University of Southern Queensland

Faculty of Health, Engineering and Sciences

Investigating Urban Stormwater Collection for Potable use; a Feasibility Study for Gloucester, NSW

A dissertation submitted by

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Abstract

During the prolonged drought across most of 2018 and 2019, Gloucester's water supply, the Barrington River ceased flowing. This led the council to source water from another local source via water trucks. Council are currently upgrading existing infrastructure within the network and are looking to investigate other potential alternatives.

Background research of urban stormwater collection indicated that high rates of pollutants within urbanised areas make the collection of stormwater impracticable, with high costs for treatment to drinking water requirements. Most collection schemes target collection for non-potable sources and are centred around larger cities. Pollutants were found in high concentrations with most studies within cities. Wetland treatment presents the most practical and cost-effective option for pollutant treatment. Gaps in literature led to the concept of a feasibility study for collection of urban stormwater for Gloucester, a small rural town on the Mid North Coast of New South Wales for potable use and to assess its feasibility as a whole.

To assess feasibility water samples were collected and tested, catchments were modelled to assess runoff yield and a concept design was completed for a wetland. Stormwater samples were tested for metals, suspend solids and nutrients, testing indicated that pollutants concentrations were within normal to low ranges for typical stormwater.

Assessment of the topography of Gloucester indicated that large scale collection of multiple catchments was difficult, a smaller catchment was chosen based on topography. This catchment was 20Ha and a parametric study was completed using MUSIC software, the study assessed how rainfall, pervious losses and reuse affect the total annual outflow of water. The study found that only rainfall and soil capacity affect total outflow with any significance. The average yield found from the site indicated that approximately 100 megalitres of water can be collected from the site each year, approximately 35% of the Gloucester annual demand. During dry periods up to 10% of the annual demand can be met.

A concept wetland design was completed and sized according to available space and average rainfall values to ensure an amount of stormwater storage within the wetland. The wetland was sized at 6000m^2 with a 300m^2 sediment basin. The wetland was assessed using MUSIC software for typical pollutant values and average rainfall indicating that reductions through the wetland able to produce pollutant reductions of 90% in total suspended solids and between 50% and 60% for nitrogen and phosphorus removal, these reductions meet water sensitive design requirements and reduce pollutants to approved drinking water requirements.

This study was able to determine that with the right catchment parameters and rainfall values urban stormwater can be a feasible alternative to existing supplies. Water collected from mostly residential areas with pervious areas of mostly clay based soils ensure that the runoff is of suitable quality and with a large enough quantity to provide an alternative.

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Nicholas Kellner

[redacted]

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1. Introduction

The need for the study was identified after consultation with the water resilience team at MidCoast Council. During 2018 and 2019 much of New South Wales experienced the worst period of little to no rainfall since records were collected around 120 years ago, the town of Gloucester was no exception. Towards the end of 2019 the only water source the town has, the Barrington River ceased flowing, this prompted council to transport water from an aquifer at nearby Tea Gardens, approximately 110km away. The potential for urban potable reuse at Gloucester may have delayed or even negated the need for the water transport. This study looks into background of urban stormwater reuse, pollutants found in stormwater, typical discharge from urban stormwater and treatment options of stormwater.

Gloucester is a small town on the Mid North Coast of New South Wales. The town has a population of approximately 2500 people. Industry within the town is shared between agriculture, mining, manufacturing, retail and tourist trades. In recent years the tourism industry has seen an increase where other sectors have seen a decline. The tourist trade provides a great source of income to the local economy however with increased number of guests particularly in the warmer months of the year, this provides a strain on the water supply network. Gloucester requires on average 275 million litres of potable drinking water annually. (COUNCIL 2021)

MidCoast Council identified several issues with the existing distribution network and have set about rectifying some issues. These include:

- Upgrade and replace existing dilapidated reservoirs with higher capacity
- Upgrade the water treatment plant to provide a higher quality potable water for users
- Construct a 150 megalitre off stream storage dam
- Incorporate a fully integrated recycled water system.

All of these upgrades and solutions are currently being implemented by council with completion expected with the next 10 years. (COUNCIL 2021)

The major concern with the solution of off stream storage is that it mostly relies on the existing river system to provide enough volume of water to fill existing reservoirs and the off-stream storage dam. During periods of prolonged low rainfall, the smaller creeks and tributaries decrease in discharge to the larger rivers that supply the Gloucester network.

Urban areas consist of impervious and pervious layers. Roads, footpaths, house and business roofs provide the largely impervious areas of an urban stormwater system. With almost zero infiltration a large proportion of water will be allowed to runoff into the stormwater network and discharge at the bottom of the catchment. This may provide additional runoff that would not normally be experienced in undeveloped areas.

Infiltration is where rainfall falling on a surface will seep into that surface reducing runoff thus reducing discharge at the outlet of a particular system. The issue is amplified during prolonged dry periods where the moisture within the soil is at a minimal so that if any rain is falling over an area, the vast majority of the water will make it into the ground and not the river or stream.

The problem that Gloucester faces is that when low rainfall periods are present for long periods of time, the flows in the Barrington River decrease and as the ground dries the runoff decreases. Any rainfall that falls does not provide enough inflow to increase the rivers flows to levels acceptable for extraction and use at Gloucester.

The concept of an urban potable reuse scheme has been discussed by council. There have been no significant studies completed for any of council’s sites. The idea of alternative water solutions was brought to attention during the height of the recent drought where the Barrington River ceased flowing and extraction was stopped for the first time in the town's history.

This study will look into the viability of urban stormwater collection by completing a feasibility study in Gloucester, with broader feasibility to be examined for urban stormwater collection as an alternative to other options across Australia.

1.1. Aims

With the continuing threat of climate change changing typical and historical weather patterns it is predicted that rainfall will decrease and become more unpredictable in the coming years. This means that traditional methods for water supply need to be offset with other methods such as recycling, desalination and groundwater.

Stormwater is often perceived as wasted water as it flows down gutters, pipes and into existing river systems. Urban stormwater collection presents an option to harness this water when weather patterns provide enough rainfall.

To provide an understanding of urban stormwater and its potential use for urban water supply the following aims will be investigated:

- Investigate urban stormwater collection feasibility
- Investigate water quality and pollutants in stormwater
- Investigate stormwater yield
- Undertake a parametric study for stormwater yield
- Investigate stormwater treatment
- Determine the viability of an urban stormwater collection scheme for Gloucester and more broadly to supplement water supply requirements.

MidCoast Council has a large population with significant water supply requirements, due to the nature of this project it was decided to complete the feasibility study on a smaller catchment in Gloucester.

1.2. Objectives

In order for this project to be successful, objectives will need to be met. These will ensure that all requirements are covered and remain on track. They are as follows:

- Conduct research into urban stormwater, pollutants, yield, treatment and designs currently available and in use across the industry.
- Collect water samples from various locations within Gloucester's stormwater system. The analysis of these samples is compared with pollutants found in background research.
- Complete a yield analysis on the Gloucester stormwater network. This will be incorporated with a parametric study inputting a range of variables to provide a broad array of water volumes discharging from the stormwater network.
- Analyse water quantity and quality from the parametric studies. This will determine the requirements of the design.
- Design a suitable treatment option for stormwater, ensuring that the treatment area is large enough provide treatment of pollutants.

- Complete a cost estimate for the construction of a wetland and ongoing maintenance costs for a 20-year design life.
- Complete a feasibility analysis on the collected data and options to determine the viability of a stormwater collection scheme for Gloucester.

1.3. Expected Outcomes

The expected outcome of this project is that the quantity of water will be able to provide an offset for the typical water supply in Gloucester. It is expected that the topography of the town and difficulties in collecting stormwater in a single place for storage and treatment will prove that it is not a feasible replacement option.

An expected alternative outcome will be that a percentage of the stormwater can be collected from a smaller catchment providing an offset to traditional water supply options

The quality of water is expected to be within requirements and treatment will ensure that the water is of drinkable quality after treatment through a wetland and water treatment plant.

2 Background research

The research component of this project is broken into four significant parts:

1. Urban Stormwater Collection
2. Water Quality
3. Yield of stormwater networks
4. Treatment of stormwater

Stormwater is defined as water draining off a site from rain or snow that falls on roofs and land (WOODCOCK 2013). This water is then transported through pipes, kerb and gutter systems, grassed swales, concrete channels to be discharged into nearby rivers, streams or the ocean. The issue with stormwater is that as water flows from roofs, lawns, carparks, roads and parks it picks up and carries numerous sources of pollution. The pollution comes in numerous forms and each has an effect on water quality.

Water quality is of utmost importance, not just for human use and possible consumption. Poor water quality and management of stormwater can lead to health and environment risks, with loss of life in fish and marine animals possible if not treated accordingly.

The yield of a system will play an important role in this project. The amount of water that can be collected from the system will form an important part of the feasibility analysis. If the collection of stormwater does not yield a significant amount of usable water, the system will be of no use for potable use. Research investigates typical climate for the Gloucester area and provide historical data that will be placed into the parametric study. Research into losses, infiltration, evaporation will provide inputs and variables that can be used to provide significant data for several scenarios that the climate of Gloucester will likely produce over the life of an urban stormwater scheme.

Research has shown that the installation of native wetlands can provide a solution to a number of pollutants. Native wetlands can provide benefits to the environment, with the installation of wetlands within urban areas providing a location for public use and recreation along with the benefits of the wetland plants to improve the quality of the water. The research looks into typical wetland options and any other options that may be able to provide a solution in relation to water quality (HUNTER 2013).

The research into the design of a wetland or treatment pond looks into sizing, retention times for pollutants, overall capacity for historical rainfall, location and topography for a site for best design outcomes.

The research aims to provide a broad range of possible inputs and options for the collection and treatment of stormwater to provide a feasibility analysis for a system in Gloucester.

2.1. Urban Stormwater Collection

(MCARDLE et al. 2011) investigated the feasibility of urban stormwater harvesting for potable reuse. The case study investigates Styx Creek, a drainage channel through a number of suburbs to the west of the city of Newcastle. The report outlines the location of the catchment area, it found that quantity of runoff was high with pollutant levels also high.

Further research will be conducted to assess options available and looking into the current stormwater infrastructure at Gloucester and whether any upgrades may be required to improve the system and allow it to accommodate an Urban Stormwater Collection scheme.

Urban stormwater collection is utilised in large cities across the world. Cities with high and consistent rainfall have demonstrated the ability to harvest, treat and collect stormwater to provide additional non-potable water supply to US cities as well as internationally.

The concept of stormwater is to mitigate the effects of flash flooding by providing sufficient drainage capacity for high and intensive rainfall. This is achieved through pipes and drainage channels that direct water as quickly and efficiently as possible to stormwater outlet (rivers, oceans etc.). By discharging non treated stormwater to natural water courses this increases pollution and effects water quality. Due to the nature of stormwater systems, the collection, treatment and reuse of water can be challenging in relation to the physical collection of water.

The idea of urban stormwater runoff collection for potable use is a relatively new concept in Australia. During the millennial drought, the public perception around alternative water supply options began to change (DILLON et al. 2009). Water knowledge within a community is an important factor when proposing an alternative to what is already widely accepted. Surveys within Australia have shown that a greater knowledge of water is met with a significant increase in conservation and support for alternatives (DILLON et al. 2009) .

