS PLAN

Soil and Water has been engaged to develop a Gully Rehabilitation Plan to rehabilitate the eroding sidewalls of a large erosion gully located on Lot 1 DP 1243196, 66 Brooklands Road, Wallaroo, NSW, 2618.

The purpose of this plan is to ensure that gully rehabilitation is undertaken in a way that minimises potential impact to the local and downstream environments and delivers a stable and sustainable rehabilitated riparian zone that is no longer delivering sediment and turbidity to the watercourse and is a reduced danger to livestock and farm management activities.

As the proposal includes using Excavated Natural Material (ENM), a Development Application is required by Yass Valley Council. As approval is also required from another regulatory authority (Controlled Activity Approval from the Natural Resource Access Regulator under the Water Management Act 2000), the Development Application is to be considered as an Integrated Development. The scope of the assessment is designed to provide the information necessary for Yass Valley Council and the Natural Resource Access Regulator to assess the proposal including:

- Local landscape, soils, geology and historical context of erosion in the area
- Location, extent and significance of the erosion gully (to be rehabilitated) on water quality, landscape function and agricultural productivity
- Design principles and rehabilitation goals for the project
- Proposed rehabilitation actions to remediate the gully and improve water quality, landscape function and agricultural productivity, including:
    - Soil and water management works required to enable gully filling activities to proceed without impacting water quality
    - Gully rehabilitation method to be used
    - Sequencing of works
    - Final rehabilitation measures to stabilise the site
- Type and amount of imported material to be used in the gully rehabilitation including:
    - Source and certification of material
    - Estimated volumes required to rehabilitate the gullies
- Truck movements and plant operations including:
    - Truck configuration and expected movement per day/week/year
    - Plant and equipment to be used in gully rehabilitation activities
    - Hours of operation

  - Site supervision and security
- Approvals
- Recommendations.

As the proposal involves works within the riparian zone of a watercourse a Controlled Activity Approval (CAA) is required from the Natural Resource Access Regulator (NRAR). This will be considered as part of the Development Application process through the Integrated Development process with the regulator (Natural Resource Access Regulator) to provide General Terms of Approval which will be included as conditions of consent.

CONSULTANT INFORMATION

This evaluation has been undertaken by John Franklin who is a Certified Environmental Practitioner with over 30 years' experience in natural resource management in the ACT and Murrumbidgee region. This experience includes site and soil assessment around the southern tablelands, south-west slopes and upper Murrumbidgee region. John has provided extensive soil and water management advice to State and Local Government and the urban / rural residential development sector across the region.

John also has extensive experience in erosion control and wrote the *Gully Erosion Assessment and Control Guide* (Franklin, Glover and Parker, 2004) for the NSW Department of Infrastructure, Planning and Natural Resources.

Inspection location	Date	Consultant
Lot 1 DP 858593, Southwell Road, Wallaroo, NSW 2618	15 May 2020	John Franklin M App Sc, BSc, EIANZ

LOCATION

The erosion gully to be rehabilitated is located on Lot 1 DP 1243196 in the Yass Valley Council Local Government Area, refer **Figures 1-5**. The site is located approximately 10 kms north of Canberra, which is the source of considerable volumes of Excavated Natural Material (ENM) which is suitable for use in gully rehabilitation (in conjunction with soil and water management works).

Access to the site is from Brooklands Road with the gate being located approximately 2.4 kms from the junction of Southwell Road and Wallaroo Road, which in turn is approximately 6 km from the Barton Highway junction. The area of gully rehabilitation will be accessed by approximately 650 metres of private gravel road which already exists. This access will be upgraded and maintained at a standard suitable for use by the rigid truck and dog trailer combinations.

The gully area to be rehabilitated is located on a gentle westerly sloping site which is effectively screened from Brooklands Road by existing landscaping and remnant vegetation around the dwelling and outbuildings yards which are located between the gully and the road, refer **Figures 1-5**.

Figure 1: Locality Map

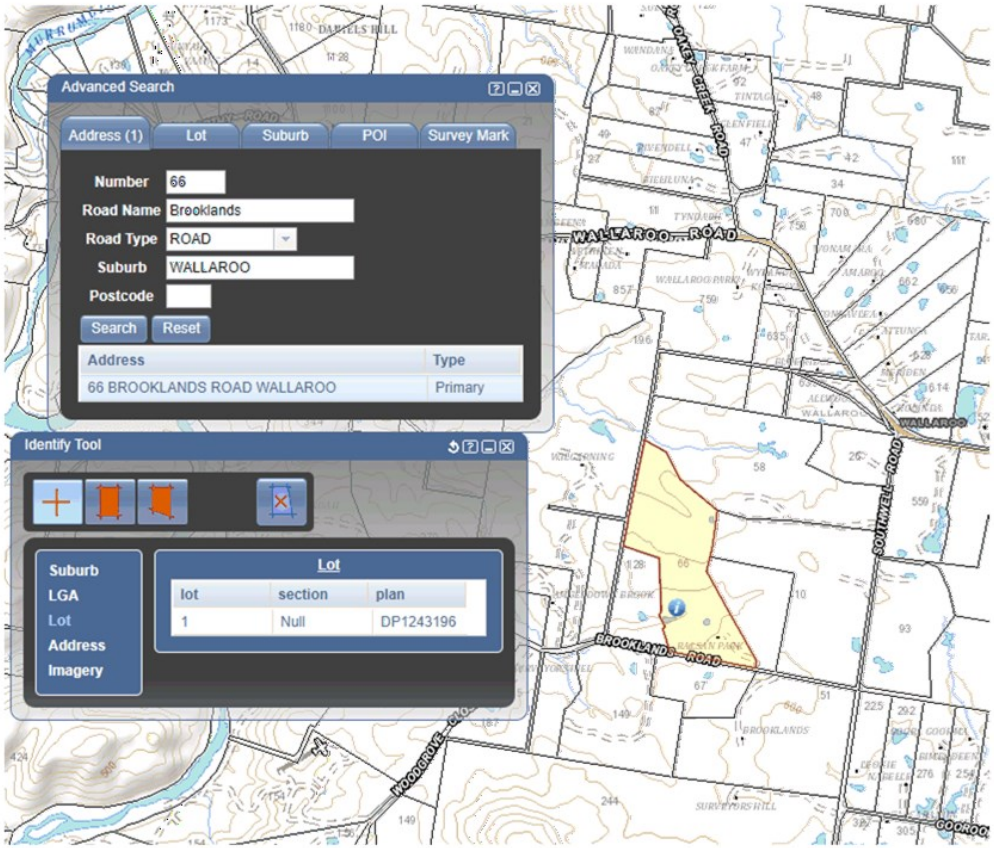


Figure 2: Catchment Area

Figure 3: Site Locality and Access

Figure 4: Distance to Murrumbidgee River

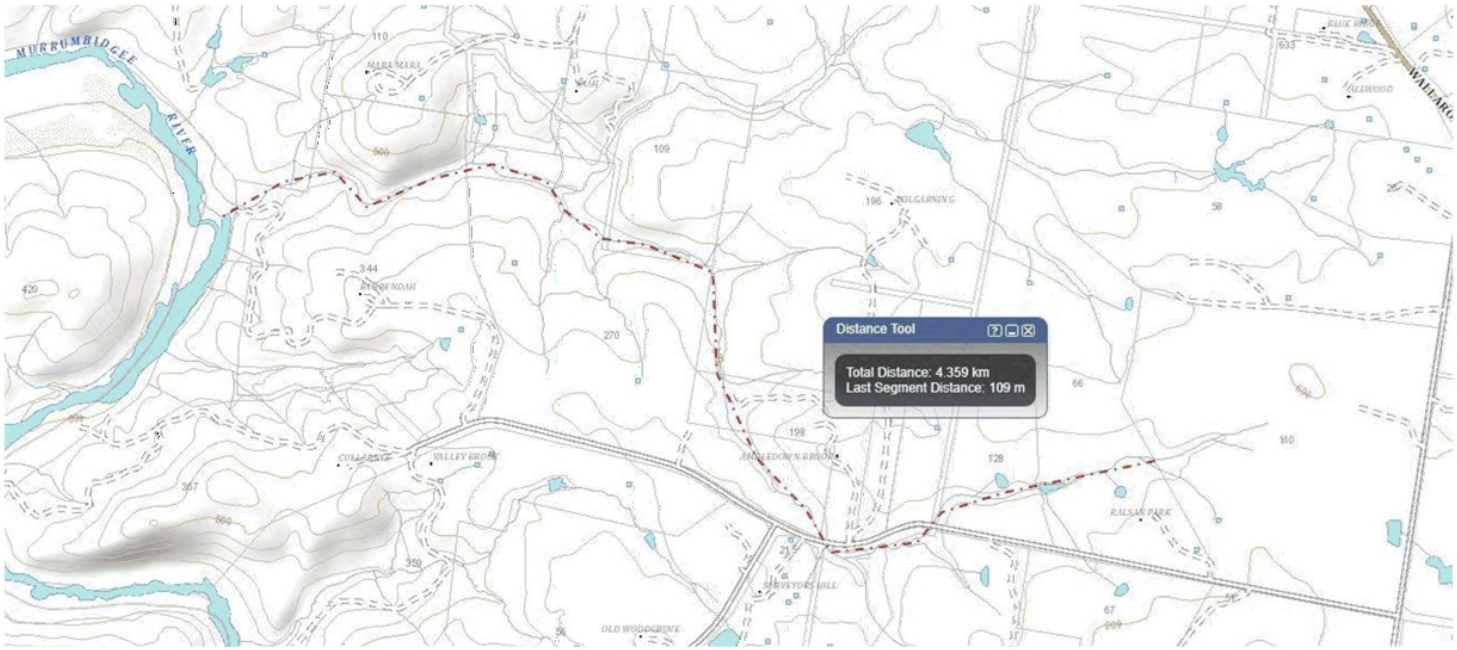


Figure 5: Stream Order

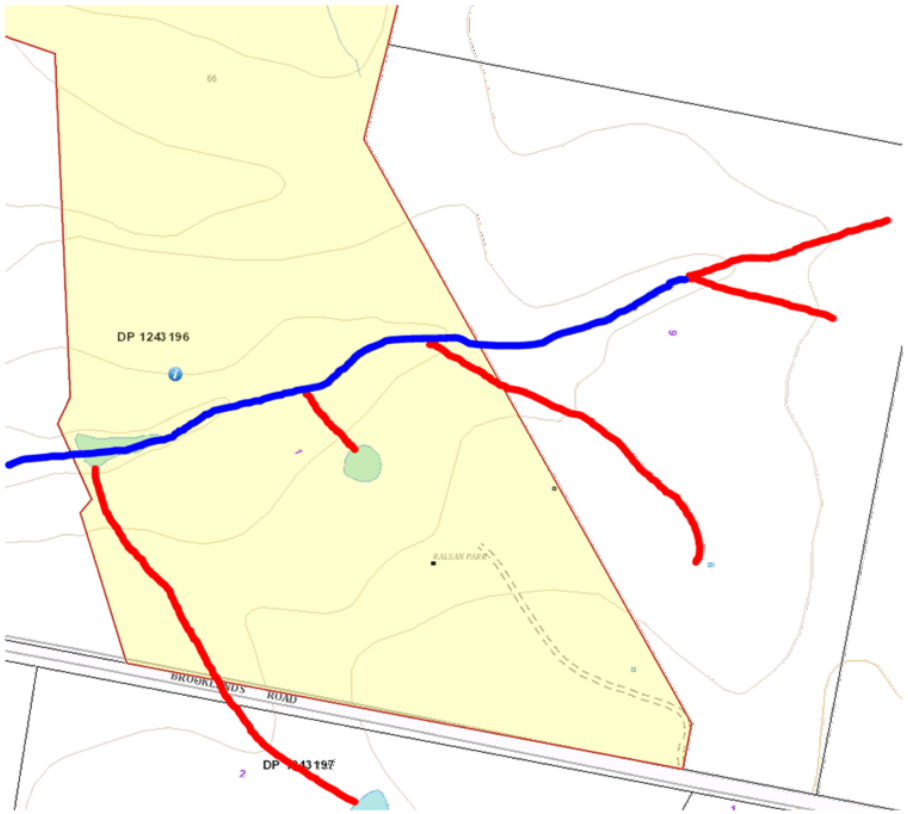
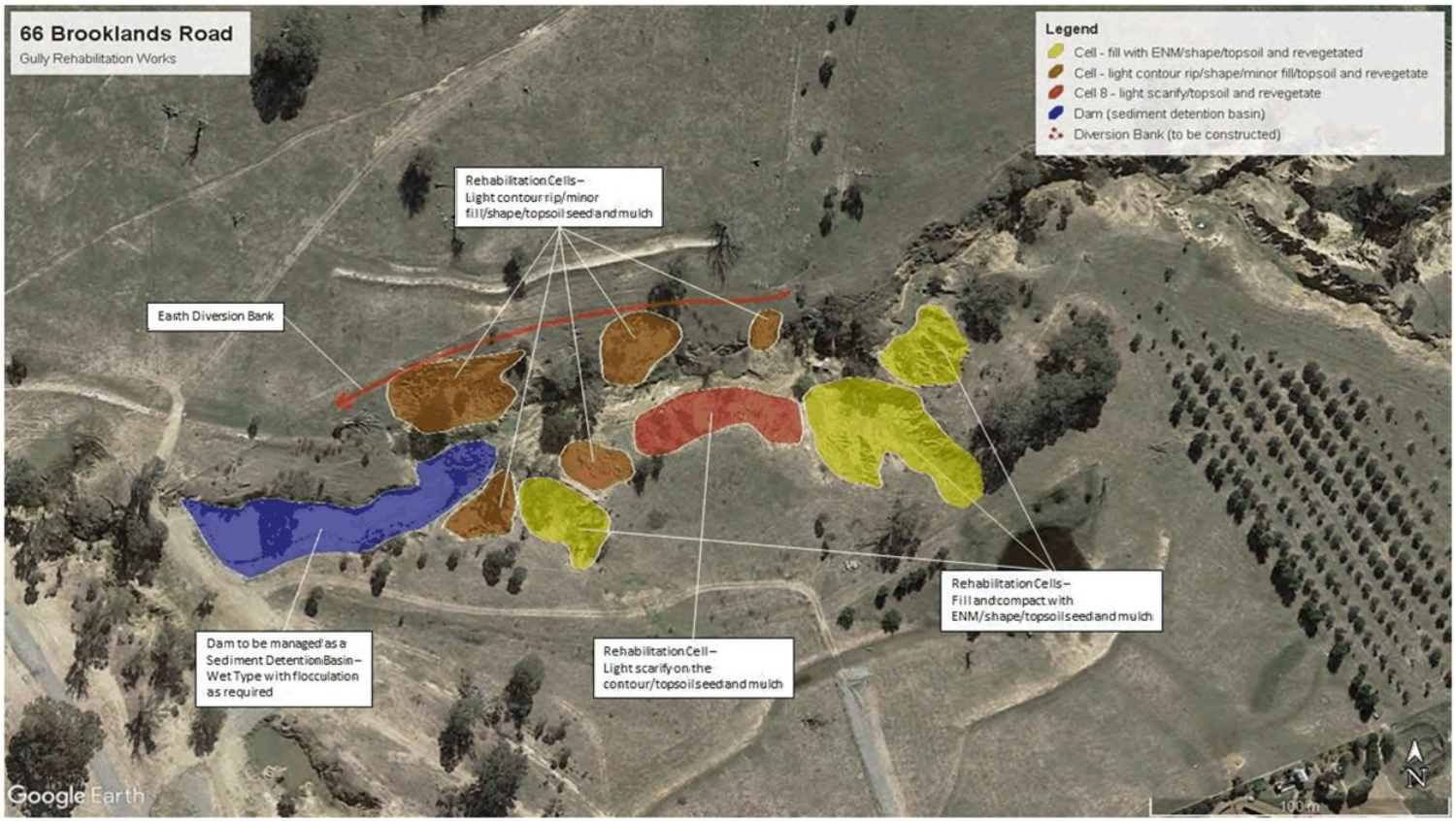


Figure 6: Gully Rehabilitation Plan



LANDSCAPE AND SOILS

The hills and rises in the area are identified as part of the Burra Unit in the *Soil Landscapes of the Canberra 1:100000 Sheet Report*, Jenkins (2000). This landscape is described as undulating to rolling low hills and alluvial fans on Silurian Volcanics. Local relief is <90m with elevations ranging between 650-900m. Slopes range between 5-30% and the landscape has been extensively cleared for grazing purposes.