Orange City Council utilising wetlands for pollutant removal, on average supplies 25% of water supply requirements. In 2007 the city of Orange's water supply had fallen below 40%, measures were employed to minimise water consumption. By 2010 supply had fallen to the lowest point of 23%. Council needed a quick solution. The topography of the city allowed for water to be collected and discharged into a constructed weir and wetlands arrangement. The hydrological modelling predicted that 15%-30% of the annual water usage requirements could be collected through stormwater harvesting. Water is treated in the wetlands to a standard suitable for treatment at Orange water treatment plant. (PORDAGE 2018)

The overall impacts of the system are an increase of up an additional 25% potable water supply and water monitoring indicates that the water from the wetlands is of a better quality than the main supply dam.

2.2. Water Quality

2.2.1. Gloucester's Treatment System

Gloucester's water treatment plant was constructed in the 1930's and has undergone upgrades in the 1980's and again in 2016. The plant is a very basic treatment plant, water is collected from the river where coagulants are added. This draws the particles together causing them to sink to the bottom. The clean water on top then is passed through sand filters to remove finer particles. Finally, chlorine and fluoride are added prior to pumping to reservoirs for consumption (COUNCIL 2021a)

This basic process is able to remove some of the common pollutants associated with fresh river water. The combination of coagulation, sand filtration and disinfection are able to provide drinking water up to a standard currently accepted.

The issue with stormwater is that there are other pollutants present that the treatment plant at Gloucester is unable to remove. These will be looked at in greater detail below. The pollutants found in stormwater will form the basis for the wetland design for removal of said pollutants to ensure drinking water quality requirements are met from this system.

Consultation with MidCoast Council engineers, looking at sampling for numerous locations at discharge points within the Gloucester stormwater network to provide an idea of pollutants found within the network.

2.2.2. Pollutants Associated with Stormwater

Stormwater networks are primarily designed to collect and discharge water from roofs, footpaths, roads, gardens and parks as quickly and efficiently as possible. This means that whilst water is removed from the surface preventing flash flooding, many pollutants also make their way through the network and are discharged at the outlet of the system.

The discharge of pollutants presents significant challenges for stormwater to be considered safe for human consumption, pollutants in urban runoff include:

- Solids, sediment and organics.
- Nitrogen and Phosphorus
- Pathogens
- Petroleum Hydrocarbons
- Metals

Each of these pollutants can have a harmful impact on the quality of stormwater. Table 1 shows typical stormwater pollutants and their sources. The following sections will outline typical pollutants found, where they originate from and typical treatment options for their removal (HORNER 1994)

Table 1 Typical Stormwater Contaminants and Sources (HORNER 1994)

Contaminant	Contaminant Sources
Sediment and Floatables	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/ Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

2.2.3. Solids

As water is collected in a stormwater system, the water collects and pushes solid items along with it. These solids often end up in the kerb and gutter and into drainage networks. The concern with larger items is that they can often cause blockages and treatment plants are not designed to deal with larger solid materials.

Solids are the most common contaminant that is found in stormwater can be classified into two parts, sediments and floatables and suspended solid particles trapped within the water.

The larger items are much easier to see and also remove.

Some of the common items found in a typical stormwater system include:

- Leaves, sticks, branches and other plant materials
- Rubbish and litter
- Sediment
- Lawn clippings

The most common way to remove larger solid items from a stormwater system is the use of a filter called a gross pollutant trap. A gross pollutant trap is essentially a large sieve that allows water to pass through it while collecting larger solid items. This is the first step the treatment process of stormwater (HORNER 1994).

2.2.4. Nitrogen and Phosphorus

The presence of large quantities of nitrogen and phosphorus in stormwater can be harmful to river ecosystems as higher quantities of these nutrients can allow for algae growth to be accelerated creating algal blooms. These algal blooms remove oxygen from the water potentially killing fish and other wildlife. Algal blooms can also be harmful to humans in high concentration (EPA 2020).

Studies found that the most common sources of nitrogen and phosphorus are from garden fertilisers and deposition of vehicle emissions. The site where the testing occurred was at 2 creeks in metropolitan Perth, the Wanneroo and Bannister creeks (KHWANBOONBUMPEN 2006).

The study found that typical input load for nitrogen was 0.45 g/m^{-2} at the first site and 1.75 $g/m^{-2,}$ this indicates a disparity between the two test sites in this study. Phosphorus loads varied from 0.13 g/m^{-2} to 0.07 g/m^{-2} across the two test sites. Interestingly the output loads for both nitrogen and phosphorus lowered through the system. The study determined that between 40 and 90% of Nitrogen and Phosphorus removal was from plant uptake (KHWANBOONBUMPEN 2006).

In larger cities rates of nitrogen and phosphorus in stormwater generally increase. Gloucester is a small country town with a small population. The town is surrounded by agriculture which may show significant amounts of nitrogen and phosphorus entering the stormwater network from these areas. Testing of samples will provide an idea of typical levels within the Gloucester catchment.

2.2.5. Pathogens

Pathogens enter stormwater during significant rainfall events where the sewer system cannot handle the additional inflow of stormwater causes the sewer to overflow thus sewerage enters the stormwater. Pathogens are defined as organisms that cause disease (SANTOS-LONGHURST 2019).

Typically, sewer overflow occurs during significant rainfall events where the capacity of the sewer is limited by inflow of rainwater.

MidCoast Council is currently in the process of investigating sewer inflow using CCTV and smoke detection. The aim of this process is to eliminate illegal sewer connections, but it also will help to minimise sewer overflow, helping to eliminate pathogens appearing in stormwater. The testing of pathogens will not form part of this project however any future investigation would need to complete thorough testing.

The typical treatment of water within existing water treatment plants provide sanitation that is likely to remove pathogens and waterborne pollutants. (GOVERNMENT 2011)

2.2.6. Petroleum Hydrocarbons

In Australia the vast majority of all motor vehicles are powered by fuel combustion engines (STATISTICS 2020). found that of the 19.8 million motor vehicles registered in Australia in the year 2019-2020 72.7 percent were petrol and 25.6 percent were diesel. This leaves just 1.8 percent of all vehicles in Australia using alternatives such as electric.

This overwhelming statistic indicates that the pollution created by petrol and diesel engines will continue to be a contributing factor to climate change, however water quality can be affected by petroleum hydrocarbons present in stormwater.

Allen et al. found that most pollutants were found to be from atmospheric deposition (combustion fires) and evaporation from storage. The study also found that vehicle and business losses accounted for a portion of pollutants (ALLEN et al. 2016).

Interestingly the study found that the levels that were present downstream of the stormwater were typically below the maximum concentrations allowed in New Zealand for aquatic and waterway health.

Brown and Peaker (2006) completed testing on two sites in New Zealand, they found that typical ranges of Polycyclic Hydrocarbons (PAHs) across the two sites ranged from 1.20-11.6 µg/g. The study was completed in an area considered 20% urban. The study found that in 100% urban environments the concentration of PAHs increased two to six times higher than the 20% urban area (BROWN & PEAKER 2006).

The rural township of Gloucester would be further towards the 20% urban as opposed to the 100% urbanisation of a city.

2.2.7. Metals

As stormwater appears as runoff in rainfall events, it collects and carries numerous pollutants as discussed earlier. In industrial areas often with factories and industry the presence of metals in stormwater is increased.

(BROWN & PEAKER 2006) found after testing two stormwater catchments in Dunedin, New Zealand that contained within the suspended sediment (SS) were lead, copper and zinc along with Polycyclic Hydrocarbons.

The study found the following data relating to metals:

- Lead: 119-527 µg/g
- Copper: 50-464 µg/g
- Zinc: 241-1325 µg/g

This data was collected from a 20% urbanised environment. Other studies will provide differences in data where more industrial sites are present or less urban environments where largely rural runoff results in lower results.

As discussed, Gloucester is a mostly rural town with a small industrial area to the south of the village. Strategic testing of stormwater is to be conducted at several sites around the township to provide details on typical pollutant levels, providing a direction for the collection and treatment of specific pollutants found within the Gloucester stormwater network.

2.3. Treatment of Stormwater

The treatment of stormwater is largely dependent on the type of pollutants that are present in a particular stormwater network. There are numerous treatments options available for a range of pollutants found in stormwater, with specific treatments available for successful removal.

Very little documentation exists relating to the treatment of stormwater to reach required levels for drinking water. Australian Drinking Water Guidelines does not contain any written guidelines or documentation for the specific treatment of stormwater to drinking water requirements. (GOVERNMENT 2011)

'Managing Urban Stormwater: Harvesting and reuse' outlines treatment options for stormwater. The report identifies several treatment options with their approximate effectiveness, these include wetland, swales and sand filters (GOVERNMENT 2006).

Table 2 shows treatment options and their effectiveness based on a typical residential stormwater catchment area. It indicates that there are several water quality treatment options each with varying levels of effectiveness for treatment of specific pollutants. As can be seen from the table, the wetland provides the most effective single stormwater treatment measure.

Table 2 Typical Stormwater Treatment Measures and Effectiveness. (GOVERNMENT 2006)

Stormwater treatment measure	Suspended solids	Total phosphorus	Total nitrogen	Turbidity	*E. coli*
Retention					
GPT	0–70%	0–30%	0–15%	0–70%	Negligible
Swale	55–75%	25–35%	5–10%	44–77%	Negligible
Sand filter	60–90%	40–70%	30–50%	55–90%	–25–95% (up to 1.5 log)
Bioretention system	70–90%	50–80%	30–50%	55–90%	–58–90% (up to 1 log)
Pond	50–75%	25–45%	10–20%	35–88%	40–98% (0.5–2 log)
Wetland	50–90%	35–65%	15–30%	10–70%	–5–99% (up to 2 log)
Outflow*					
GPT	42–140	0.18–0.25	1.7–2.0	18–60	9,000
Swale	35–63	0.16–0.18	1.8–1.9	14–34	9,000
Sand filter	14–56	0.08–0.15	1.0–1.4	6–93	500–11,000
Bioretention system	14–42	0.05–0.13	1.0–1.4	6–93	900–15,000
Pond	35–70	0.14–0.19	1.6–1.8	7–81	200–5,000
Wetland	11–67	0.09–0.16	1.4–1.7	19–53	100–9,000

* concentrations in mg/L except for turbidity (NTU) and *E. coli* (cfu/100 mL)

Gross pollutant traps (GPTs) are the simplest method to remove large solids from stormwater. According to Melbourne water, GPTs are effective at collection of solids greater than five millimetres in size. With the removal of larger pollutants, the downstream treatment can occur much more efficiently (WATER 2017).

As GPTs are not efficient in the removal of nutrients the GPT is best used in conjunction with other treatment options such as a wetland or bio-retention system (WATER 2017).

Wetlands occur naturally all over the world, they provide a natural process to collect and remove pollutants providing healthier waterways. Constructed wetlands are often designed in a similar way, they are typically a shallow water body, heavily vegetated. They are able to remove several pollutants found in stormwater through filtration, nutrient uptake and sedimentation (WATER 2020).

There are several types of wetlands that can be constructed, each serves a particular purpose depending on treatment, required residence times and potential additional storage requirements. According to the Wetland Education and Training Program at Sydney Olympic Park there are typically four specific designs for a wetland. They are a shallow marsh system as shown in figure 1. This wetland takes a large surface area and a shallow wetland area, it requires constant flows from higher rainfall or groundwater flows (HUNTER 2013)

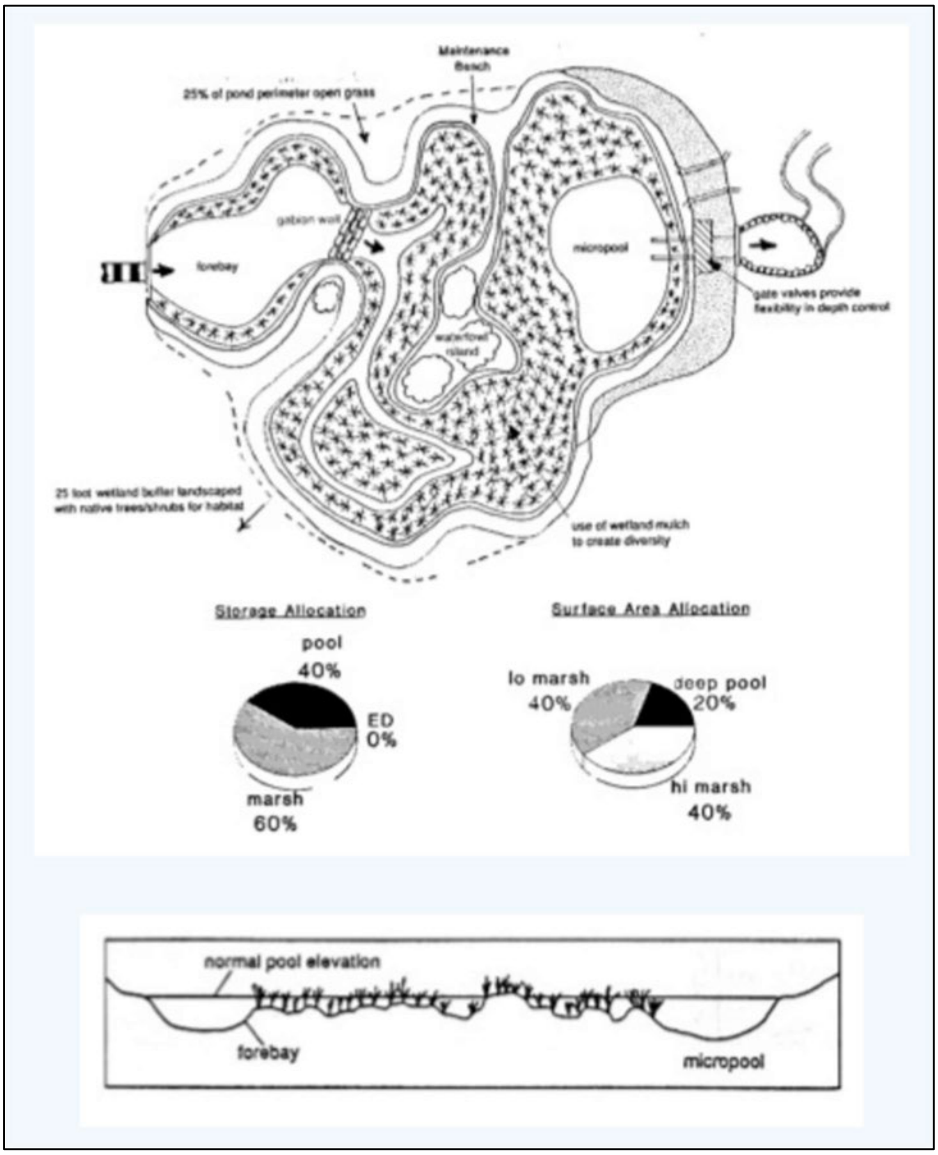

Figure 1 Shallow Marsh Wetland (HUNTER 2013)

The second is the pond/wetland system, this system utilises 2 cells. The first is a wet pond with the second a wet marsh area. This option is good where space is of importance as the marsh area can be smaller as the majority of the treatment happens in the wet pool section of the wetland. The pond wetland system is shown in figure 2. (HUNTER 2013)

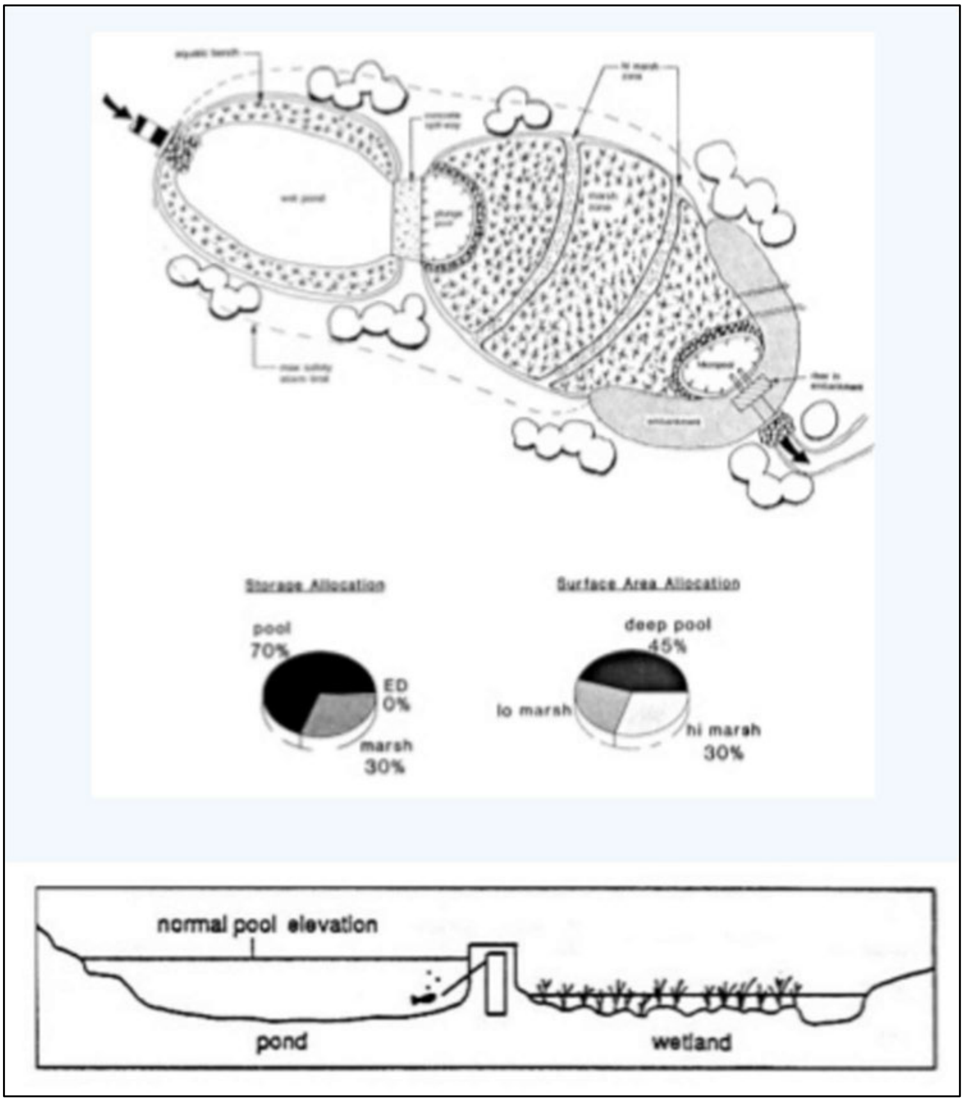

Figure 2 Pond/Wetland System (HUNTER 2013)

The third is an extended detention wetland, it allows for additional storage to save space and provide additional storage, this wetland can provide up to 50% additional storage collected from storm events. The wetland can increase by up to one metre in depth and return to normal levels within 24 hours without affecting the plant life. A new growth zone of plants is created along the edge of the side slopes. This type of wetland can provide additional storage and also protect downstream areas from erosion whilst reducing the wetland's footprint. The extended detention wetland is shown in figure 3. (HUNTER 2013)

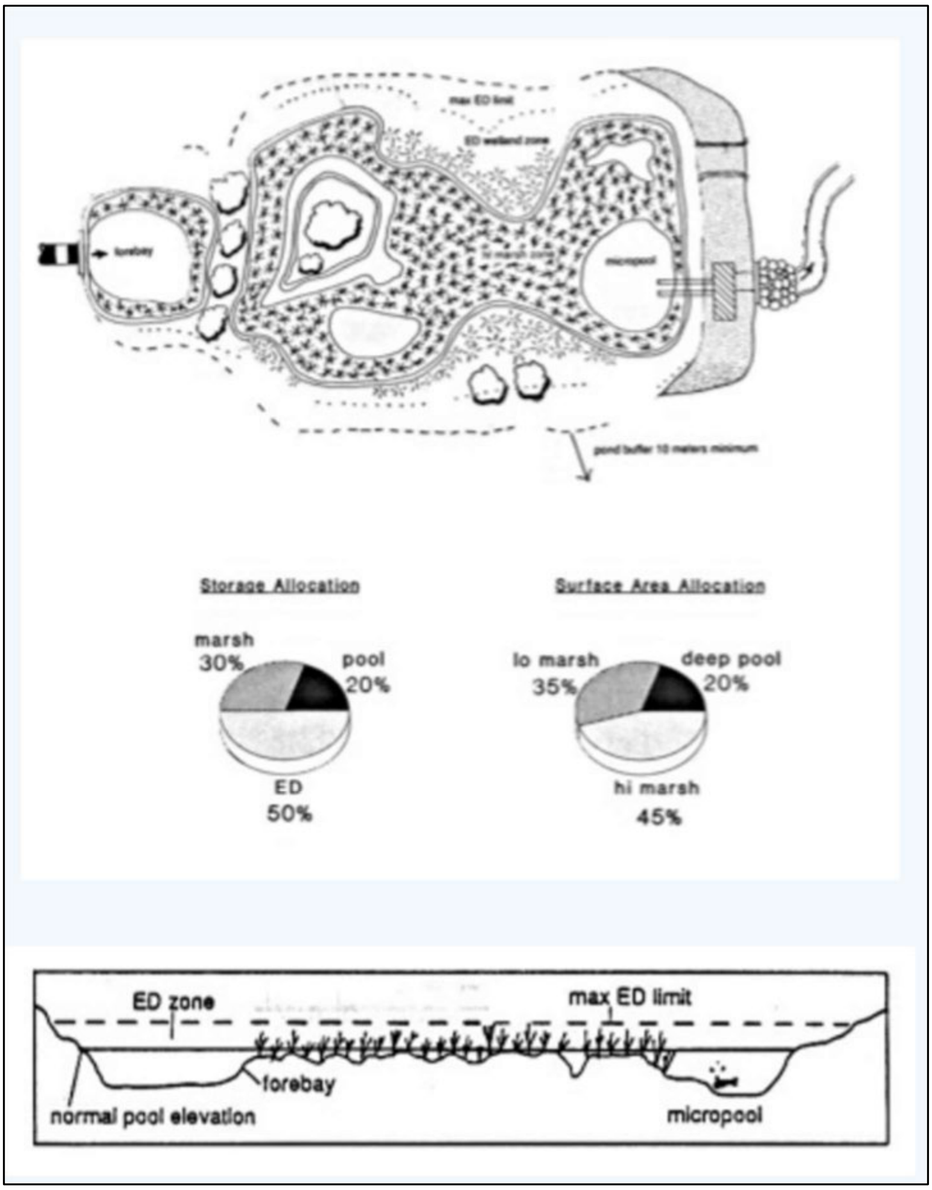

Figure 3 Extended Detention Wetland (HUNTER 2013)