Soils associated with the Burra Unit range from shallow poorly formed Tenosols and Rudosols on crests and ridges to moderately deep and moderately drained Red Kurosols on side and lower slopes to Brown Chromosols in drainage depressions. Sheet erosion is common on these soil types.

The lower areas correspond to the Williamsdale Unit which is described as undulating rises, fans, valley flats and depressions on Silurian Volcanics of the Canberra Lowlands. Local relief is 5-50m with elevations between 550-650m. Slopes are generally <10%.

Soils associated with the Williamsdale Unit include moderately deep and moderately drained Yellow to Red Chromosols on upper rises and fans to moderately deep and poorly drained Sodosols in lower areas. Gully erosion is common and widespread in the soil types which correspond to the location of the gullies to be rehabilitated in this project.

The local landscape has been extensively modified for agricultural activities with the main activity being sheep and cattle grazing. Much of the original woodland vegetation has been cleared leaving only scattered paddock trees.

EXTENT AND SIGNIFICANCE OF EROSION

The gully sides to be rehabilitated are located on a 1st and 2nd order drainage depressions which combine to exit the downstream (western) property boundary, refer **Figure 5**. The drainage depression flows generally east to west to eventually join the Murrumbidgee River approximately 4.4 kms to the west, refer **Figure 4**. The catchment area for this gully sequence is moderate (62 hectares) and commences at the ridge which runs north south parallel to Southwell Road and crosses Brooklands Road refer **Figure 2.**

The gully reach to be rehabilitated consists of a deeply incised 2nd Order Stream with lateral incised 1st Order Streams which branch off to the south at three points. The reach starts at the upstream eastern boundary as an incised 2nd Order Stream and finishes in a large dam on the western boundary, refer **Figures 5 & 6.** The length of the reach is approximately 440 metres and depth of the gullies ranges between 2 and 6 metres and widths range from 5 metres to more than 20 metres.

The gully floor through this reach is generally stable and eroded material from the upstream property is depositing on the gully floor through much of the reach, refer following images.

The large dam located at the western boundary of the reach has captured significant volumes of medium to coarse sediment. Finer eroded material (colloidal clays) which remain in suspension in the water column are transported downstream to adversely impact water quality.

The gully sides along this reach are actively eroding in many sections, particularly where lateral subsurface flows intersect the gully walls. Upslope surface water flows have largely been controlled through the construction of soil erosion control earthworks including dams. These earthworks were constructed by the Soil Conservation Service and consist of numerous earth diversion banks which capture and divert flows away from the active areas of erosion. The diversion banks discharge in stable areas of the paddock and flows spread out across the landscape before re-entering the incised gully.

These works have been successful in reducing the erosion related to surface drainage (overland flow) however there are several areas where the gully sides continue to erode due to subsurface flows combined with small amounts of surface flow which accumulate below the erosion control earthworks (diversion banks). These eroding areas remain active and continue to deliver sediment to the watercourse thereby reducing downstream water quality.

The significance of the gully sidewall erosion in this system is increased due to the relatively proximity to the Murrumbidgee River (4.4km) and connectivity to this system with direct linkage by 2nd or Higher Order Streams to the river. There are limited opportunities for mobilised (particularly suspended) sediment to be re-captured within the drainage system as there are no significant in-stream wetlands or similar between the gully sequence and the Murrumbidgee River. Therefore, sediment mobilised through ongoing erosion in this gully sequence is likely to be transported directly to the Murrumbidgee River impacting on downstream water quality and habitats.

The gully sidewalls are actively eroding and present a significant risk to downstream water quality and habitats.

Photo 1: Downstream dam with high suspended sediment load

Photo 2: Deposited sediment in dam backwaters

Photo 3: Severely eroding gully sidewalls - sediment deposited in channel from upslope erosion

Photo 4: Lateral gully erosion – to be filled to restore gully profile

Photo 5: Lateral gully erosion – to be filled to restore gully profile

Photo 6: Stable vegetated gully sides – deposited sediment from upstream erosion

Photo 7: Moderate gully sidewall erosion – minor fill prior to shape, topsoil and revegetation

Photo 8: Lateral subsurface flows - intersecting gully sidewall and driving erosion

Photo 9: Stable vegetated gully sidewalls – natural regeneration of native trees and shrubs

Photo 10: Stable gully sidewalls – minor bed lowering (erosion)

RISK OF CONTINUING EROSION

In determining the risk of continuing erosion risk associated with the gully it is important to consider the three main structural components of the system which are the gully head(s), gully floor and gully sidewalls (or banks).

The gully bed is relatively stable where bed grade is low and the gully width is large. There are however some sections close to the upstream boundary where the gully sequence is narrow (<5m) and where bed grade is substantial, in these areas the bed is incised and eroding, refer **Photos 9-10**.

The main gully heads are located on the adjacent upstream property and have largely been stabilised through the installation of erosion control earthworks. It is understood that additional works are proposed for erosion upstream of the property boundary which will further stabilise erosion and sediment loads from this source.

The sidewalls (banks) of the gully are stable in places where the grade has reduced to the point that topsoil material has remained in place and vegetation has been able to establish. In other places the gully sidewalls remain vertical or close to vertical and have not vegetated, refer **Photos 1-10**. In these areas the depth of gullies (up to 6 metres) combined with the dispersible soil types and lack of groundcover result in extensive cumulative areas of eroding sidewalls. In some places the movement of stock up and down gully sidewalls has also contributed to erosion.

Subsurface lateral flows intersecting the gully sidewall are a driver of moderate to severe erosion in these locations, refer **Photo 8**. This demonstrates that even where surface water flows are controlled through the installation of erosion control earthworks, erosion can persist due to lateral subsurface flows. These typically occur where sandy loam topsoils rapidly drain to the less permeably clay subsoils which form a constraint to vertical drainage therefore water flows laterally through soils at the boundary between topsoils and subsoils until it discharges in low parts of the landscape.

Therefore it is considered that eroding areas will continue to erode without intervention to reduce the batter grade of gully sides (through filling and shaping), prior to reintroducing a suitable growing medium (through topsoiling) and revegetating (with suitable grass and pasture species) to reinstate an adequate groundcover and prevent further erosion.

A continuation of erosion will see an ongoing degradation of downstream water quality and presents an ongoing risk animal health and welfare and farming operations.

OPTIONS FOR REHABILITATION

There are a number of strategies which are used to rehabilitate areas of gully erosion. Determining which options are suited to the site, and ultimately which is the optimal solution, depends on an assessment of a variety of issues. The most relevant options are briefly evaluated below.

1. Continue existing land management (do nothing)

The continuation of the existing land management practices will not address the areas of active erosion at the site nor the potential for this to continue and worsen overtime. This is demonstrated by the historical soil erosion control works which have slowed erosion but have not reduced erosion to the point that stabilisation will naturally occur overtime.

As a result, environmental degradation will continue and as areas of active erosion increase in size and severity, the offsite impacts to water quality and downstream aquatic habitats will increase.

Maintenance of the existing land management practices will not address the farm management issues generated by the eroding gully sides including potential injury and loss of stock due to falls and the gradual loss of area of productive land to continuing erosion.

As the erosion of gully sides continues laterally into the productive pasture paddocks these impacts will increase.

2. Fence, destock and revegetate

The fencing (destocking) of the entire gully line and revegetation with native trees and shrubs has the potential to address some of the areas of active sidewall erosion. Due to the highly dispersible subsoils and the extent and severity of existing gully sidewall erosion, it is considered that destocking and revegetation in these areas would not be sufficient to ensure that all erosion is stabilised. There would be an environmental benefit from revegetating the riparian area with native trees and shrubs as this would improve the habitat value of the area.

As a result, there will be a local improvement in environmental outcomes due to the improved habitat value and some decrease in erosion activity in some areas, however the improvement in downstream water quality related environmental outcomes would be limited as significant areas of erosion areas (and sediment sources) would remain active.

Fencing and destocking of the riparian zone without more active erosion control measures to address existing erosion, would potentially be counterproductive as the considerable capital cost associated with fencing and revegetating would be at risk from the continued lateral erosion of gully sides into surrounding paddocks undermining fencing and revegetating efforts.

As a result, there will be a net detrimental impact on farm productivity due to the loss of areas of grazing and capital costs of fencing and revegetation, and ongoing costs of maintenance, management and lost grazing income.

3. Gully shaping and revegetation (no imported material)

Shaping the gully sides to reduce batter grade and revegetating these shaped areas with suitable pasture and grass species will reduce erosion and therefore water quality impacts. However, gully shaping and revegetation alone will not be fully effective in addressing erosion as revegetation without imported topsoil material will be ineffective in establishing a suitable groundcover (>80%) and therefore ineffective in stabilising all erosion.

Shaping without imported ENM material will also limit the final bank profile that can be achieved and increase the total area of disturbance associated with rehabilitation. Without the capacity to fill areas shaping will result in a concave profile which will tend to concentrate flows rather than dissipating (spreading) flows and reducing potential for erosion. Without the capacity to fill the eroded lateral gully areas, the battering of the gully side will need to consume additional areas of productive pastures in order to achieve a desirable batter grade of <2:1.

As a result, gully shaping and revegetation will reduce erosion and deliver an improvement to biodiversity and water quality however will not be effective at fully addressing all areas of erosion.

Shaping and revegetation alone will have some farm productivity benefits due to reducing rate/extent of some erosion area. The net impact to farm productivity is however considered to the negative due to the costs associated with shaping and revegetation and the loss of a greater area of productive agricultural land associated with battering to achieve <2:1 grade on gully sides.

4. Gully filling, shaping and revegetation

The shaping of the gully sides to reduce the batter grade to a more sustainable slope (<2:1 batter grade), filling of lateral gullies to recreate a suitable gully side profile, introduction of topsoil to enable a successful groundcover to be established and revegetation with deep rooted trees and shrubs to intercept subsurface groundwater flows will address all the aspects of the site which are contributing to erosion and water quality issues.

Th rehabilitation of the site using strategic lateral gully filling, shaping and revegetation will be effective in addressing all areas of active erosion and subsequently reducing sediment mobilisation off the site and water quality impacts. Revegetation with native trees and shrubs to intercept lateral subsurface flows will also increase biodiversity values of the site and provide an effective habitat linkage to scattered remnant native trees and shrubs upstream and downstream of the site.

The strategic filling of lateral gullies and revegetation of gully sides would stop the expanding impact on adjacent productive pasture paddocks and recover some periodic crash grazing

potential in the riparian area. Risk of injury to stock would be minimised due to reduced batter grades associated with shaping and filling of areas of vertical batters.

As a result, there will be a net positive impact on farm productivity due to the increased area available to grazing and low capital cost (to the landholder) involved with the upgrade of the erosion control works and rehabilitation of the gully.

The extent of earthworks and revegetation required would be considerable. As the filling of the gully will utilise clean waste material (VENM/ENM) from Canberra construction industry the contractors disposing of this material will contribute to project costs in conjunction with the landholder. There will be small ongoing cost associated with the maintenance of works. This cost offsetting makes the project viable and enables a comprehensive rehabilitation effort which maximises environmental and farm productivity benefits.

JUSTIFICATION FOR REHABILITATION

The rehabilitation of the gully will be beneficial for local and downstream environments as the stabilisation of the areas of active and continuing erosion will reduce the sediment and nutrient load entering the local and downstream flowlines, creeks and rivers. The reduction of sediment and nutrient load in creeks and rivers will improve aquatic habitats through reduced siltation of habitat features and improved water quality (reduced turbidity and nutrification). The reduction of sediment being mobilised will also reduce the potential for damage to downstream drainage infrastructure such as pipes, culverts and bridges, through siltation.

Revegetation with native trees and shrubs will provide biodiversity benefits locally and will increase regional connectivity of riparian zone habitat.

The rehabilitation of the gully by strategic gully filling combined with shaping and revegetation, will also improve the productivity and manageability of the property as a rural agricultural enterprise.

Activities which deliver both improved environmental and farm productivity outcomes are generally considered to be effective and efficient land management measures for rural lands.

PROJECT MANAGEMENT

The project, operation and site will be strictly managed to ensure desired outcomes are delivered with no perverse impacts on the environment or neighbouring properties. The management mechanisms to be used are detailed in the following sections.

Material Quality

All material to be transported to the site will be certified VENM or ENM to be sourced and delivered by a single contractor (Lentro). Certification will be checked by the full-time site manager (landowner). All staff including drivers and earth moving operators will be inducted onsite which will include specifying that all material to be delivered onsite is to be certified VENM or ENM.

Material Volume

Truck movements and volumes of material received will be managed through daily truck run sheets. These will specify the number and timing of truck movements as required in Council consent and detailed in a later section of this report. The truck run sheets will be managed by the onsite manager.

Site Access and Security

The site will be secured by a locked access gate to ensure no unauthorised access to the site. During the hours of operation, the site manager will be present to check deliveries against the truck run sheet, the certification and quality of material entering the site and driver behaviour.

Driver Behaviour

All drivers delivering material to the site will be the employees of contractor (Lentro) and will be inducted into the project which will include the behaviour of all operators. An contact number (site manager/landowner) will be provided to Council so that incidents of poor behaviour reported to Council can be forwarded to the project manager. The site manager will report incidents to the contractor. The contractor's driver disciplinary process will apply to operations on the site. NSW road rules will apply to all public roads and any breaches reported to the site manager will be forwarded to the relevant authorities for action.