The fourth type is the pocket stormwater wetland, this wetland is often used when servicing smaller sites, as the catchment areas of the wetland is small, the levels within the wetland are variable. These wetlands are often dry or very shallow. The effectiveness of treatment is usually poor. These are often used in small development however its variable effectiveness makes it a difficult option. The Pocket wetland is shown in figure 4. (HUNTER 2013)

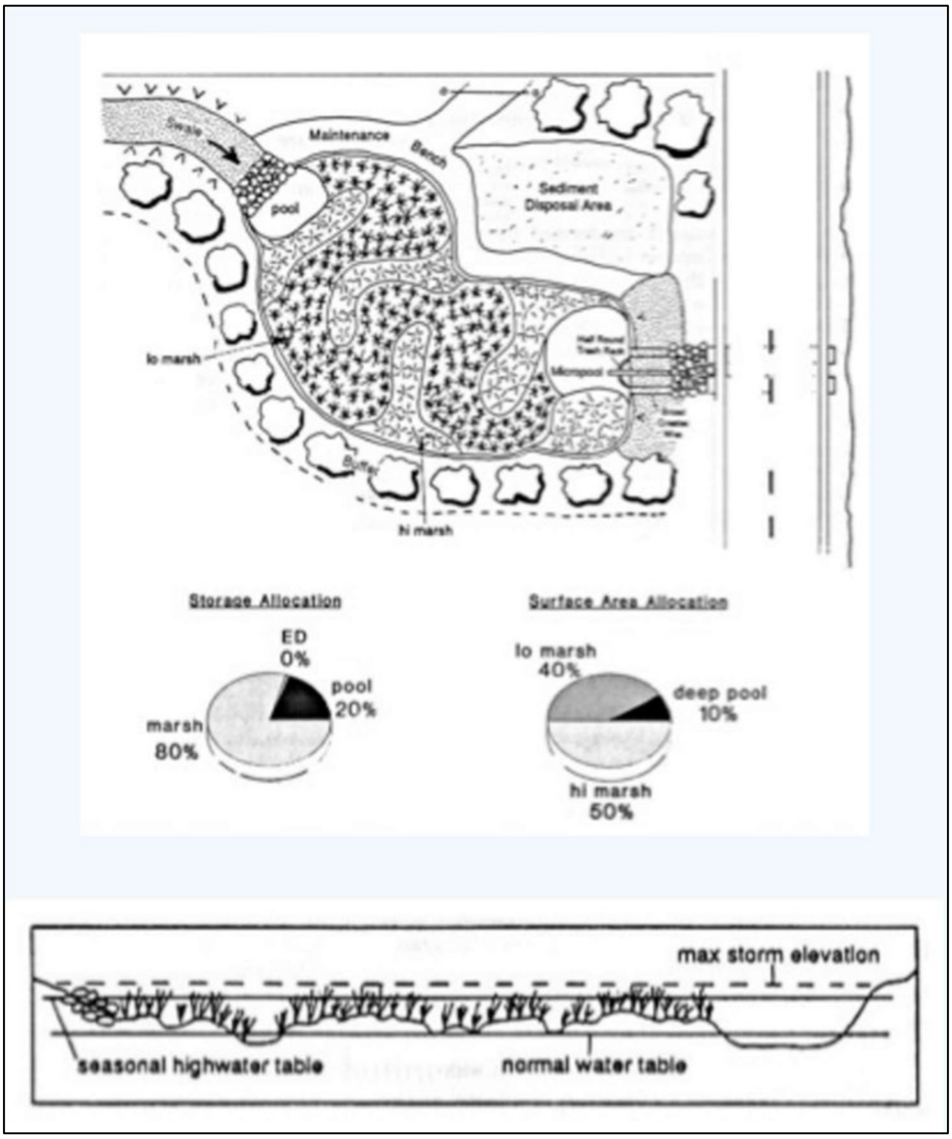

Figure 4 Pocket Stormwater Wetland (HUNTER 2013)

Wetlands have been proven to be one of the best ways to remove gross pollutants, sediments, nitrogen and phosphorus, they have also been effective at the removal of metals, pathogens and organic compounds (WATER 2020).

The report indicates that there are three treatment methods commonly used in the treatment and removal of pollutants.

- Physical removal where sediment is captured allowing sedimentation to occur down to fine colloidal particles. This aids in the removal of absorbed particles.
- Biological and chemical uptake through epiphytic biofilms present on the surface of the vegetation. Fine suspended particles are then removed through sedimentation and adhesion through macrophytes and biofilms.
- Pollutant transformation can occur through the wetting and drying cycles within a wetland, allowing for the removal of phosphorus and other metals. Nitrification and denitrification processes allow for the conversion of ammonium and nitrate to nitrogen gas allowing it to disperse into the atmosphere. UV treatment allows for disinfection to occur.

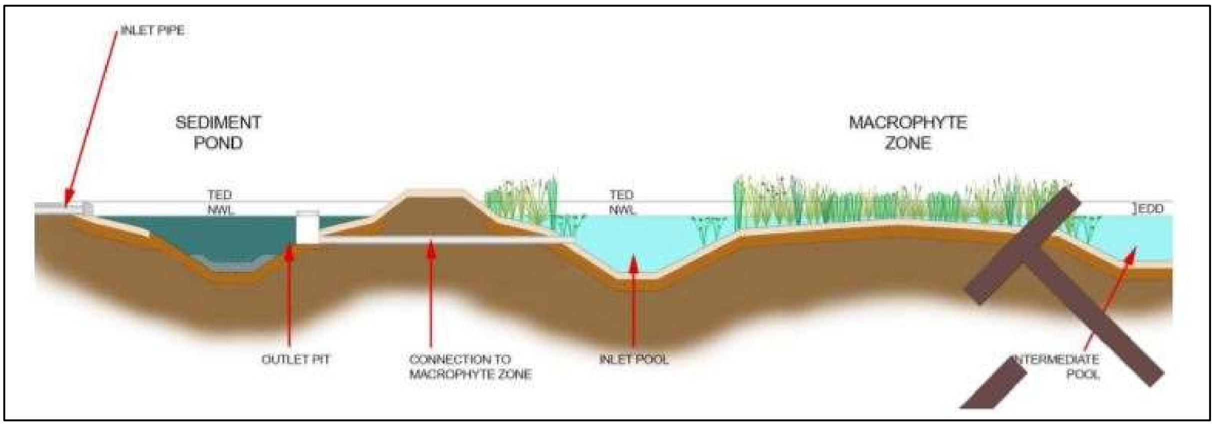

Figure 5 Typical Wetland Cross Section (WATER 2020)

Figure 5 shows a typical wetland cross section, starting with an inlet pipe to direct water into the sediment pond. The sediment pond is sized to ensure that adequate residence time is available for particles to settle within the sediment pond. It is important that sufficient volume is available for build-up of sediment for a period of time before routine maintenance is completed usually once every five years (BROWNING, G et al. 2017).

Research indicates that a wetland specifically designed to handle volume and pollutant loads provides the most efficient solution in terms of costs and effectiveness. This project will look to design a wetland to provide treatment required for stormwater and help to determines its feasibility.

2.4. Yield

The yield of a catchment is an important part of the analysis and feasibility of water collection for any type of water reuse, if the catchment is unable to provide sufficient volume of water it is impracticable and unfeasible to collect water from that catchment. Stormwater yield is a function of parameters that effect the total volume of water that ultimately is received at the outlet of any catchment. These factors are often a constant value that do not change with the weather. Others are more variable and can change the runoff volume considerably depending on the current climate.

As will be discussed below each parameter plays a significant role in the final runoff and yield of any stormwater catchment. They will be broken into variable and constant sections; these will be used as part of the parametric study and to find a typical yield for the Gloucester stormwater network.

2.4.1. Runoff

Runoff is a relatively simple calculation considering, rainfall, infiltration, evapotranspiration. Typical runoff can be calculated with the following equation.

$$R = (P - ET) - (S2 - S1) \quad (1)$$

Equation 1 is a simple equation for runoff calculation from a catchment with known parameters, it provides a simple analysis of runoff using values of Soil infiltration (S1 and S2), Evapotranspiration (ET) and precipitation (P) (QUEENSLAND 2019)

Figure 6 is indicative of runoff calculation; this provides a simple equation for an approximate estimation of runoff with known soil and evapotranspiration properties.

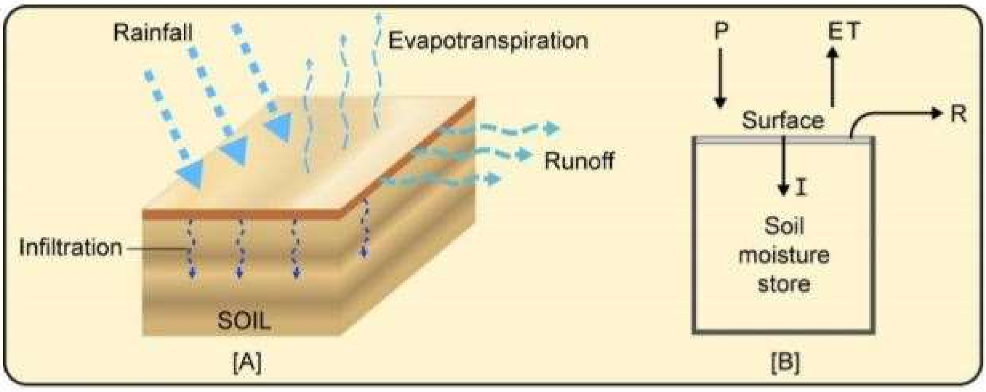

Figure 6 Typical runoff model (QUEENSLAND 2019)

Software such as MUSIC employ similar calculations for runoff generation through their programming, incorporating a number of variable and constant values that produce a volumetric output of water. For the purposes of this study the values produced by MUSIC will be used for wetland calculations and final yield volumes. MUSIC software takes several key values and uses them to simulate rainfall scenarios for a given timestep. The software takes inputs and losses in the form of rainfall and groundwater, with losses occurring from evapotranspiration, reuse, infiltration and groundwater flows, the factors will be discussed below.

2.4.2. Variable Factors

2.4.2.1. Rainfall

Rainfall is the driving factor for all runoff, without it runoff does not occur. The Bureau of Meteorology is Australia's government agency for rainfall and weather. Gloucester's rainfall is collected at the Post Office within the township and has historical data from 1888, this has collected daily rainfall data which will form the basis for the calculation of rainfall yield.

With such a large range of data available, average rainfall values can be assumed to be accurate for runoff calculations. Rainfall will be taken from the Bureau of Meteorology with historical data showing that Gloucester's typical annual rainfall is around 940mm annually (METEOROLOGY 2021a). rainfall is assumed to be the most significant factor in rainfall runoff calculations as it is the most variable input across the range of typical inputs.

2.4.2.2. Soil Infiltration

Soil infiltration is in relation to the soils ability to allow water to move into and through it (AGRICULTURE unkown). There are a few factors that affect soil infiltration, some of which cannot be changed. These are its texture and its makeup, percentage of sand, silt and clay. Water will move quickly through the large open pores of sand whereas the smaller pores in clay will slow infiltration (AGRICULTURE unkown).

Infiltration is also affected by the amount of moisture already held by the soil. In dryer times infiltration will be higher as the soil will require more rainfall to fill its pores before it can allow for runoff. During wet periods the soil may be full or near full allowing for almost 100% runoff during these periods.

The Gloucester township is located along a ridge between two surrounding river flats. Generally, the soil profile is mostly clay with some gravel and alluvial soil materials.

Clay based soils tend to have a slow infiltration rate, holding onto water in their pores for long periods of time.