Monitoring and Dust Mitigation

A protocol for managing dust will be developed prior to the commencement of the project which will include monitoring weather forecasts for periods of strong winds and wet weather and adjusting onsite operations to mitigate impacts from dust. A water cart will be available onsite during operating hours water from the existing dam will be utilised for dust suppression and soil moisture management for compaction. The contact number provided to Council will also be used for the reporting of dust or other impacts on neighbouring properties. The site manager will be responsible for addressing any issues in a timely manner.

Record Keeping

Records will be maintained by the site manager.

Records will include:

- VENM/ENM Certification
- Truck Run Sheets
- Safe Work Method Statements
- Induction Processes
- Incident Reporting
- Progress Reporting to Council and Regulators (as required)
- Complaints Management

Council and other regulatory authorities will be provided with contact details for the site manager to which all complaints can be referred. The site manager will be available to respond to all complaints or enquiries and will shut down or modify operations in accordance with any direction received by Council and or regulatory authorities. All complaints or enquiries received will be logged in a complaint register which will be kept by the site manager. All actions taken in response to complaints will also be recorded in this register.

Neighbour Relations

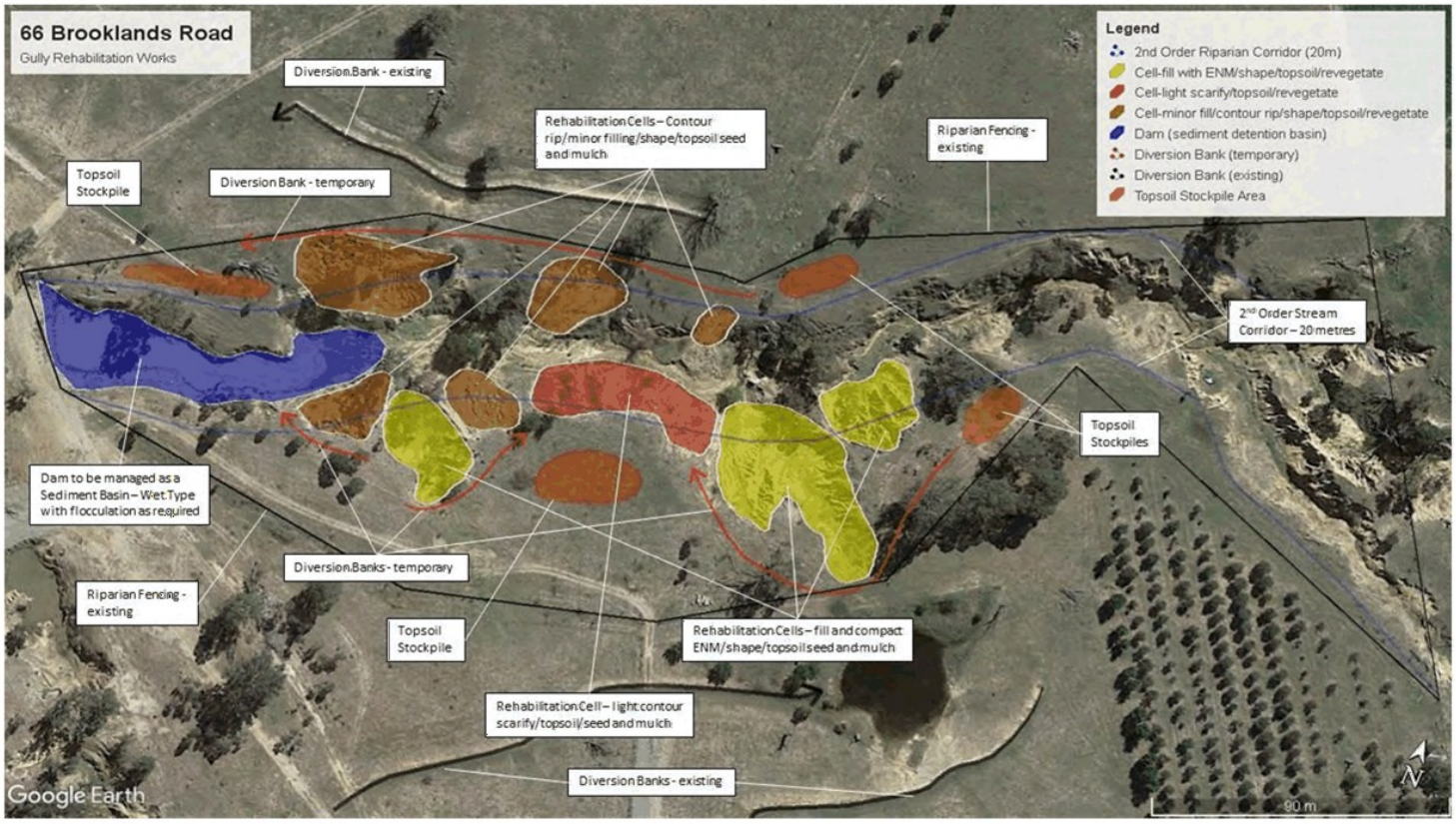
A register of neighbouring property holders will be established including contact details. The site manager will inform all neighbours on any issues which may impact their properties and are outside the normal operating procedures as approved by Council. The site manager will contact neighbouring properties at the inception of the project and provide a direct contact number for them to report any issues impacting their properties.

DESIGN AND CONSTRUCTION PRINCIPLES

The following design and construction principles are intended to minimise potential adverse environmental impacts and optimise the effectiveness of gully rehabilitation:

- The base of the watercourse will not be impacted by the rehabilitation activities
- Gully rehabilitation activities will be staged so that each section is progressively rehabilitated
- Runoff will be directed away from the lateral gully areas to be filled by the existing permanent sediment supplemented by temporary sediment and erosion control measures where required
- The existing dam will be used as sediment detention basin for the duration of gully rehabilitation works. This may include the use of flocculants as may be required to achieve acceptable water quality prior to downstream release
- Any fill material used will be certified ENM
- All disturbed areas will be topsoiled, fertilised and seeded on completion
- The rehabilitated area will be fenced to manage stock access and ensure revegetation is successful
- Trees and shrubs to be used in revegetation will be native and endemic to the area.

Figure 7: Rehabilitation Works Plan



REHABILITATION PLAN

The rehabilitation plan in **Figure 7** will be implemented in the following sequence to minimise the area of land disturbed at any one time thereby reducing erosion and sediment movement risk associated with rehabilitation works. The type and/or sequence of works detailed should only be varied in consultation with the author of this report.

STAGE 1 – REHABILITATE LATERAL GULLY CELLS

1. *Construct Diversion Banks Above Lateral Gullies To Be Filled*

Construct the new diversion banks located above the three area of lateral gully to be filled with ENM material. These banks will direct all upslope run-on water around the areas to be filled to a safe disposal area where they can be conveyed safely to the base of the gully, refer **Figure 7.**

The banks should be constructed according to the Standard Drawings included in **SD 5-5, Appendix 1** with a channel grade between 0.5 - 1%. The finished banks should be topsoiled and vegetated with suitable pasture species.

2. *Construct Sediment Fencing*

Temporary sediment fencing should be constructed adjacent to the low flow channel at the downstream toe of the lateral gully areas proposed to be filled with ENM. The location of the sediment fencing should extend across the entire cell to be filled and tied into the in-situ bank on either side of the area to be filled. The fence should be constructed out of the low flow channel of the main watercourse and should be parallel to the main creek. The sediment fence should be constructed according to the Standard Drawings included in **SD 6-8, Appendix 1.** The sediment fence should be maintained until revegetation on the filled and rehabilitated cell has reached >80% groundcover.

3. *Fill Lateral Gully Cells with ENM*

The eroded lateral gully should be filled with certified ENM material to create a flat to slightly convex (mounded) profile. Filling should progress from the upslope to downslope end of the gully section. Dumped material should spread in even layers on the gully floor and compacted by track rolling with a bulldozer and/or using a sheep's foot or vibrating drum roller to achieve levels close to field compaction. The height of fill material should be brought up evenly across the gully.

At the downstream end of the fill material should be tapered/battered to achieve a sustainable streambank profile of 2:1 or flatter batter grade which can be topsoiled and vegetated successfully. The dam should be managed according to requirements of a Wet Type Sediment Detention Basin, refer **Appendix 1**.

4. *Stockpile Topsoil*

Stockpiles of suitable topsoil material should be constructed in areas shown as suitable in **Figure 7.** These stockpiles should be constructed and managed according to **SD 4-1, Appendix 1.** Stockpiles should be a maximum of two metres in depth with stable batters of less than 2:1. A sediment fence should be installed downslope of each stockpile in accordance with **SD 6-8, Appendix 1.**

5. Topsoil and Revegetate

The finished area of ENM fill material should be topsoiled with a minimum 150mm of suitable loam overlaying 100mm of clay loam material. The topsoiled area should then be seeded with a suitable pasture seed mix and fertilised with a Starter type fertiliser. The seeded area should be mulched with suitable material to provide an immediate groundcover and encourage revegetation to establish.

6. Manage Dam as a Sediment Basin – Wet Type

Whilst the lateral gullies are being filled and rehabilitated the existing downstream dam should be managed as a Sediment Basin – Wet Type according to **SD 6-4, Appendix 1.** This includes flocculating turbid water to an appropriate quality prior to discharge to reinstate sediment detention capacity to required levels.

STAGE 2 – REHABILITATE GULLY SIDEWALLS

1. Construct Diversion Banks Above Gully Sidewall Areas To Be Rehabilitated

Construct the new diversion banks located above the three area of gully sidewall to be rehabilitated on the northern side of the main watercourse and the two sections on the southern side, refer **Figure 7**. These banks will direct all upslope run-on water around the areas to be rehabilitated to a safe disposal area where they can be conveyed safely to the base of the gully, refer **Figure 7.**

The banks should be constructed according to the Standard Drawings included in **SD 5-5, Appendix 1** with a channel grade between 0.5 - 1%. The finished banks should be topsoiled and vegetated with suitable pasture species.

2. Construct Sediment Fencing

Temporary sediment fencing should be constructed adjacent to the low flow channel at the toe of the gully sidewall areas to be rehabilitated. The sediment fencing should extend parallel to the low flow along the entire section to be rehabilitated. The sediment fence should be constructed according to the Standard Drawings included in **SD 6-8, Appendix 1.** The sediment fence should be maintained until revegetation on the rehabilitated cell has reached >80% groundcover.

3. a) Rehabilitate the Gully Sidewalls with Minor ENM Filling and Shaping

The deeply eroded sections of gully sidewall should be filled with certified ENM material to create a flat to slightly convex (mounded) profile. The area should be contour ripped to ensure imported fill material is properly integrated into in-situ material. Imported material should be spread in even layers and compacted by track rolling with a bulldozer.

The fill material should be battered to achieve a sustainable streambank profile of 2:1 or flatter batter grade which can be topsoiled and vegetated successfully.

b) Rehabilitate the Gully Sidewalls with Minor Shaping

The moderately eroded section of gully sidewall, refer **Figure 7**, should be lightly scarified to smooth out any minor erosion rills and to ensure topsoil material is properly integrated into in-situ material. The scarified area should be left rough prior to the spreading of topsoil.

4. Stockpile Topsoil

Stockpiles of suitable topsoil material should be constructed in areas shown as suitable in **Figure 7.** These stockpiles should be constructed and managed according to **SD 4-1, Appendix 1.** Stockpiles should be a maximum of two metres in depth with stable batters of less than 2:1. A sediment fence should be installed downslope of each stockpile in accordance with **SD 6-8, Appendix 1.**

5. Topsoil and Revegetate

The finished area of shaped rehabilitated gully sides should be topsoiled with a minimum 150mm of suitable loam overlaying 100mm of clay loam material. The topsoiled area should then be seeded with a suitable pasture seed mix and fertilised with a Starter type fertiliser. Stock should be excluded from the area whilst the vegetation is establishing. The seeded area should be mulched with suitable material to provide an immediate groundcover and encourage revegetation to establish.

6. Manage Dam as Sediment Basin – Wet Type

Whilst the gully sidewall areas are being filled and rehabilitated the existing downstream dam should be managed as a Sediment Basin – Wet Type according to **SD 6-4, Appendix 1.** This includes flocculating turbid water to an appropriate quality prior to discharge to reinstate sediment detention capacity to required levels.

GULLY FILLING MATERIAL

The fill material to be used in the rehabilitation of the gullies will be restricted to certified ENM. This material will be sourced from Canberra Construction sites. Records of the ENM certification of all material to be used on site will be maintained by the proponent and provided to Council as required. The material will be conveyed to the site in contractor (Lentro) rigid truck and dog trailer combinations and managed onsite by contractors' plant and equipment.

Topsoil to be used in the final rehabilitation of the gullies will mostly be suitable imported material which will be sourced by the contractor.

The volume of ENM material required to fully rehabilitate the gullies has been estimated by aerial photo interpretation and site measurements and assessment. Detailed survey has not been undertaken and is not considered necessary given the small scale of the project.

A factor of 20% has been used to account for the re-compaction of loose fill material when placed in the gully.

The volume of sub and topsoil material required for capping and revegetating the site has been estimated by measuring the total area to be rehabilitated and multiplying this by 0.2m consisting of approximately 100mm depth of subsoil finished with minimum 150mm of topsoil.

The results of this exercise are presented in **Table 1** below.

Table 1:

Gully Area	Excavation Volume to be Filled (m3)	Compaction Factor (20%)	Transported Volume Required (m3)	
Deep Lateral Gullies	4,123	824.6	4,948	
			[Tonnes	**7,422]**
Eroding Gully Sides	1,123	224.6	1,348	
			[Tonnes	**2,022]**
Subtotal Volume (m3)				**6,296**
Subtotal Volume (tonnes)				**9,444**
Subsoil/Topsoil Volume (m3)– [5887m2 X 0.2m] X 1.2				**1,413**
Subsoil/Topsoil Volume (tonnes)				**2,119**
			Total Volume of Fill Material Required	**7,709**
			Total Tonnes of Fill Material Required	**11,564**

TRUCK AND PLANT MOVEMENTS

Truck and plant movements have been estimated based on the fill volumes detailed in the previous section and the capacity of the onsite works crew to assimilate material as part of the staged gully rehabilitation program.

The results are presented in **Table 2** below.

Table 2: Truck Movements

Total Volume of ENM Required	**7,709m^3**
Total Weight of ENM Required	**11,564 tonnes**
Average Truckload	**27 tonnes** (@18m^3)
Total Truck Movements	**428 (approximate)**
Annually (based on one-year timeframe)	**428**
Weekly (average based on 40 weeks/year)	**10**
Daily (average based on 200 days/year)	**2**
Maximum Daily Truck Movements	**8**

A project lifecycle of approximately one year from commencement has been adopted. This may be extended due to weather delays, time required for the construction of associated soil and water management works time required for topsoiling and revegetation activities, and the time required for supporting infrastructure works on access track.

Plant and equipment operating on the site at various times will include a bulldozer, roller, watercart, bobcat, excavator and tractor (+ implements), in addition to the trucks delivering the ENM material for gully filling. The site will be controlled by the site manager who be responsible for ensuring a safe working environment. Security of the site will also be maintained by the site manager who will ensure that all material delivered to site is in accordance with Council and other regulatory requirements and that no illegal dumping activities occur.

The closest residences to the rehabilitation site are:

- 151m southeast to the site manager/landowner's dwelling and
- 563m southwest
- 641m north
- 718m west
- 727m northeast to dwellings on adjacent properties

The proposed hours of operation of the site (including truck movements) will be between 9am and 4pm on weekdays. This will minimise noise impacts on neighbours and limit traffic during peak vehicle movement times associated with school buses and commuter traffic.

APPROVALS

Advice has been sought from the Natural Resource Access Regulator (NSW Department of Primary Industry) on whether a Controlled Activity Works Approval (CAA) is required to undertake the gully rehabilitation activities proposed. Advice provided stated a CAA would be required and the Development Application should therefore be treated as an integrated development.

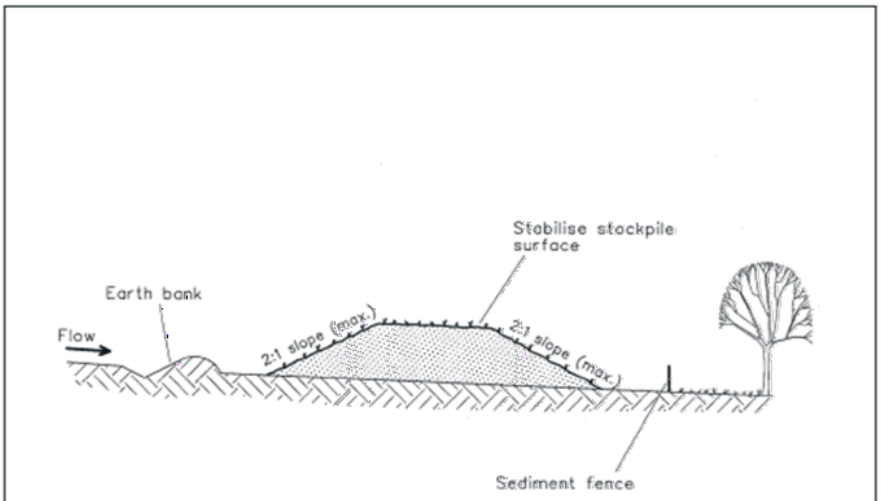
Development Consent from Yass Valley Council is required and is being sought through the provision of this report and the accompanying Yass Valley Council Development Application and supporting Statement of Environmental Effects.

CONCLUSIONS

It is considered that the proposal to rehabilitate the areas of existing gully erosion will deliver considerable environmental and farm productivity benefits. It is further considered that any potential adverse impacts will be adequately addressed provided activities are undertaken in accordance with the measures outlined in this report.

APPENDIX 1:

Erosion and sediment control works will be designed and constructed in accordance with *Managing Urban Stormwater: Soils and Construction, Volume 1 (Landcom, 2004)* as detailed in the following standard drawings:



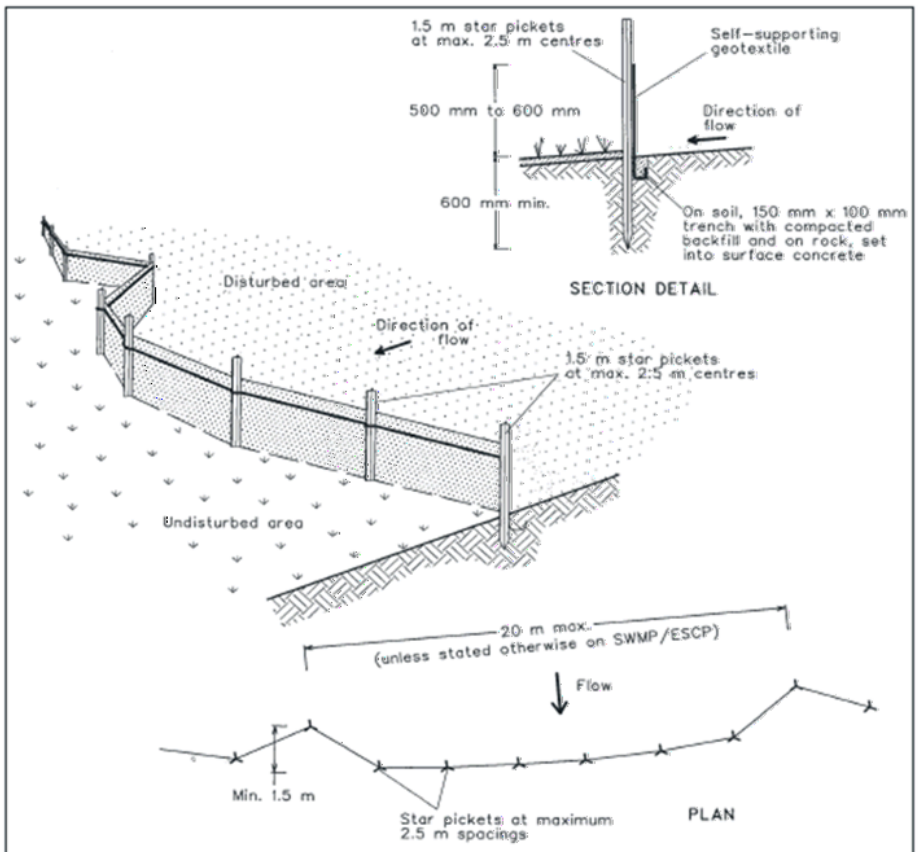
Construction Notes

1. Place stockpiles more than 2 (preferably 5) metres from existing vegetation, concentrated water flow, roads and hazard areas.
2. Construct on the contour as low, flat, elongated mounds.
3. Where there is sufficient area, topsoil stockpiles shall be less than 2 metres in height.
4. Where they are to be in place for more than 10 days, stabilise following the approved ESCP or SWMP to reduce the C-factor to less than 0.10.
5. Construct earth banks (Standard Drawing 5-5) on the upslope side to divert water around stockpiles and sediment fences (Standard Drawing 6-8) 1 to 2 metres downslope.

STOCKPILES **SD 4-1**

Stockpiles will be restricted to topsoil material and will be located outside drainage depressions, watercourses and the flood zone. Stockpiles will be managed according to Standard Drawing SD 4-1.

APPENDIX 1



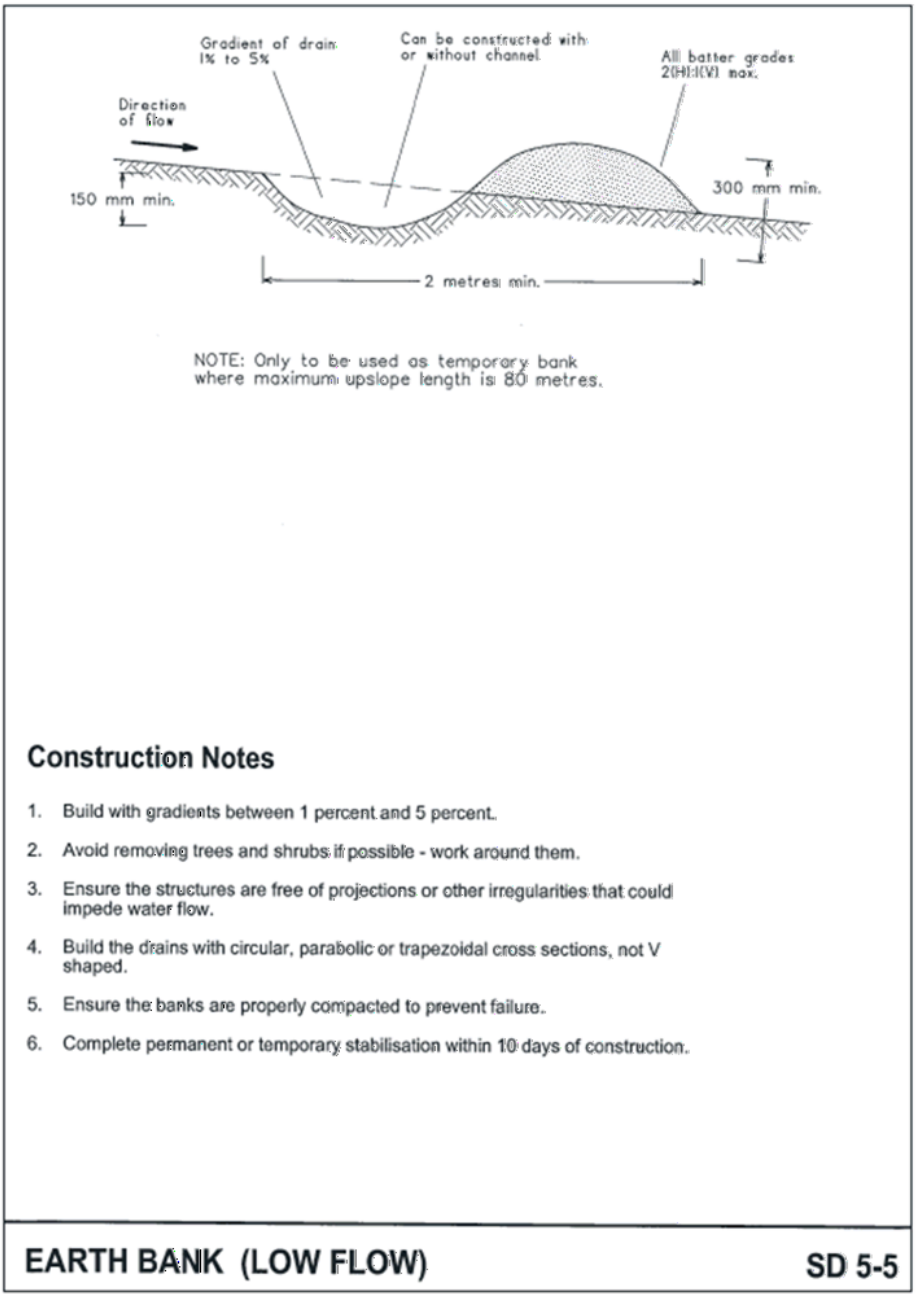
Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.
2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.
5. Join sections of fabric at a support post with a 150-mm overlap.
6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE **SD 6-8**

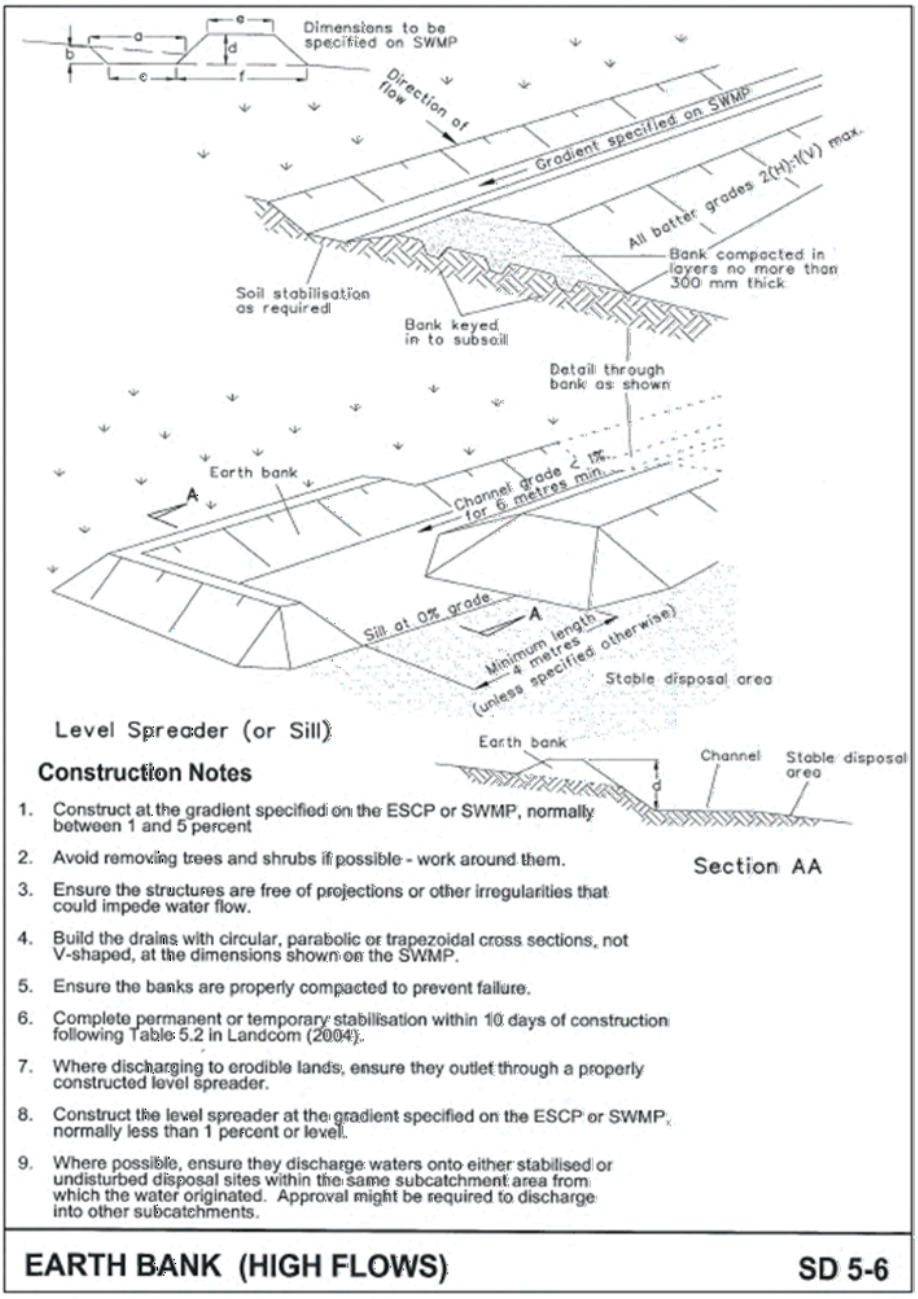
Sediment fencing below topsoil sites will be constructed according to Standard Drawing 6-8.