Infiltration rates for New South Wales are presented by the Department of Primary industry providing a general overview of soil characteristics across the state. As indicated in Figure 7, the Gloucester and surrounding regions fall into the category of very low infiltration rates. This lines up with the typical soil profiles of the Gloucester region with predominantly clay-based soils (ENVIRONMENT 2021)

Figure 7 Soil Infiltration Rates (ENVIRONMENT 2021)

MidCoast Council have specific requirements when it comes to water sensitive urban design relating to soil types and its characteristics particularly for MUSIC modelling. It specifies soil depths, ratios and groundwater properties that are to be implemented in the software for modelling purposes. As part of the study these values will be implemented. The guideline also specifies soil moisture content, which is the percentage of moisture within the soil profile at the beginning of modelling.

Figure 7 shows that Gloucester falls within the very low infiltration rate hydrologic soil group. The Council guideline specifies this as type 4 soil, which is a high clay content with very little opportunity for infiltration with low groundwater flows. (MCKAY et al. 2019)

2.4.2.3. Evapotranspiration

When rain falls within a catchment, losses begin to remove potential for runoff almost immediately, a portion of this is by a process called evapotranspiration. Evapotranspiration is the combination of evaporation of water into the atmosphere and transpiration which is where plants take up water in order to grow. Depending on location, time of year and conditions each of these values can vary significantly. This means that an accurate collection of data for these values is important as part of the collection of yield for a catchment.

The Bureau of Meteorology provides historical data from across Australia, maps are created indicating these historical average values of evapotranspiration. The Bureau also have potential evapotranspiration values for when water supply is high, generally during high annual rainfall periods (METEOROLOGY 2021b)

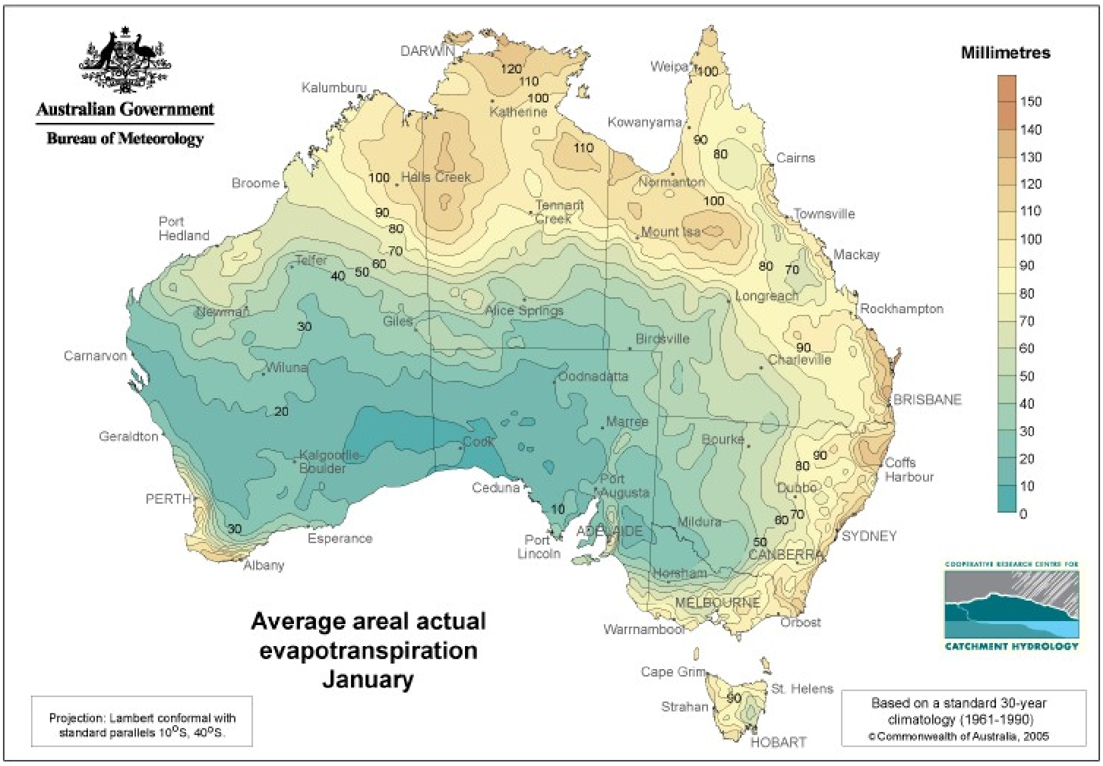

Figure 8 Average Areal Actual Evapotranspiration January (METEOROLOGY 2021b)

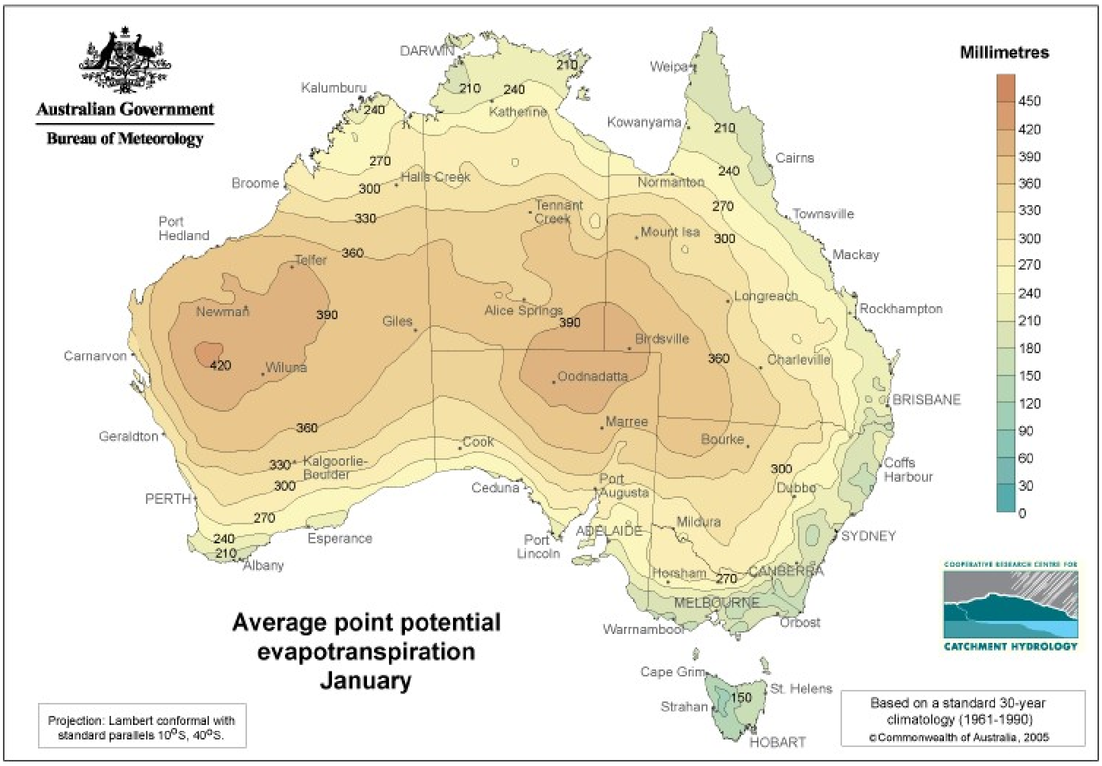

Figure 9 Average Point Potential Evapotranspiration (METEOROLOGY 2021b)

Figure 8 and Figure 9 show the difference in evapotranspiration values, these values will be used as part of the parametric study for stormwater yield assessing the affect evapotranspiration has on potential runoff volumes.

2.4.2.4. Storage

A feature of many residential and industrial sites is the presence of water storage. This serves as an additional form of water loss whereby water collected off roofs and awnings, directed into storage tanks which then will have a form of overflow that makes its way into the existing stormwater network.

MidCoast Council have guidelines for non-potable demand for water tanks as part of its water sensitive urban design. These values are taken from estimate for each household across the entire local government area. Non-potable water requirements are usually toilet flushing, washing machines and outdoor taps and gardens.

Council's water usage estimates are shown below:

- Toilet Flushing = 55L/day/Dwelling
- Washing Machine = 95L/Day/Dwelling
- Outdoor = 100L/Day/Dwelling

(MCKAY et al. 2019)

As part of the study, assumptions will be required to be made for tank storage and reuse and will be discussed in the methodology and results section.

2.5. Design

A constructed wetland is considered an arrangement of water bodies that hold a volume of water and also aquatic plants. The stormwater that is directed into a constructed wetland undergoes physical, biological and chemical processes that help remove waterborne pollutants. The process takes approximately 48 hours to provide effective treatment (COOMBES & ROSO 2019)

The Australian Rainfall and Runoff Guide; Part 9 specifies the use of guidelines for the design of constructed wetlands, the guideline by Water by Design provides a step by step approach to size the wetland and subsequent infrastructure to provide sufficient treatment and hi-flow protection to ensure the wetland is able to effectively provide treatment of stormwater for the improved water quality that leads to the possibility of water reuse. (COOMBES & ROSO 2019)

The design of a water treatment area is an imperative part of water collection and reuse. Without treating water to a suitable standard, the construction of a wetland is unnecessary as it provides no benefit in the collection and reuse of water.

There are several papers and journals documenting the effectiveness of wetland designs for treatment of stormwater and wastewater. Several government agencies have also produced guidelines for wetland design, the most prominent is a document providing detailed calculations, reference to the Australian Rainfall and Runoff Book 9 Urban Runoff, this document will form the basis for the wetland design (BROWNING, G et al. 2017; COOMBES & ROSO 2019)

The design process looks at the design from two parts. The first is the sizing of a sediment basin to collect sediments prior to water being directed into a larger wetland area for continued treatment. The outlet sizes are determined by calculation relating to design rainfall (BROWNING, G et al. 2017). The guideline specifies that the wetland is designed to handle flows for up to a 1-year average recurrence interval (ARI), this will be determined by the chosen catchment for the concept wetland. The second part is the design of the wetland macrophyte zone which is the shallow section with aquatic plant life designed to remove pollutants as the water slowly meanders its way through the wetland before finally reaching the outlet where the treated water will discharge. The water would then be transferred to the water treatment plant for final treatment and distribution.

Horner states that in order to achieve some storage within the wetland, an extended detention wetland will need to be chosen to hold additional storage of stormwater before it is moved to a larger dam storage in the future. The volume of water is calculated using average annual rainfall, number of days rainfall, runoff coefficients and typical residence times for pollutants to provide an estimate of runoff volume required in additional storage. (HORNER 1994)

MidCoast Council have specific requirements for pollutant reduction targets that are to be met as part of its water sensitive design guideline. These values are for suspended solids, nitrogen and phosphorus. They are as follows:

- Total Suspended Solids - 70%
- Total Nitrogen - 40%
- Total Phosphorus - 40%

(MCKAY et al. 2019)

By following the guidelines as set out by Water By Design and inputting values into MUSIC software, it can be seen whether pollutant reductions can be met and whether they meet drinking water requirements (GOVERNMENT 2011; BROWNING, G et al. 2017)

2.6. Justification

The background research has been able to identify that there have been several studies for urban stormwater collection, there are very few studies that research stormwater collection for potable use. It is noted that there is very little documentation in Australia relating to guidelines and requirements to be met for stormwater collection in relation to pollutant removal and treatment.

As most studies are for highly urbanised areas with little documentation relating to small and rural towns, a gauge on the typical quality of stormwater from less urbanised catchments is largely unknown.