APPENDIX 1



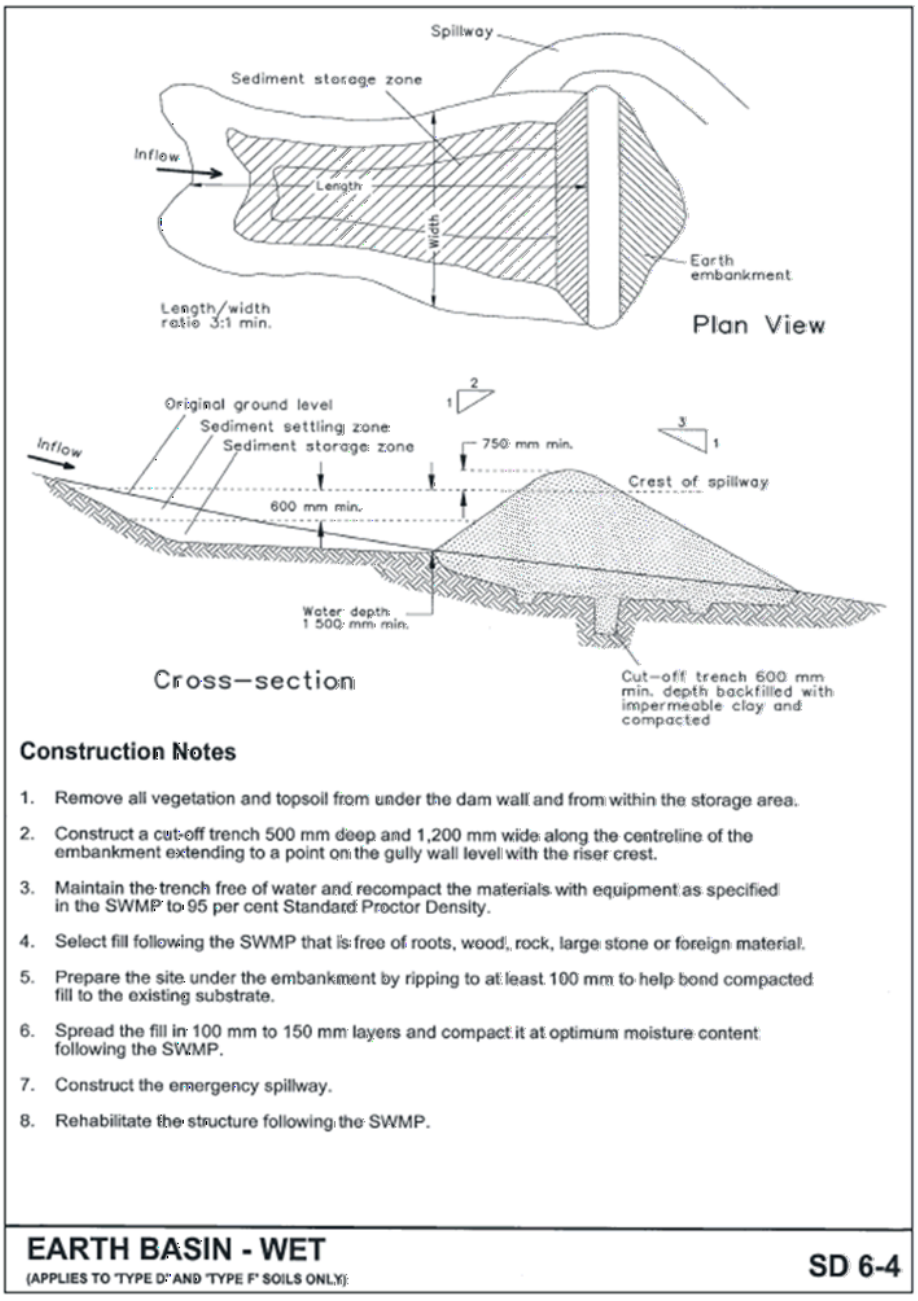
Diversion banks above topsoil stockpile sites will be constructed according to Standard Drawing SD 5-5.

APPENDIX 1



Diversion Banks 1 and 2 (refer Figure Aa2) will be constructed according to Standard Drawing SD 5-6.

APPENDIX 1



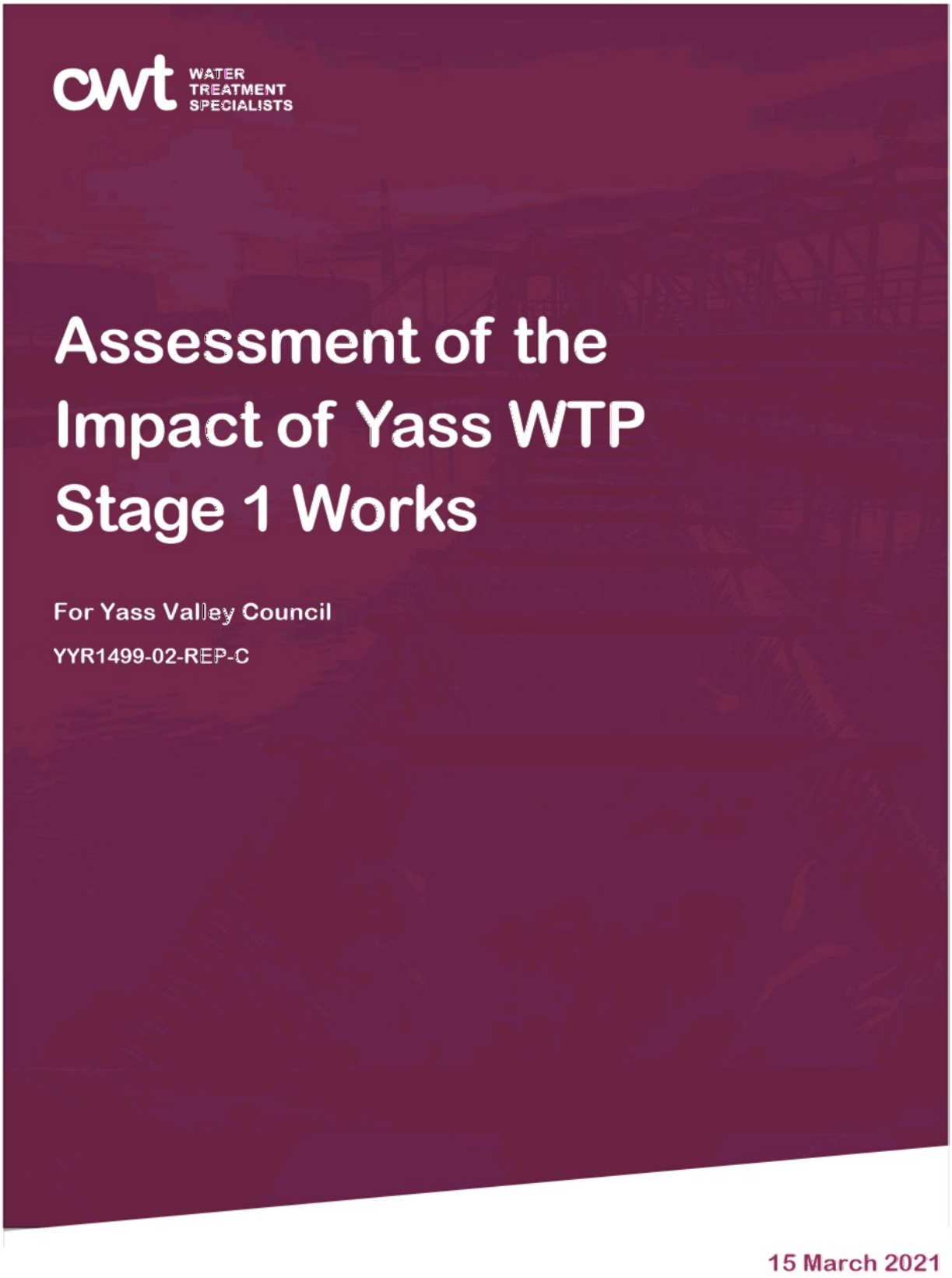
Construction Notes

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Construct a cut-off trench 500 mm deep and 1,200 mm wide along the centreline of the embankment extending to a point on the gully wall level with the riser crest.
3. Maintain the trench free of water and recompact the materials with equipment as specified in the SWMP to 95 per cent Standard Proctor Density.
4. Select fill following the SWMP that is free of roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Construct the emergency spillway.
8. Rehabilitate the structure following the SWMP.

EARTH BASIN - WET
(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

SD 6-4

The existing dam will be managed according to Standard Drawing SD 6-4.


cwt
WATER
TREATMENT
SPECIALISTS
Assessment of the Impact of Yass WTP Stage 1 Works
For Yass Valley Council
YYR1499-02-REP-C
15 March 2021

Assessment of the Impact of Yass WTP Stage 1 Works

For Yass Valley Council

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Issue Date	Revision	Issued to	Prepared by	Reviewed by	Comments
22/02/2021	A	YVC	EK	BAM	Preliminary Draft for discussion
01/03/2021	B	YVC	EK	BAM	Draft for discussion
15/03/2021	C	YVC	EK	JO/BAM	Final draft

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Contents

Figures

Tables

1 Introduction

City Water Technology (CWT) has been engaged by Yass Valley Council (YVC, Council) to complete an independent peer review of the proposed concept design for a new Yass Water Treatment Plant (WTP) as prepared by Hunter H_2O (HH_2O). The concept design has been prepared based on an options investigation initially undertaken by Public Works Advisory and further developed by HH_2O. This design has been presented to the Department of Planning, Industry, and Environment (DPIE) for approval to proceed, however, queries have been raised about operational aspects of some of the proposed processes. To enable the project to proceed while a complete peer review of the proposed concept design is completed, Stage 1 upgrades to improve the water quality and plant capability in the short term have been identified.

This report defines the raw water quality envelopes to be considered for treatment at the WTP under different operating conditions and provides commentary on the expected effectiveness of the proposed Stage 1 Works in addressing shortfalls in the current treatment process. This assessment of the impact of Stage 1 works will inform the timeline and guide the review of the implementation of future upgrades.

1.1 Background

The existing WTP was built in approximately 1990 and is located on Cooks Hill Rd, close to the town centre of Yass, NSW. The plant draws surface water from Yass Dam on the Yass River for treatment.

Figure 1-1: Yass WTP Location

The WTP employs a conventional treatment processes comprising of:

- Raw water pH/alkalinity adjustment with soda ash (when required);
- Coagulation with alum;
- Oxidation for manganese removal by pre-chlorination;

- Powdered activated carbon (PAC) dosing for taste and odour removal (when required);
- Dissolved air flotation (DAF) clarification;
- Filtration in 4 mono media (sand) rapid gravity filters;
- Post pH adjustment with soda ash;
- Fluoridation with sodium fluorosilicate;
- Disinfection with chlorine; and
- Sludge/wastewater management with drying lagoons.

The WTP has a maximum design raw water flow of 13 ML/day (165 L/s) and is operated at a fixed flow rate. Treated water production capacity is approximately 11.9 ML/day over 22 hours. Production is matched to demand by adjusting the hours the plant is run each day, with limited turndown achieved by manual restriction of the inflow by throttling.

Council receives numerous customer complaints about colour, taste, and odour resulting from shortcomings in the existing treatment process. Poor performance during storm events coupled with limited ability to buffer changes in raw water quality has also led to several boil water notices being issued by NSW Health for breaches of treated water turbidity targets following significant rainfall. As a result, the media has been calling for Council to invest in a robust WTP capable of dealing with the varied influent water quality typically experienced at Yass WTP.

Figure 1-2 Orange-brown water in Yass resident's home (Published in Canberra Times, 25th January 2021)

The Yass WTP upgrades project aims to address these concerns by completing a number of upgrades across two stages. Stage 1 consists of immediate works to address variability of raw water quality and to reduce taste, odour, and colour issues. Stage 2 consists of further upgrades, the extent of which are to be finalised pending the outcomes of the peer review in liaison with Council and DPIE.

Figure 1-3 Yass WTP Site Layout

HH_2O, YVC, and DPIE have previously completed an options assessment, options assessment workshop, and value management workshop and are at the concept design stage. In the options assessment, 7 options were identified as possibilities for treatment. Option 7, a new WTP, has been identified as the preferred option by HH_2O and YVC.

1.2 Catchment Classification

The Yass WTP catchment has not been formally categorised by way of a Tier 1 Source Water Assessment however, HH_2O has estimated it to be Category 4: Unprotected Catchment due to the following risk factors:

- Sheep and cattle in the inner catchment area;
- Recreational use of Yass Dam; and
- Upstream communities and onsite sewer management systems within the catchment with the potential to impact river quality.

The potential for wastewater treatment plants nearby to discharge to the Yass River in the future has also been identified as a concern. The conditions and activities above suggest that the water source has the potential for high pathogen loads, particularly due to the recreational use and animal presence near the dam. Based on these classifications, the minimum pathogen log reduction required for treatment of a Category 4 source are:

- Bacteria = 6.0-log
- Viruses = 6.0-log
- Protozoa = 5.5-log

The WTP in its current state is not capable of achieving the required pathogen reduction for a Category 4 source based on the available performance data. To achieve these pathogen removal targets the following treatment processes would be required:

Table 1-1: Current LRV Shortfalls and Treatment Processes Required

Scenario		Bacteria LRV	Virus LRV	Protozoa LRV	Comment
Current Configuration with Stage 1 Upgrades	LRV Credits	6.0	6.0	3.5	C.t >15mg/L
	Category 4 Difference	**0**	**0**	**-2.5**	**Protozoa (Crypto) shortfall**
Stage 1 Upgrades & Refurbishments (Option 1)	LRV Credits	6.0	6.0	8.5	C.t >15mg/L
	Category 4 Difference	**0**	**0**	**0**	**Satisfactory – with UV addition**
Preferred design – additional UV disinfection (Option 7)	LRV Credits	10.0	6.5	8.5	Strict critical limits UV dose >40 mJ/cm^{2}*
	Category 4 Difference	**+4.0**	**+0.5**	**+2.5**	**Satisfactory**

*Note: the minimum UV dose has used for comparison, higher UV doses give higher LRV credits

This shortfall is addressed with any of the potential Stage 2 treatment options (Options 1-7) and additional barriers are included in HH_2O and YVC's preferred design (Option 7).

During significant rainfall events elevated *E. Coli* levels above 20,000 cells/mL (the limit for drinking water sources) have been measured at the plant.

CWT recommends YVC undertake a sanitary survey and catchment assessment to identify sources of pollution and consider strategies for improved management of these in future.

Typically, a shortfall in protozoa LRV is addressed by the addition of UV disinfection and is to be addressed in Stage 2 upgrades. This has been included by HH_2O in proposed preferred design (Option 7).

1.3 Treated Water Targets

Treated water targets have been identified by HH_2O and YVC and are aligned with ADWG recommendations and best practice targets. A summary has been included for reference.

Table 1-2: Recommended Treated Water Quality Targets

Parameter	Units	ADWG		Treated Water	
		Health	Aesthetic	95th%ile	Absolute
Turbidity	NTU	≤ 1 / ≤ 0.2 *	≤ 5	≤ 0.15 ex filter	≤ 0.3 ex filter
True Colour	HU	-	≤ 15		≤ 5

Parameter	Units	ADWG		Treated Water	
		Health	Aesthetic	95th%ile	Absolute
Total Manganese	mg/L	≤ 0.5	≤ 0.1		≤ 0.02
Total Iron	mg/L	-	≤ 0.3		≤ 0.1
Total Aluminium	mg/L	≤ 0.2	-	≤ 0.1	≤ 0.2
Dissolved Organic Carbon	mg/L				>50% removal
pH		-	6.5 – 8.5		7.5 – 8.5
Fluoride	mg/L				0.95 – 1.05
Free Available Chlorine	mg/L	≤ 5 >0.2	-		Setpoint ± 0.2
Chlorine C.t	mg.min/L				≥ 15
Disinfection By-products	mg/L				<0.25
Total Hardness	mg/L as $CaCO_3$		≤ 200		≤ 200
Taste & Odours					N/A

*** ADWG (2011) turbidity targets are ≤ 1 NTU for effective disinfection and ≤ 0.2 NTU for effective filtration of *Cryptosporidium* and *Giardia* cysts. Stricter filtered water turbidity targets are preferred under the Health Based Targets**

These treated water targets have been developed through discussions between YVC and HH_2O.

2 Water Quality Analysis

2.1 Overview

Typically, the influent water quality at Yass WTP is reasonably good. However, during dry periods and significant rainfall events the water quality varies significantly and becomes difficult for the current WTP to handle. The following parameters are of particular concern and will need to be considered further in the design of the WTP upgrades.

- Turbidity – turbidity remains relatively low (~20 NTU) for most of the year, however, following significant rainfall events it can spike to upwards of 1,000 NTU. Characterisation of turbidity events is investigated further in Section 4.
- Hardness & Alkalinity – hardness increases over time during periods of low rainfall. It was not monitored prior to the 2020 monitoring program, however, HH_2O and CWT have used 2003-2019 treated water hardness results for analysis. Typically, hardness is between 100 and 300 mg/L as $CaCO_3$ and increases to 320 – 360 mg/L as $CaCO_3$ during drought conditions. The ADWG recommends an aesthetic limit of 200 mg/L as $CaCO_3$.
- pH – pH fluctuates depending on rainfall. During periods without significant rainfall, pH increases up to 8.4 before dropping below 7.0 after significant rainfall.

- Iron & Manganese – iron and manganese levels increase over periods without rainfall and are typically flushed through the WTP following significant rainfall and dam turnover. Manganese in particular is an issue at Yass WTP as treated water has historically failed to meet ADWG (aesthetic) guidelines of < 0.1 mg/L and has led to frequent customer complaints about colour and odour. Manganese peaks of up to 0.7 mg/L during significant rainfall events have been seen.
- *E. coli* – the Yass water supply is classed as a Category 4 catchment. *E. coli* typically increases following significant rainfall as a result of run off into the dam and river. Measured concentrations can exceed 20,000 cells/mL which is considered not suitable for drinking water accruing to the Manual for the Application of Health Based Targets (HBT) for Drinking Water Safety (WSAA, 2015).
- Algae – totall algae biovolumes and potentially toxic blue green algae counts indicate there is higher levels of potentially toxic blue green algae present in the dam in summer months. Total blue green algae concentrations can be >10,000 cells/mL. At this level there is the potential for algal blooms to occur.
- Taste & Odour Compounds – relatively low levels of MIB and Geosmin have been detected in the Yass Dam during 2020 water quality monitoring. Elevated levels are experienced following significant rainfall events, indicating accumulation over time and dam turnover flushing these compounds through the WTP. These high levels are typically between 11.2 – 12.3 ng/L for Geosmin and 4.0 – 10.6 ng/L for MIB. The ADWG recommends a combined limit for 10 ng/L.
- Colour – true colour (23-27 HU) has only been monitored during 2020 rainfall events.
- Organics – TOC and DOC levels in the dam increase following rainfall. HH$_2$O has indicated this is likely due to rainfall washing leaves, debris, and soil into the catchment.

2.2 Raw Water Quality Envelopes

CWT have identified three scenarios of interest at Yass WTP: typical, drought, and significant rainfall. The development of the water quality envelopes for the key water quality parameters experienced at the existing WTP determined by a review of the water quality during these periods.

Typical water quality has been defined as the 10th – 90th percentile water quality data of all of the parameters of concern. It typically includes periods of occasional low to moderate rainfall.

Drought water quality has been defined as the high and very high levels of parameters which are of concern during drought periods. These parameters include algae, pH, and hardness.

Significant rainfall water quality has been defined as the high and very high levels of parameters which are of concern during these periods. These parameters include turbidity, organics, iron, manganese, pH, MIB, Geosmin, *E. Coli* and true colour.

2.2.1 Typical

Typical water quality indicates that for the majority of the time raw water is good and can be treated to sufficient standards by the existing Yass WTP.

Table 2-1 Typical RWQ envelope

Parameter	Units	10th %ile	50th %ile	90th %ile	Comments
Turbidity	NTU	5.9	22.8	40.9	July 2012- December 2020 RWQ log sheets monitoring
DOC	mg/L	8.8	14.1	20.5	2020 monitoring program
TOC	mg/L	10.9	17.4	25.6	2020 monitoring program
Conductivity	mS/m	23.8	42.0	75.1	2020 monitoring program
Total Iron	mg/L	0.17	0.88	2.33	RWQ Log Sheets monitoring July 2012- Dec 2020 NB: not monitored May 2019 - Feb 2020
Total Manganese	mg/L	0.10	0.23	0.38	
pH	-	7.1	7.5	8.0	RWQ Log Sheets July 2012- Dec 2020
Total Hardness	mg/L as $CaCO_3$	100	190	300	2003-2019 treated water quality monitoring
Geosmin	ng/L	0.5	3.2	6.2	2020 monitoring program
MIB	ng/L	0.5	1.6	2.0	2020 monitoring program
E. coli	CFU/100 mL	11	3209	1376	2020 monitoring program

2.2.2 Drought

During periods of drought, hardness is of particular concern as it increases to >300 mg/L. Numerous complaints have been received from businesses and consumers in Yass. The ADWG recommends an aesthetic limit for hardness of 200 mg/L. Algae, while elevated to potential bloom levels during drought conditions, does not pose a significant threat to the treatment process at the concentrations historically observed.

Table 2-2 Drought RWQ envelope

Parameter	Units	High (95th%ile)	Very High (98th%ile)
Potentially Toxic Blue Green Algae	cells/mL	10,014	10,473
Total Algae Biovolume	mm^3/L	9.1	10.7
pH	-	8.4	8.4
Total Hardness	mg/L as $CaCO_3$	320	360

2.2.3 Significant Rainfall

The main concerns during significant rainfall are elevated turbidity and manganese levels. Turbidity spikes above 200 NTU cannot be deal with by the current plant. Manganese levels of 0.5-0.7 mg/L require additional treatment.

Table 2-3 Significant rainfall RWQ envelope

Parameter	Units	High (95th%ile)	Very High (98th%ile)
Turbidity	NTU	51.2	720[1]
DOC	mg/L	21.5	21.6
TOC	mg/L	26.5	31.9
Total Iron	mg/L	5.2	10.7
Total Manganese	mg/L	0.5	0.7
pH[2]	-	6.9	6.9
Geosmin	ng/L	11.2	12.3
MIB	ng/L	4.0	10.6
E. coli	CFU/ 100 mL	10,500	36,000
True Colour	Hazen	23	27

[1] Very High Turbidity is based on the 99.9th percentile value

[2] High and Very High pH values are based on the 5th and 2nd percentiles respectively

3 Evaluation of Stage 1 Works

3.1 Stage 1 Scope

The following activities are proposed to be completed in Stage 1 works:

- Installation of a bubble plume destratification system;
- Installation of a permanent potassium permanganate ($KMnO_4$) dosing system;
- Installation of a raw water pump with variable speed drive (VSD) *OR* upgrading of current raw water pumps with the addition of a VSD;
- Upgrades to the dosing capacity and safety aspects of the existing soda ash (Na_2CO_3) system; and
- Updates to monitoring, operations, and maintenance documentation.

The goals of this work are to:

- Improve the performance of the existing WTP;
- Address urgent WTP shortcomings;
- Improve treated water quality; and
- Reduce treated water manganese concentrations.

3.2 Destratification

The goal of destratification is to improve the influent water quality by smoothing the peaks of manganese, iron, colour, and algae received by the WTP during significant rainfall and drought

events. A bubble plume destratification system will be installed with the treatment goal of achieving at least 4 mg/L of DO throughout the vertical profile of the dam. As the dam destratifies, online monitoring of DO at various dam depths is essential to ensure the system is operating satisfactorily. As noted by DPIE, YVC should aim for a DO level of 4 mg/L. This should be monitored at a point as deep as possible in the dam.

CWT notes that Yass Dam used to have WEARS mixers in the dam for destratification however they have been washed away in recent floods. It was also planned to monitor DO in the 2020 monitoring program however this was not done. Temperature and DO readings are required along with both soluble and total manganese to effectively monitor dam eater quality. These must be monitored at a location most representative of the water at the offtake.

Typically, sampling is performed monthly with increased sampling during high risk periods (summer and change of season) and/or when an elevated reading is recorded.

Online monitoring of manganese is useful to implement as an indicative tool for operators to gauge the effectiveness of bubble plume destratification and potassium permanganate dosing. However, current analysers require numerous chemicals, frequent checking, and calibration, and could be potentially challenging to implement and operate.

It is likely that when bubble plume destratification is turned on peaks in manganese concentrations will be seen in the raw water entering the plant. It is important YVC develop an operations strategy to ensure the bubble plume is operating during strategic periods to smooth manganese peaks.

Online monitoring of DO from near the bottom of the dam is highly recommended to enable proper management of the destratification system.

The installation of a bubble plume destratification system has the potential to reduce peaks in raw water manganese concentrations, colour, and taste and odour compounds. It also has the potential to reduce algae formation during warmer months and drought periods.

3.3 Potassium Permanganate Dosing

A permanent potassium permanganate dosing system will be implemented at Yass WTP with the goal of removing manganese to <0.02 mg/L. For this system to work effectively, soluble manganese must be fully oxidised prior to flocculation for it to be removed. CWT has found that a contact time of at least 3 minutes (at an optimum pH of 8.5) is required, but a preferred contact time of at least 15 minutes (especially at a low pH of 7 – 8.5) is recommended.

Following discussions with YVC, CWT has confirmed that the current contact time following $KMnO_4$ dosing for the existing WTP is less than 1 minute. As such, the soluble manganese will not have precipitated prior to flocculation and will only partially be removed.

The installation of a permanent $KMnO_4$ dosing system is supported and we understand will improve operability and operator safety. However it is unlikely to improve manganese removal performance without also increasing oxidation time prior to coagulation. CWT strongly recommends YVC install a contact tank to ensure adequate manganese removal.

3.4 Flow Smoothing

Currently Yass has two raw water feed pumps that operate via a duty/stand-by configuration. As a part of Stage 1 works YVC intends to either retro-fit VSDs to the existing pumps or install new raw water pumps with VSDs. This will allow variable speed operation of the raw water pumps and allow the plant to operate at reduced flow rates. Reduced flow rates will assist during periods of low demand and significant rainfall events.

However, YVC anticipates that over time demand will increase as population at Yass grows and the Murrumbateman village is connected to the water supply network. Exact population projections are pending confirmation following the Integrated Water Cycle Management (IWCM) strategy update.

The current solids removal process at the existing WTP of dissolved air flotation followed by single media filtration was designed for a maximum raw water turbidity of 100 NTU. However, this is not feasible for periods of heavy rainfall.

CWT agrees that downrating the plant during periods of poor raw water quality and low demand will improve water quality. However, there is a risk during very poor water quality events that the WTP will need to be downrated to below customer demand to meet treatment targets and therefore requires upgraded and/or additional processes to operate under these conditions. There are also WQ events that are outside the capability of the downrated WTP.

3.5 Soda Ash Dosing Upgrades

The current soda ash dosing system is unable to achieve dose rates required to reach the optimum pH for manganese removal, alkalinity addition following rain events, and optimum alum coagulation (when required). Performance and maintenance issues identified by HH_2O will be addressed during the Stage 1 works to ensure required operation can be achieved.

Soda ash dosing upgrades will ensure optimum pH for manganese removal and coagulation can be achieved, improving the overall suspended solids removal and thus the treated water quality.

3.6 Distribution System Improvements

Recent colour events experienced by consumers have been traced to manganese build up in the distribution system. To address these issues, Stage 1 works will include the following:

- Monitoring of manganese concentrations throughout the distribution network; and
- Identification of manganese hotspots and the planning and completion a flushing/cleaning programme.

CWT understands YVC have begun this exercise and identified that locations of frequent customer complaints are linked to locations of the distribution network which have not been flushed for up to 3 years.

CWT recommends YVC implement a management strategy to ensure the reticulation network is flushed periodically to avoid manganese and biofilm build-up.

3.7 Summary of Stage 1 Impact on WTP Capability

In summary, the proposed Stage 1 upgrades will address some performance issues to an extent, however, there are further improvements required to achieve the targets of these upgrades.

Table 3-1 Summary of the effects and further improvements required following Stage 1 upgrades

Upgrade	Effect	Further Improvements
Bubble Plume Destratification	Has the potential to reduce the peaks of some water quality parameters and provide some control over BGA blooms.	The expected raw water quality (with smoothed peaks in some parameters) will remain significantly outside of the plant's treatment capability. Turbidity will not be significantly affected and still needs to be addressed by further works in Stage 2.
Raw Water Pump Station Add VSDs	Allows the plant to be run at lower flow rates.	A raw water storage tank could provide additional buffering of poor water quality – and for PAC/ oxidation contact time.
Soda Ash Dosing	Will allow Yass WTP to achieve optimum pH levels during heavy rainfall periods.	
$KMnO_4$ Dosing	Installation of a permanent dosing system.	Oxidation Contact Tank and online manganese monitoring are still required to achieve sufficient removal and effectively monitor performance.
Distribution System Improvements	Strategic flushing of the reticulation will reduce the likelihood of colour events.	

4 Key Water Quality Parameters Investigation

4.1 Turbidity Investigation

As part of discussions with YVC, turbidity has been identified as a key parameter of concern as during heavy rainfall and flooding events turbidity spikes to levels well above the 95th percentile data values (several hundred NTU) and persists in the water supply at high levels for days before returning to more treatable levels, and often weeks before returning to pre-rainfall levels. Characterisation of the influent water quality during significant rainfall events is difficult as it requires looking beyond the 99th percentile data to capture true peaks. A review of turbidity between July 2012 and December 2020 identified five major turbidity events with spikes above 200 NTU.

Focusing on these five turbidity events the following has been identified.

Table 4-1 Observations from five significant turbidity events

	T1	T2	T3	T4	T5	Average
Days above 200 NTU	4	5	4	4	2	4
Days above 100 NTU	5	5	5	5	3	5
Days above 50 NTU	13	18	11	7	7	11
Maximum Turbidity (NTU)	495	729	777	1058	639	740
Turbidity after 24 hours (NTU)	390	485	763	541	395	515
Reduction in Turbidity in first 24 hours (%)	21	33	2	49	38	29

The turbidity is typically above the treatable limit for DAF followed by single media filtration (200 NTU) for 4 days. It is above the design maximum (100 NTU) for 5 days and above optimum treatable turbidity (50 NTU) for 11 days. The average maximum turbidity peak is 740 NTU.