These gaps in the literature provide the justification for this project as it aims to provide an overall feasibility analysis for urban stormwater collection with focus on water quality, stormwater yield, collection and treatment to provide an offset for water demand and its potential use in an ever changing climate with water becoming an ever diminishing resource.

3 Methodology

To fulfil to requirements of the objectives as set out in Chapter 1 of this report, methodology will be set out and followed as follows:

- Collect and test water samples
- Calculate theoretical runoff yield using MUSIC software and parametric study
- Analyse volume and quality
- Design a suitable treatment option
- Complete a feasibility analysis on stormwater collection

These steps will be followed and completed in conjunction with one and other in order to determine the feasibility of an urban stormwater collection system.

3.1. Water Samples

In order to provide an accurate design for suitable stormwater treatment, samples will need to be collected and tested for pollutants. MidCoast Council has a NATA accredited laboratory at their Bootawa water treatment facility. The sampling will be broken into two parts, sample collection and sample testing.

3.1.1. Sampling

A number of samples are to be collected across several localities within the Gloucester urban area. Gloucester can be broken into 3 separate categories; Central business district, residential and industrial. 6 samples are to be collected across several discharge points within Gloucester, incorporating the CBD, industrial and residential areas of Gloucester in order to provide a good variation of samples to provide the most accurate interpretation of possible pollutants found in Gloucester's stormwater network.

3.1.2. Testing

Testing will be conducted at Council's Bootawa Laboratory. The testing will provide pollutants and their quantities within each sample. This will provide a baseline for treatment for the removal of said pollutants in order to provide safe clean drinking water to the residents of Gloucester.

Testing will be specifically designed to test for the following pollutants as discussed in Chapter 2:

- Solids
- Metals (Zinc, Mercury, Lead, Copper)
- Nutrients (Phosphorus & Nitrogen)

The results of these samples presented in chapter 4 will provide details of quantities of pollutants within stormwater and therefore provide details required for treatment solutions for particular pollutants.

3.2. Yield

The calculation of stormwater yield for the entire network required significant calculation and modelling to predict and determine volume of runoff likely to reach the chosen storage and treatment facility. For this report a number of inputs will be utilised with variables included in order to complete a parametric study. The inputs and variables will be discussed below.

For this report values are broken into static and variable values that will used in the parametric study component of this report.

Static values are values that will not change over time or differing weather events, some will never change others may with further investigation in future works. The static values used are:

- Catchment Area
- Impervious and Pervious Areas

Variable values are inputs that have the tendency to change over time, are often weather and climate dependant. The variables chosen as part of this study will form the basis of the parametric study and provide the best educated answer in relation to the feasibility of the stormwater reuse scheme. For this report the variable values will be:

- Rainfall
- Soil depth and rates of recharge
- Soil field capacity
- Evapotranspiration values
- Tanks and water reuse
- Seepage rates
- Groundwater depth

The modelling software MUSIC will be utilised for its ability to assess a number of variable inputs to provide a range of discharge volumes across all catchments. The analysis of this data will determine the location and size required for the treatment area to provide sufficient water quality to be used as an alternative drinking water resource.

3.2.1. Static Values

The first task is to calculate catchment areas for the stormwater within Gloucester. The township is effectively split into two major catchments due to a high ridge that runs in a northerly direction through the centre of the township.

The ridge that traverses through the township provides an issue relating to collection of stormwater for treatment within one centralised location. Options could be investigated around the use of two treatment wetlands or a single large wetland supplied by pumps from both major catchments.

The collection of catchment areas utilises council's mapping system including, stormwater infrastructure and contours. Local knowledge of catchments is also used in order to provide the most accurate data available. In some cases, assumptions are made in relation to catchment boundaries and missing stormwater information. All of the catchment areas incorporate all of the Gloucester townships available catchments, with analysis to follow to determine which catchments will provide the best fit in terms of outflow, terrain and location to ensure that this project will be feasible for water supply alternatives.

In relation to the ridge providing separation the town's catchment areas the analysis will be broken into each catchment namely Gloucester River (Western Side) and Avon River (Eastern Side), the following sections detail each section indicating specific properties that will be used as part of the modelling of the stormwater.

The calculation of pervious and impervious areas was undertaken by collecting all of the known pervious (parks, sports fields, farmland) and impervious areas (roads, carparks) subtracting them from the total value. Once this reduction has occurred the remainder of was largely residential houses. To minimise the amount of time in calculating each individual house's impervious area, ten houses were used across all of Gloucester with a percentage calculated for impervious areas. This is then used to provide the pervious and impervious percentages to input into the modelling software. The results of these calculations determined that for most houses the percentage impervious was approximately 35%. This value was adopted for all residential houses across the entire town. The industrial estate was calculated to be approximately 50% impervious and is adjusted accordingly. Sample calculation is shown in table 3, further analysis of all catchments is in appendix G and H.

3.2.1.1. Catchments and Impervious Percentages

Catchment one is a large catchment encompassing a large residential area and the Gloucester high school. This catchment has a significant grass swale that acts as the main stormwater main where the water finally discharges across Church Street into a grass paddock towards the Gloucester River.

An outline of the catchment is shown in Figure 10.

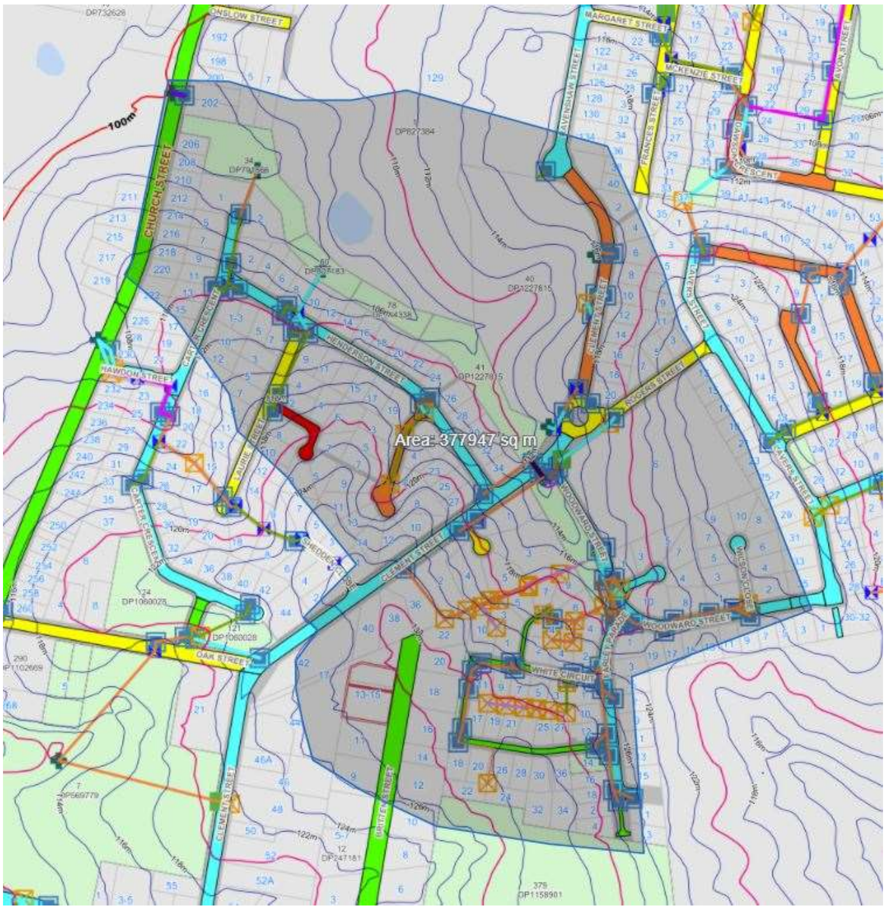

Figure 10 Catchment 1 Gloucester River Side(Council 2021b)

Table 1 shows calculations for catchment percentages, with reductions made for roof areas, roads and pervious areas. This is then used to calculate an impervious percentage for each catchment, this can then be used within the MUSIC software for calculation for stormwater yield. For all catchments, calculations are provided in Appendix I.

Catchment		1		
Area	m^2	377947	Ha	37.79
Area Less Roof		293326	Ha	**29.33**
Grass	m^2	256198	Ha	25.62
Road	m^2	37128	Ha	3.71
Roof	m^2	84621	Ha	**8.46**
Total Catchment				
Impervious	%	12.66		
Pervious	%	87.34		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Table 3 Catchment calculations for Catchment 1

Gloucester River (Western)					
Catchment	**Area Less Roof (m^2)**	**Roof Area (m^2)**	**Impervious (%)**	**Pervious (%)**	**Tanks**
1	29.33	8.46	12.66	87.34	62
2	4.292	1.79	18.78	81.22	20
3	0.823	0.258	13.03	86.97	3
4	7.864	0.729	55.03	44.97	62
5	32.664	11.312	8.12	91.88	80
6	4.229	5.566	35.55	64.45	25
7	11.787	2.099	13.33	86.67	18
8	1.562	0.686	14.38	85.62	18
9	5.67	2.156	29.4	70.6	18
10	4.701	0.76	42.46	57.54	16

Table 4 Gloucester River (Western) Overall Catchment Data.

Table 4 shows all catchments on the Gloucester River side of the Gloucester catchment. Detailed catchments and calculations for all catchments is located in appendix I. As can be seen from Table 5 there are a varying number of catchment sizes with variable impervious percentages.

Avon River (Eastern)					
Catchment	Area Less Roof (m^2)	Roof Area (m^2)	Impervious (%)	Pervious (%)	Tanks
1	1.24	0.45	18.54	81.46	5
2	1.328	0.48	30	70	8
3	2.614	0.973	27.86	72.14	12
4	4.986	1.52	18.42	81.58	27
5	12.185	3.592	16.86	83.14	60
6	1.82	1.764	49.92	50.08	8
7	13.82	5.778	20.01	79.99	60
8	5.79	2.24	28.13	71.87	22

Table 5 Avon River (Eastern) Overall Catchment Data

Continued analysis of the catchment areas indicated that each of the individual catchments would have individual outlet locations which would require a pumped system in order to collect entire catchments for treatment through the designed wetland. This is considered to be an unnecessary expense, however for the purpose of modelling and assessing the ability of the catchment to provide runoff a small parametric study on the entire catchment was completed to provide an estimate of the entire stormwater network and its yield capacity. It is noted that a portion of the total stormwater was removed as part of the entire network, it was decided that the topography and vicinity of the town centre would make collection from these catchments unfeasible under any scenario in the future, so collection and modelling of these areas would provide inaccurate data for analysis.

3.2.2. Variable Values

3.2.2.1. Rainfall

As previously discussed in the background research, historical rainfall data was collected from the Bureau of Meteorology, for this project and the parametric study values collected were collated and sorted. The values used are shown below.

The historical rainfall provides a good range of values across a large span of years, meaning that the data can be considered of good quality for the assessment of rainfall and runoff across the catchments.

Historically Gloucester receives approximately 940mm annually, collected at the Gloucester Post Office. The minimum rainfall recorded for Gloucester occurred in 2018 where a total of 430mm fell across the 12-month period. Highest rainfall occurred in 1950, a total of 1874mm fell, representing the wettest year on record (METEOROLOGY 2021a)

Figures 11, 12 and 13 show rainfall values from 1943, 1950 and 2018, they represent the closest historical annual rainfall for the lowest, highest and typically average years.