In addition to having limited treatment effectiveness at or above the design capacity of 100 NTU, WTP performance is further impacted when these conditions persist for extended periods or reoccur within weeks. The maximum turbidity that a WTP utilising a DAF clarification process followed by single media filtration could treat is anecdotally in the order of 200 NTU, with an influent turbidity of <50 NTU being preferred for optimum DAF performance. To successfully treat water with high turbidity, the WTP in its current state would need to be downrated significantly to increase air/water interface for effective flotation.

The graphs below illustrate the gradual reduction in turbidity after each of the five rainfall events analysed.

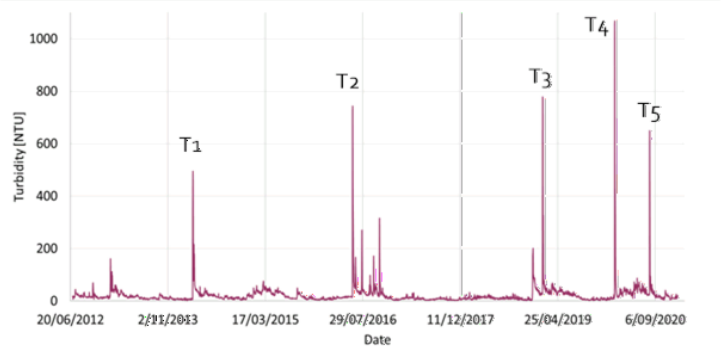


Figure 4-1 Turbidity fluctuations over July 2012-December 2020 period

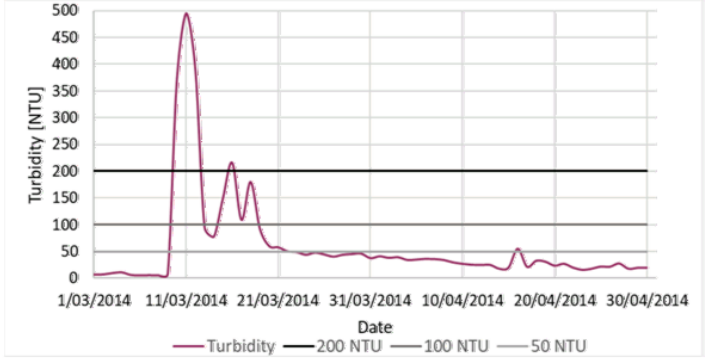
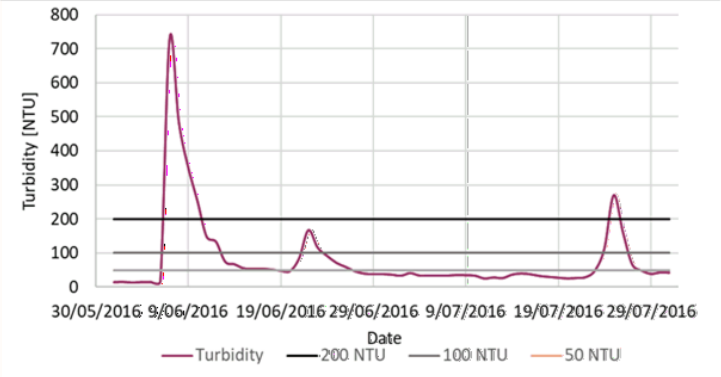


Figure 4-2 Turbidity event 1 (T1), March 2014



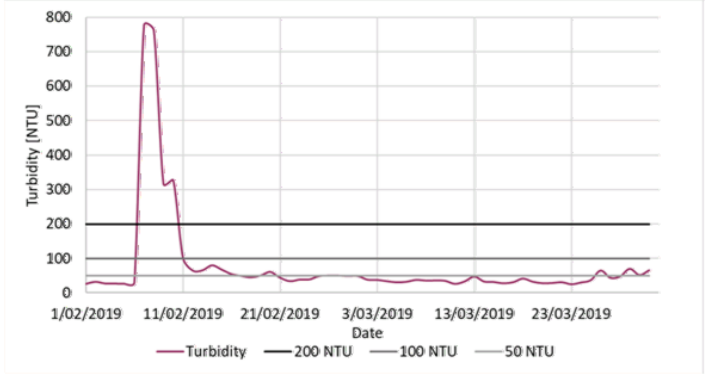


Figure 4-3 Turbidity event 2 (T2), June 2016

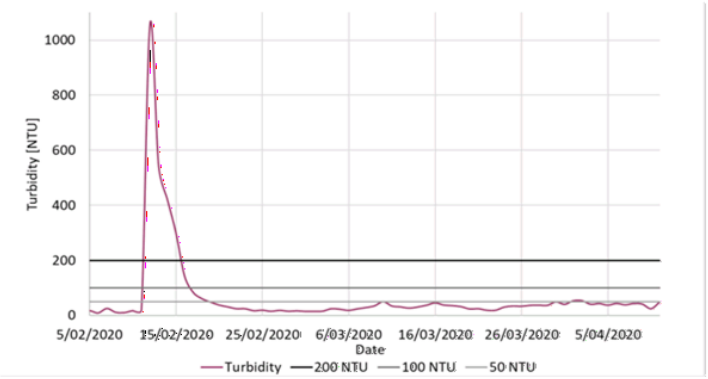


Figure 4-4 Turbidity event 4 (T4), February 2020

Figure 4-5 Turbidity event 3 (T3), February 2019

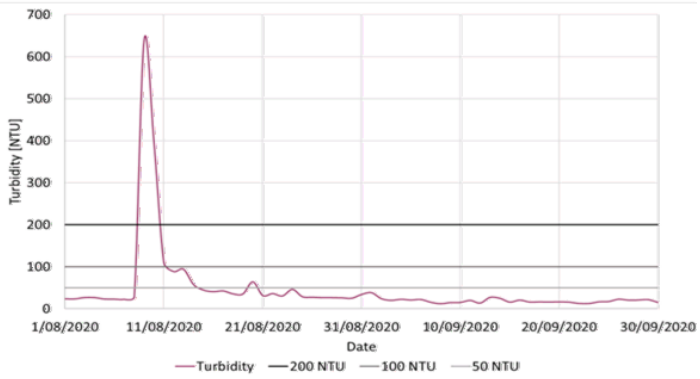


Figure 4-6 Turbidity event (T5), August 2020

4.1.1 Filtration

A raw water turbidity of 720 NTU during storm events is >7 times the maximum design turbidity of the existing WTP (100 NTU). The typical solids removal efficiency of DAF is 80 – 90%, however at this high solids load performance would likely be reduced to ~80%. Single media filtration typically has a 90-99% removal efficiency, but when receiving higher turbidity water from the DAF unit it may be closer to 90%. CWT has assumed, for calculation purposes, the following efficiency ranges:

- Minimum efficiency = 80% for DAF and 90% for single media filtration
- Average efficiency = 85% for DAF and 95% for single media filtration
- Maximum efficiency = 90% for DAF and 99% for single media filtration

Table 4-2 Theoretical turbidity throughout the process during significant rainfall events*

Influent Water	Minimum Efficiency (NTU)			Average Efficiency (NTU)			Maximum Efficiency (NTU)		
	Raw	Post-DAF	Treated	Raw	Post-DAF	Treated	Raw	Post-DAF	Treated
Average	22.8	4.6	0.5	22.8	3.4	0.2	22.8	2.3	0.02
Significant Rainfall - High	51.2	10.2	1.0	51.2	7.7	0.4	51.2	5.12	0.05
Design Maximum	100	20	2.0	100	15	0.8	100	10	0.1
Absolute Treatment Limit	200	40	4.0	200	30	1.7	Not achievable		
Significant Rainfall - Very High	720	Not achievable							

*This is a theoretical calculation to give an indicative turbidity expected during best, average, and worst-case operational efficiencies.

The existing WTP has a maximum filtered water turbidity target of 1 NTU, which is only just acceptable for potable water as the ADWGs state that disinfection is compromised above 1 NTU. The existing plant does not meet the current ADWGs which require a filtered water target of 0.2 NTU and not to exceed 0.5 NTU.

YVC and HH$_2$O have specified turbidity removal targets for the upgraded WTP in line with best practice as outlined in the Manual for the Application of Health Based Targets (WSAA, 2015):

- <0.15 NTU for 95% of samples (excluding the first 15 minutes after backwash, taken at least every 15 minutes); and
- Individual filter turbidity must not exceed 0.3 NTU for more than 15 consecutive minutes at any time.

In its current state, the WTP cannot reliably achieve the current ADWGs or the latest WQ targets for many water quality scenarios. At an average treatment efficiency, a raw water turbidity of 100 NTU (design maximum) would yield a treated water turbidity of approximately 0.8 NTU. At average efficiency and a feed of 200 NTU, the expected treated water turbidity increases to 1.7 NTU, exceeding the ADWG turbidity limit for effective disinfection. If the WTP is only able to achieve minimum efficiency, then it will fail the current filtered WQ target of 1 NTU at a RW turbidity of around 50 NTU.

The existing WTP is able to treat the average raw water quality envelope, however there is a risk of exceeding best practice water quality targets and ADWGs for any other raw water quality envelopes. Downrating the WTP will assist to some degree and shift WTP performance from minimum efficiency to average or better efficiency.

This is expected to assist performance at up to 100 NTU raw water quality but will not have enough impact beyond this raw water quality envelope.

The increased solids load on the filters also leads to increased backwash frequency, leaving the plant with only 3 of 4 filters online for significant periods of time. Council has noted that filter backwashing is required constantly during significant rainfall events which puts the plant under additional pressure. When operating with 3 filters, the filtration rate in each filter increases from 10 m/h to 13.3 m/h compromising process efficiency and performance reliability, which during rainfall events has previously led to boil water notices being issued.

The existing WTP has an insufficient number of filters to manage satisfactory filter backwashing during rain events and thus runs with 3 filters operating for considerable periods of time. This leads to poor filter operation efficiency and poor treated water quality.

The proposed Stage 1 Works will not significantly improve raw water turbidity levels and will only allow the downrating of WTP throughput to some degree. WTP performance during periods of elevated turbidity will continue to be poor and therefore further upgrades will be required to address this shortfall of the existing WTP.

4.1.2 Dry Solids Production

During periods of high influent turbidity, the sludge load on the existing lagoons used for wastewater handling will significantly increase.

Sludge production is estimated using the known water quality of the raw water source and the following formula:

Sludge Production (mg dry solids / L raw water) = 1.5 x Turbidity (NTU) + 0.1 x Colour (HU) + Metals (mg/L) + 0.44 x Coagulant (Alum as Filter Alum) (mg/L) + Floc Aid Polymer (mg/L)

Sludge production calculations show that during periods of very high turbidity, sludge production can increase up to 26 times what is typically produced by the plant during normal operation.

Table 4-3 Dry Solids Concentration

Parameter	Units	Sludge Factor	Average	High	100 NTU	200 NTU	Very High
Turbidity	NTU	1.5	34.2	76.8	150	300	1080
Colour (true)	HU	0.1	2.3	2.3	2.7	2.7	2.7
Iron (total)	mg/L	1	0.9	5.2	10.7	10.7	10.7
Manganese (total)	mg/L	1	0.2	0.5	0.7	0.7	0.7
Coagulant: Alum (As Filter Alum) *	mg/L	0.44	5	8	8.2	8.2	8
Polymer	mg/L	1	0.2	0.3	0.3	0.3	0.3
Total	mg dry solids/L of raw water		**43**	**93**	**173**	**323**	**1103**
				2 x Average	**4 x Average**	**8 x Average**	**26 x Average**

*Using 47% of delivered alum as filter alum
*Using average filter alum dose of 26 mg/L and alum dose during rainfall events of 42 mg/L

Sludge production is then calculated by multiplying the dry solids concentration by the WTP flow.

Table 4-4 Sludge Production

Parameter	Units	Average	High	100 NTU	200 NTU	Very High Sludge
Dry solids concentration	mg dry solids / L raw water	43	93	173	323	1103
WTP raw intake	ML/d	13	13	13	13	13
Daily dry solids load	kg/d	**556**	**121**	**2243**	**4193**	**14333**
			2 x Average	**4 x Average**	**8 x Average**	**26 x Average**

This level of increased solids load leads to a significantly faster filling rate of the sludge lagoons. Additional sludge production during rainfall events will need to be taken into account during the assessment of the existing WTP's wastewater handling capacity and any subsequent upgrades required as part of the Stage 2 works.

4.2 Organics Investigation

Raw water DOC and TOC levels are relatively high. If left untreated, organic matter can consume free chlorine in the treated water, potentially creating a health risk for consumers from inadequate chlorine residual to prevent recontamination in the network. Organics are also the main precursor for the formation of potentially carcinogenic disinfection-by-products (DBPs).

Typically, up to 50 % of organics can be removed by well operated conventional treatment processes (coagulation, clarification, and filtration) and up to 60 % with enhanced coagulation. An additional 15% of organics can sometimes be removed as a result of oxidation (from potassium permanganate dosing) and/ or PAC dosing with suitable contact time.

YVC and HH_2O have specified a target of 50% removal of organics to be achieved by the upgraded treatment process. During significant rainfall events, DOC increases to approximately 21 mg/L. Likely organics removal can be estimated using the following:

- Minimum removal of 50% - conventional treatment;
- Average removal of 65% - conventional treatment, enhanced coagulation, and $KMnO_4$ / PAC dosing; and
- Maximum removal of 75% - conventional treatment, enhanced coagulation, and $KMnO_4$ / PAC dosing functioning at peak efficiency.

Table 4-5 Theoretical dissolved organics removal at a range of removal efficiencies

Dissolved Organics (mg/L)	Feed	Minimum Removal	Average Removal	Maximum Removal
10th %ile	8.8	4.4	3.1	2.2
Average	14.1	7.1	4.9	3.5
90th %ile	20.5	10.3	7.2	5.1
95th %ile	21.5	10.8	7.5	5.4
98th %ile	21.6	10.8	7.6	5.4

Yass WTP has not trialled enhanced coagulation and is not dosing PAC or $KMnO_4$ into contact tanks. With Stage 1 upgrades, it is likely that organics removal falls in the minimum removal category. This means there is likely to be a significant concentration of dissolved organics remaining in the raw water at 90^{th} – 98^{th} percentile.

Yass WTP has PAC dosing available, and upgrades are planned in Stage 2. However, at current dosing there is very little contact time which leads to the PAC being rapidly bound, losing effectiveness. Ideally, PAC should contact the raw water for at least 30 minutes prior to coagulation. The PAC can then be captured in the floc formed in coagulation and better removed in the DAF float.

CWT recommends a dedicated PAC tank with 30 minutes of effective contact time be implemented to boost organics removal preferably as part of the Stage 1 works.

The WTP is capable of dealing with organics at average feed quality, however above this envelope high levels of dissolved organics remain in the treated water and further treatment processes beyond Stage 1 works are required.

4.3 Manganese Removal Strategy

4.3.1 Overview

Manganese is present in Yass Dam with elevated concentrations experienced during drought periods. Elevated levels of manganese in dam water can be due to reduced dissolved oxygen (DO) levels. There is event-based data that the existing WTP is not reaching the ADWG (aesthetic) target of <0.1 mg/L in the treated water. YVC receives many complaints from customers that the water is a rusty-brown colour and there is an odour and metallic taste to the water. In previous manganese investigation projects CWT has observed that customer complaints typically increase when the treated water manganese levels increase above 0.02 mg/L.

CWT favours a multi-barrier approach to manganese removal which consists of source water destratification, potassium permanganate dosing at optimised pH, coagulation, clarification and pre-filter chlorination. A treated water manganese target of 0.02 mg/L is preferred.

4.3.2 Destratification

Dam destratification can be employed to minimise build-up of iron and manganese experienced in Yass Dam. This is achieved by maintaining DO at satisfactory levels (>4 mg/L) throughout the depths of the storage. Elevated DO levels continually oxidise soluble metals and lead to the precipitation of metal and phosphate compounds. Continuous monitoring of DO at the bottom of the intake tower is recommended to assist in management of the destratification system.

Employing a bubble plume destratification system should gradually push surface water through the various layers of colder and denser water until it penetrates the full Dam, creating a homogenous water source. This would be expected to smooth the manganese peaks experienced by Yass WTP during significant rainfall events making manganese removal at the WTP easier – especially by oxidation with potassium permanganate.

4.3.3 Potassium Permanganate Dosing

Potassium permanganate ($KMnO_4$) dosing is commonly used for oxidation to convert soluble manganese to insoluble manganese, precipitating it for removal via coagulation/flocculation and filtration. This process can work down to a pH 7, however, it works best at a pH of 8.5 (shortest contact time required).

The ratio of permanganate dose to soluble manganese in the river water can vary significantly due to organic compounds and can be anywhere from 2:1 to 10:1. As noted by DPIE, optimisation of this dosing ratio can be difficult to achieve with variable raw water quality. This will require regular, additional monitoring of the soluble manganese in the raw and filtered water and jar testing at least daily by operators.

For effective manganese removal, an effective contact time of at least 3 minutes at optimum pH is required with up to 15 minutes preferred to account for interference from organics and process inefficiencies.

4.3.4 Manganese Oxide Coated Media

Soluble manganese can be removed from water using chlorination prior to the filters together with a manganese oxide coated media. In this process, the absorptive removal capacity of the manganese oxide

coating is chiefly responsible for the manganese removal. Pre-chlorination is an essential part of the process as it increases the oxidation state of the manganese oxide coating, which in turn, improves its manganese adsorption capacity.

The coating is generated by soaking each filter in a solution of potassium permanganate and chlorine for several hours. Although in the presence of chlorine the coating can generate naturally on filters with feed waters containing manganese, this coating process takes significant time to achieve. The coated media process can remove residual soluble manganese concentrations of up to ~0.6 mg/L.

4.3.5 Multi-Barrier Approach

Both $KMnO_4$ and manganese coated media strategies can be implemented at Yass to achieve a multi-barrier approach for removal. Combined with destratification, this is likely to have the best results for effective manganese removal. The following process would be followed:

- Bubble plume destratification for smoothing of manganese concentrations in the raw water by maintaining a DO of at least 4 mg/L throughout the storage;
- Raw water $KMnO_4$ dosing at the inlet of a new oxidation contact tank. The operations team must monitor soluble manganese and DOC regularly and dose at a known ratio (to be developed through jar testing for each raw water condition) – dosing at the optimum dose or slightly under this dose is the preferred approach;
- Addition of a new oxidation contact tank designed to provide at least 15 minutes of effective contact for the $KMnO_4$ with manganese contaminated water is essential for this process. Without adequate contact time prior to coagulation a high percentage of the fine manganese particles (typically around 0.1 to 0.3 microns) will form post coagulation and pass through the clarifiers and filters and flow into the network; and
- Chlorine dosing prior to the filters followed by manganese oxide coated media to adsorb any remaining soluble manganese.

Implementing a multi-barrier approach and online monitoring to provide the best possible removal efficiencies and operational monitoring has the highest success for manganese removal and is worth consideration at Yass WTP.

Manganese concentrations need to be monitored in the raw, oxidised, and treated water as well as chlorine levels in the filtered water to ensure appropriate dosing and removal is maintained at each stage.

4.3.6 Network Management

Network management is key to ensuring manganese levels in the treated water remain below acceptable levels. Manganese can build up on pipe walls in conjunction with various microorganisms and periodic sloughing off can lead to dirty water problems. Build-up of this substance causes taste, odour, and turbidity issues in the reticulation. CWT recommends YVC develop an operations and maintenance schedule to complete flushing of the reticulation to reduce event based elevated manganese levels.

5 CWT Response to DPIE

5.1 DPIE Comments on Project

In response to the proposed scope of the peer review project for the proposed upgrade to the Yass WTP, DPIE raised a number of points for further consideration, including requesting that a review of the proposed Stage 1 works be included in the scope of this project, specifically:

Assess the likely impact of the Stage 1 works on the quality of the filtered water during both normal and flood raw water conditions and provide commentary about the timing of subsequent phases.

CWT largely agrees with the proposed augmentations and operational upgrades proposed for Stage 1, however some additional considerations have been proposed in this report as discussed above and summarised below.

CWT and YVC also note that while reviewing and updating the operation and maintenance practices and supporting documentation for Yass WTP and distribution system is recommended, it is outside the scope of this review. YVC has committed to updating relevant manuals and procedures as required flowing the completion of each stage or works.

5.2 Pre-Treatment Clarifiers

In November 2019 YVC, HH$_2$O, DPIE, and NSW Health completed an Options Value Management Workshop where alternate ideas and recommendations were discussed. A potential option for addressing high turbidity during significant rainfall events posed by DPIE was the conversion of the existing sludge lagoons from wastewater handling to pre-treatment clarification.

The following process and site issues have been identified for this option:

- A new pump station and additional pipework would be required;
  - The existing raw water pump station would pump to the sedimentation lagoons via new pipework from the existing raw water main;
  - A new pump station would then be required to pump settled water from the outlet of the lagoons to the WTP inlet;
  - Chemical dosing (with rapid mixing) may be required prior to the sludge lagoons to improve performance. This would require the addition of a chemical dosing system at the lagoon site. The chemical dosing system would require a new building with bunding and telemetry;
  - The sludge lagoons are distant from the current WTP site and therefore treatment would be conducted over two sites during poor water quality events which would have some difficulty of operation.
- Additional lagoons would be required to achieve treatment requirements to ensure sufficient capacity for wastewater handling as well as pre-treatment clarification during operation to accommodate DAF sludge, backwash water, softening sludge/residuals for processing. The existing two lagoons would be in use with potentially one filling and one drying:

- In order not to scour the sludge from the existing two lagoons into the WTP, a third lagoon (at least) would be required and would need to be empty of sludge. YVC have limited space for additional lagoons, and this would likely require the procurement of an additional land.

A visual representation of these upgrades is shown in Figure 5-1. The space required for additional pump stations, pipework, sludge lagoons, and chemical dosing systems is not available at the existing WTP site and would require procurement of additional land.

CWT does not recommend moving forward with consideration of this option as it has logistic, operational, and treated water quality issues.

Figure 5-1 Additional equipment and space required for pre-treatment clarification

6 Conclusions and Recommendations

Following the Stage 1 review, CWT has identified the following:

- Initial treatment investigations and classification of raw water into envelopes show that Yass WTP is capable of dealing with typical raw water quality. However, it is not designed to treat the drought or significant rainfall water quality envelopes while meeting ADWG aesthetic and health guidelines;
- Stage 1 works do not address Yass WTPs HBT's protozoa shortfall and is a priority for Stage 2 upgrades via UV disinfection implementation;
- Stage 1 works are likely to improve the influent water quality at Yass WTP, however, further improvements are required:
  - Implementation of destratification will likely be effective in smoothing the peaks in raw water quality experienced by Yass WTP, however, additional works in Stage 2 are required because destratification alone is not able to address manganese removal;
  - The installation of a permanent $KMnO_4$ dosing system alone is unlikely to improve manganese removal performance without increasing oxidation time prior to coagulation. A 15 minute contact tank should be installed for $KMnO_4$ dosing to effectively oxidise manganese;
  - Downrating the plant during periods of poor raw water quality and low demand will improve water quality. However, there is a risk during very poor water quality events that the WTP will need to be downrated to below customer demand to meet treatment targets and therefore requires upgraded and/or additional processes to operate under these conditions. Even a significantly downrated WTP cannot treat all raw water quality conditions;
  - Soda ash dosing upgrades will ensure optimum pH for manganese removal and coagulation can be achieved improving the treated water quality;
  - CWT recommends YVC implement a distribution management strategy to ensure the reticulation network is flushed periodically to avoid manganese build-up;
- Turbidity, especially during significant rainfall events, is not addressed by the proposed Stage 1 works and requires additional treatment to meet the specified treated water turbidity targets;
- Organics remain an issue as they are present in high concentrations following significant rainfall events. Improved organics removal is not addressed by the Stage 1 works and requires further upgrades in Stage 2, including a PAC contact tank, to address this treatment shortfall; and
- CWT favours a multi-barrier approach to manganese removal which consists of source water destratification, potassium permanganate dosing at optimised pH, coagulation, clarification, and pre-filter chlorination. A treated water manganese target of 0.02 mg/L is preferred.

CWT recommends that the implementation of Stage 1 be completed as proposed, but with the following modifications:

- Regular monitoring of DO within the dam – preferably a permanent installation of a continuous analyser to assist in operation and management of destratification;

- Installation of an oxidation tank following potassium permanganate dosing to provide at least 15 minutes effective contact prior to coagulation/flocculation;
- Installation of a PAC contact tank would also have a significant impact on WTP performance under poor raw water quality conditions. The oxidation and PAC contact tanks could be combined and/ or additional raw water storage added. This tank could also receive recycled wastewater if required in the future; and
- Online manganese monitoring and chlorine residual monitoring.

The peer review of the proposed Stage 2 works will continue as scheduled to prioritise finalising the design to address the treatment and operational concerns not adequately addressed by Stage 1 alone. CWT also recommends, following this review, that Stage 2 be commenced according to YVC's current timeline as the Stage 1 improved plan is inadequate to deal with significant rainfall and drought water quality envelopes.

7 Next Steps

The next steps are as follows:

- Proceed with implementation of Stage 1 works ;
- Complete the peer review of the proposed Stage 2 works;
- Finalise and agree on the preferred design for Stage 2; and
- Prepare technical specification and tender documentation for Stage 2 D&C.

cwt

Appendix A Data Analysis

Parameter	Units	No. of Samples	Min	2nd %ile	5th %ile	Median	Average	95th %ile	98th %ile	99th %ile	Max
Turbidity[1]	NTU	3105	1.4	3.7	4.7	14.2	22.8	51.2	75.9	141.7	1058.0
DOC[2]	mg/L	61	7.8	8.0	8.5	13.0	14.1	21.5	21.6	22.1	22.9
TOC[2]	mg/L	61	8.9	9.2	9.9	15.1	17.4	26.5	31.9	35.4	39.0
Potentially Toxic Blue Green Algae[2]	cells/mL	8	211	401	687	2105	3845	10014	10473	10627	10780
Potentially Toxic Blue Green Algae[2]	mm^3/L	8	0.00	0.01	0.01	0.08	0.24	0.96	1.22	1.30	1.39
Total Blue Green Algae[2]	cells/mL	35	448	519	601	4380	7648	20464	33010	39215	45420
Total Biovolume[2]	mm3/L	34	0.00	0.00	0.01	0.18	1.36	9.13	10.68	11.02	11.35
Total Iron 1 Raw[1,3]	mg/L	182	0.11	0.13	0.14	0.47	0.88	2.68	2.77	2.94	6.23
Total Iron 1 Reservoir[1,3]	mg/L	265	0.00	0.00	0.00	0.04	0.06	0.17	0.22	0.25	0.95
Total Iron 2[2]	mg/L	106	0.17	0.28	0.51	2.79	3.55	7.79	18.69	19.65	20.40
Filterable Iron[2]	mg/L	60	0.00	0.01	0.01	0.26	0.33	0.83	1.31	1.48	1.60
Total Manganese 1 Raw[1,3]	mg/L	525	0.06	0.08	0.09	0.18	0.22	0.47	0.75	0.98	2.18
Total Manganese 1 Reservoir[1,3]	mg/L	724	0.00	0.01	0.01	0.04	0.07	0.25	0.40	0.59	1.29

Parameter	Units	No. of Samples	Min	2nd %ile	5th %ile	Median	Average	95th %ile	98th %ile	99th %ile	Max
Total Manganese 2[2]	mg/L	106	0.04	0.06	0.06	0.24	0.27	0.58	0.64	0.71	0.77
Filterable Manganese[2]	mg/L	60	0.02	0.03	0.04	0.14	0.18	0.44	0.58	0.63	0.70
Reservoir Aluminium (Soluble) [1,3]	mg/L	317	0.00	0.06	0.10	0.18	0.20	0.32	0.35	0.35	0.36
pH[1,4]	-	3095	6.5	6.9	6.9	7.5	7.6	8.2	8.4	8.4	8.5
Total Hardness[2]	mg/L	18	25	37	56	101	118	227	229	230	230
Calcium[2]	mg/L	18	3.1	4.6	6.9	13.8	16.2	31.2	32.7	33.2	33.7
Magnesium[2]	mg/L	18	4.1	6.2	9.2	16.0	18.9	36.5	36.9	37.1	37.2
Alkalinity[2]	mg/L	44	14.0	14.9	17.4	64.0	70.2	195.8	214.6	216.3	218.0
Conductivity[2]	mS/m	109	7.6	11.0	22.3	39.0	42.0	76.7	77.5	77.7	77.8
Geosmin[2]	ng/L	19	0.50	0.50	0.50	2.00	3.18	11.20	12.28	12.64	13
MIB[2]	ng/L	19	0.50	0.50	0.50	0.50	1.58	3.95	10.58	12.79	15
E. Coli[2]	CFU/100mL	18	11	11	11	26	3209	10500	36000	44500	53000
Colour[1]	Hazen	3102	10	20	30	100	129	250	394	501	3062
Temperature[1]	°C	2933	2.1	8.6	9.2	16.9	16.6	24.1	24.7	25.1	25.9

[1] RWQ Log Sheets July 2012- Dec 2020

[2] 2020 Monitoring Program

[3] Total Iron 1, Total Manganese 1 and Reservoir Aluminium not monitored May 2019 - Feb 2020

[4] NB: 5 pH readings, 0.9 (21/08/2018), 3.5 (4/11/2018), 1.17 (8/11/2018), 75 (22/02/2018), and 85 (6/11/2018) have been omitted from the data analysis as they are likely transcribing errors.