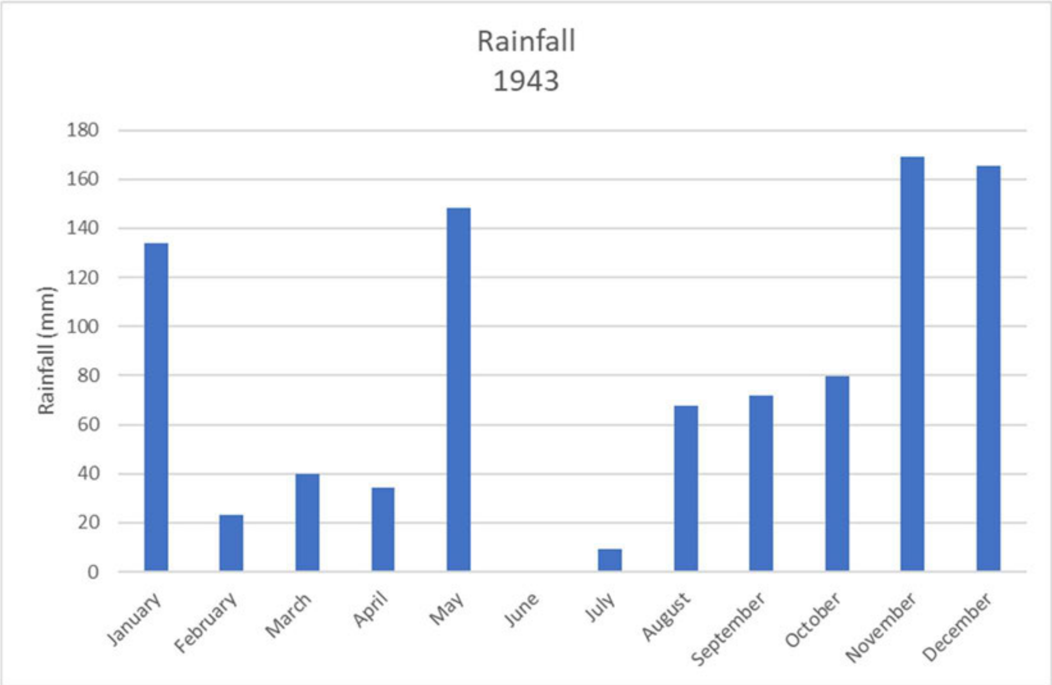

Figure 11 Gloucester Post Office Rainfall Values 1943 (METEOROLOGY 2021a)

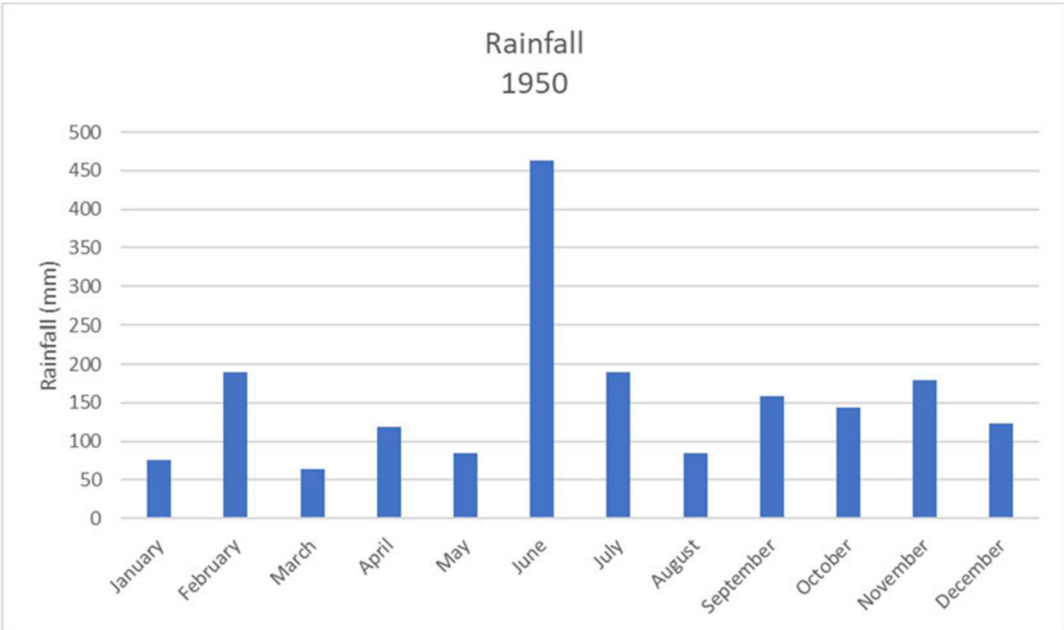

Figure 12 Gloucester Post Office Rainfall Values 1950 (METEOROLOGY 2021a)

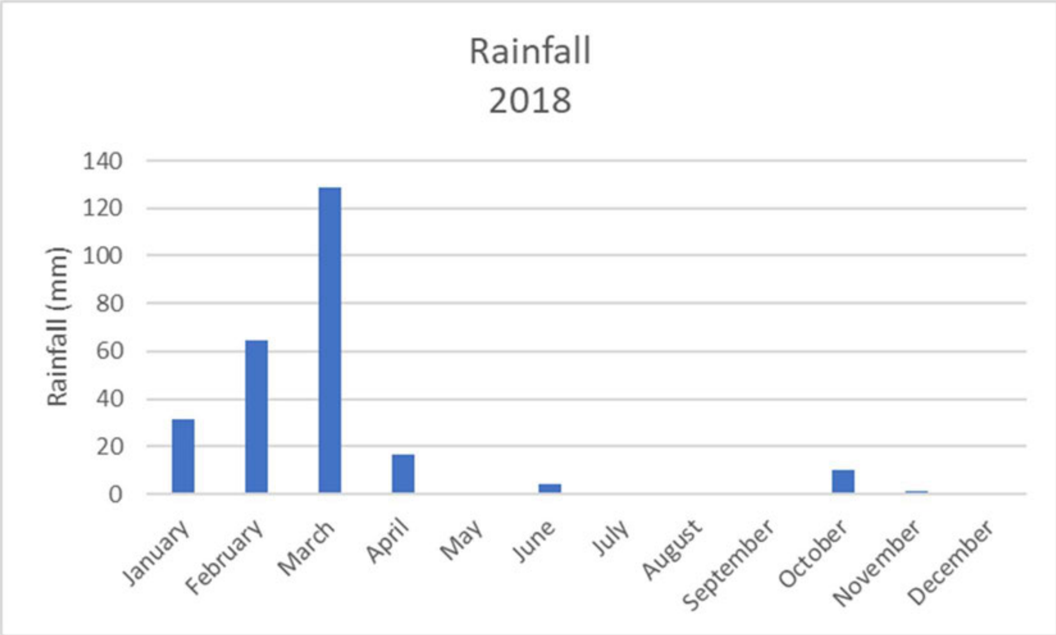

Figure 13 Gloucester Post Office Rainfall Values 2018 (METEOROLOGY 2021a)

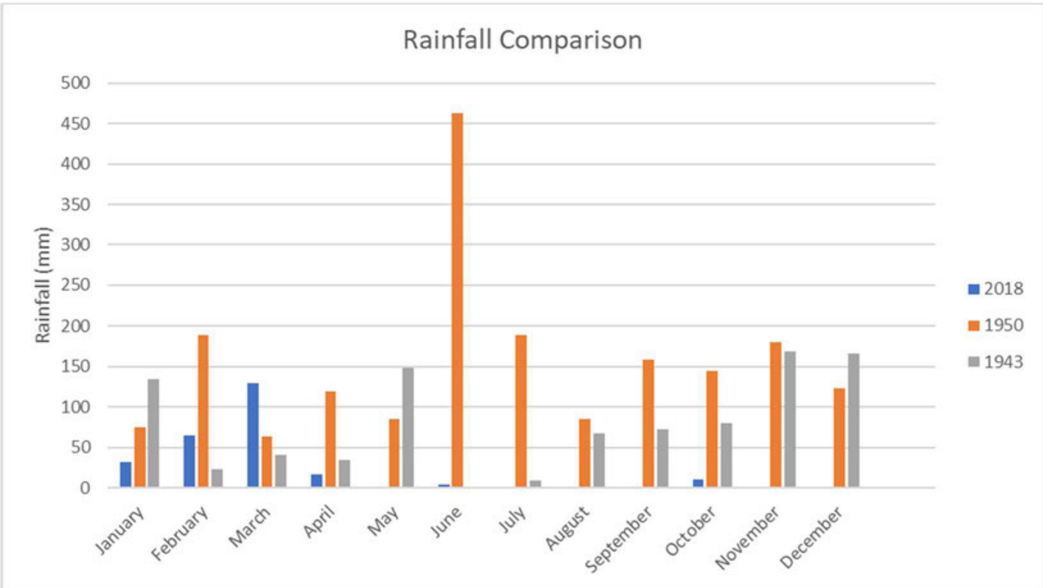

Figure 14 Gloucester Post Office, Comparison Values (METEOROLOGY 2021a)

As rainfall is such a variable value that fluctuates year on year, significant modelling and testing can be completed using historical values. Figure 14 Gloucester Post Office, Comparison Values (METEOROLOGY 2021a) indicates that the disparity between the highest and lowest annual rainfall. For the purpose of this project the three values indicating the lowest, highest and mean annual rainfall historically for the township. These will form the greatest variable for runoff calculation.

3.2.2.2. Evapotranspiration

The values of evapotranspiration play an important role in determining the total runoff of a catchment, variability of evapotranspiration is important as different weather cycles can affect the total evapotranspiration value.

The bureau of meteorology has mapping that provides approximate values for evapotranspiration based on historical data, the values are expressed as mm per day lost to evapotranspiration and this plays a part in determining the runoff calculation as part of the parametric study.

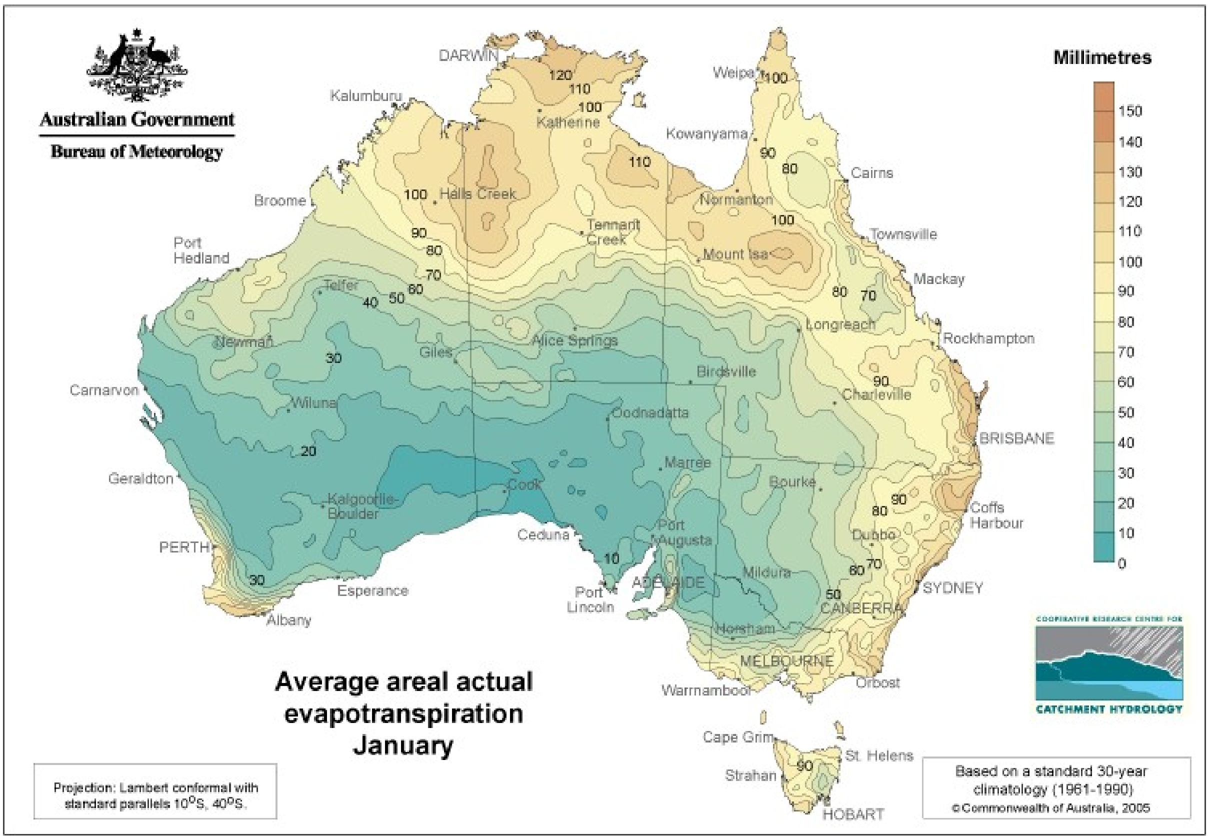

Figure 15 Areal Average Evapotranspiration Values for January (METEOROLOGY 2021b)

Figure 15 indicates average evapotranspiration values for the Month of January, as can be seen the values vary greatly across the country. Values were collected for each of the months of the year and compiled. Figure 16 shows the collection of all average values for Gloucester across an average year. These values play a role in determining some of the losses experienced in the catchment.

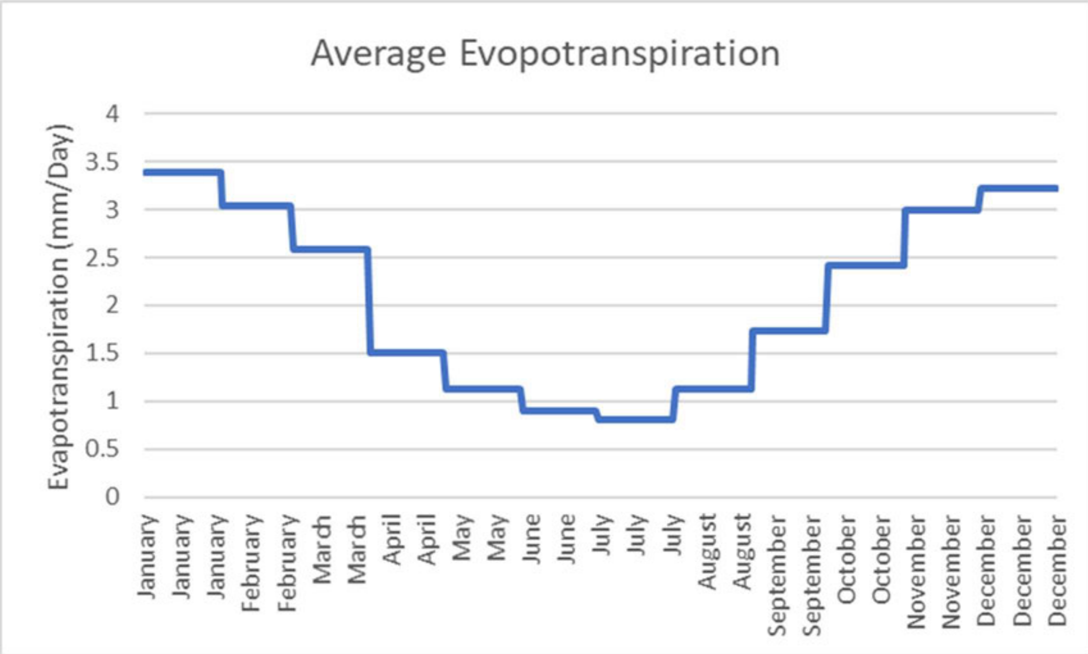

Figure 16 Average Values of Evapotranspiration (METEOROLOGY 2021b)

As can be seen the evapotranspiration rate drops throughout the cooler months, which typically coincides with lower plant growth and evaporation rates.

3.2.2.3. Soil Infiltration and Field Capacity

The soil depth profiles, and field capacity can be considered to be constant. This is based on soil profile mapping and background research. MidCoast Council also have recommended values based on NSW government mapping for soil types. As Gloucester is considered to be soil class D and possibly class C with a very low infiltration rate the following soil depth and field capacity was adopted for the parametric study (MCKAY et al. 2019; NSW 2019)

Table 6 Soil Classification and Properties (MCKAY et al. 2019; NSW 2019)

Soil Class	C	D
Soil Depth	100mm	90mm
Soil Field Capacity	70mm	65mm
Groundwater Initial Depth	10mm	10mm
Daily Recharge Rate	25%	10%
Daily Baseflow Rate	25%	10%

The parametric study will utilise the values shown in table 6 in order to produce a varying range of data that can be analysed to determine a typical stormwater yield and assess the feasibility of the stormwater reuse scheme. For the purpose of the overall smaller parametric study utilising a single daily recharge and baseflow rate as the modification in results is considered insignificant that it would not alter the results in such a way that would change the status of feasibility.

3.2.2.4. Tank Storage and Reuse

The requirements of most development within MidCoast Council requires the installation of water storage tanks to collect roof water for reuse in toilets, washing machines and outdoor use. For the parametric study the following was assumed based on background research.

- 50% of all residential houses would have a tank
- Tanks will be 10,000L
- Water reusage rates are approx. 400L/Day per tank
- Overflow will discharge into stormwater system

These assumptions were used in the parametric study to produce various results, these will be discussed in chapter 5.

3.3. Analysis of quantity and quality of water

Upon completion of yield calculations and quality modelling checks, the data collected from the parametric studies will be compiled into tables and spreadsheets for analysis. This will ensure that all variables have been adequately investigated to provide the most appropriate set of data for analysis.

The analysis will look at best and worst case scenarios for both quantity and quality of water from the system, the data will be graphed and presented as part of this report to provide any trends that may exist with differing input parameters as part of the previous steps within this methodology.

The aim of this analysis will be to determine the typical annual rainfall collection from the Gloucester stormwater network, a minimum capacity of storage required to store this runoff and will lead into the design of a wetland or similar treatment. Discussions on the analysis are presented in chapter 6.

3.4. Design a treatment option

The location of the wetland was a critical part of the potential feasibility of a stormwater collection system. It would need to be located where enough stormwater runoff will be generated to assist in Gloucester water supply network, have a large enough area to accommodate the wetland surface area and have a good quality of water to ensure that the wetland will be able to treat the water effectively enough for treatment in the water treatment plant for human consumption as potable water.

The location was chosen to the south of the high school behind some residential areas of the township, it was chosen because there is a large catchment above it, the entire catchment is available as a gravity fed collection, and there is adequate space available for a treatment area along the narrow council owned property.

A wetland should be kept away from riverine flooding wherever possible to protect the treatment areas including plant life, because of this a number of locations that may have been more suitable for yield collection were considered unsuitable.

Figure 17 Location of wetland for concept design.(Council 2021b)

Figure 17 shows the area chosen as a long a relatively narrow stretch of council owned landed. the catchment servicing this area is approximately 20.19 hectares.

As mentioned, the choice of wetland location was made based on available land, flood immunity and stormwater yield. There are other locations that would have been able to provide a greater volume of water however the presence of flood waters meant that the costs associated with repairing and maintaining infrastructure after a flood event made them untenable choices. The urban stormwater collection system used in Orange is able to collect and supply approximately 25 to 30% of the annual water consumption requirements so the location of the wetland can be justified if it meets this criterion. Detailed calculations and design details are discussed in chapter 6.

3.5. Cost Estimate and Feasibility Study

Finally, a cost estimate will be completed for the wetland treatment area using typical construction costs with broad estimates.

With the collection of all relevant data, designs and costings, the feasibility of an urban stormwater collection scheme for Gloucester can be completed. The study will look at the practicality of a collection system, uncover strengths and weaknesses of options to objectively determine the feasibility of this project.

The study will encapsulate all of the relevant research, data and analysis along with a cost estimate to ensure that the aims of this study are met and provide an answer to whether an urban stormwater collection scheme can in fact provide a solution to water shortage problems for Gloucester. Cost estimates are shown and discussed in chapter 7.

4 Sampling and Testing

Testing of water plays an important role in the design of treatment to meet current standards. The choice of testing location needs to be made in order to potentially discover worst case scenarios to assist in treatment trains and potential uses for water.

For this project water quality is focussed on a few significant pollutants that may be present within the Gloucester catchment, these are metals, nutrients and suspended solids. The following outlines the testing locations, procedures followed, and results from these tests and how they compare to typical ranges for pollutants.

4.1. Testing Locations

It was the intention to achieve a broad range of results from a small sample size to encompass all possible sources of pollution within the Gloucester stormwater system. After consultation with council and research of typical pollutants, three locations were chosen to complete testing.

It is important to note that due to time constraints and financial constraints a select number of pollutants were to be targeted through the sampling of this project. The decision was made to test for metals, nutrients, oil and grease along with a value for total suspended solids. This decision is based on local knowledge and council's history of sampling within the shire historically.

4.1.1. Location 1

Figure 18 Location 1 Gloucester Industrial Estate Tate Street

The first location shown in figure 18 is within Gloucester's industrial estate. The outlet of the stormwater network discharges via a culvert into a large storage dam forming a part of a retention system for the subdivision.

The catchment at this point in time is largely made up of large industrial blocks, most with large sheds and concrete driveways. The industrial estate has various industrial businesses including manufacturing, car repairs, rural suppliers and fabrication.

This type of works often will lead to pollutants entering waterways through the stormwater network, namely heavy metals including zinc, copper and lead. Samples detecting metals was chosen from this location. There is a percentage of vacant land currently within the catchment so a sample for total dissolved solids (TSS) was taken at this point.

4.1.2. Location 2

Figure 19 Location 2 Gloucester Residential Estate and High School Church Street

The second location shown in figure 19 is a large catchment below the Gloucester high school and agricultural farm. The outlet discharges via a three-cell culvert into a grassed paddock leading onto Gloucester River floodplain.

The catchment is largely made up of residential areas, the Gloucester High School and a grassed swale collecting the catchment before it is directed into the three-cell culvert and discharged. The primary sources of pollution within this area come from the large grassed areas associated with farming and residential lawns.

The pollutants tested here are nutrients usually associated with heavily fertilised and treated grassed areas, namely Nitrogen and Phosphorus. As the catchment flows through a grassed swale another collection for TSS was taken at this point.

4.1.3. Location 3

Figure 20 Location 3 Gloucester Central Business District Billabong Lane

The third and final location shown in figure 20 is a smaller catchment below the Gloucester business district. The outlet discharges via a single cell culvert into a drainage channel called the Gloucester Billabong. This then flows into the Gloucester River.

The catchment is made up of residential and businesses with a significant portion of roads and carparking. The assumed primary sources of pollution within this area come from the significant ratio of roads and carparking areas providing significant runoff from the catchment, along with the higher traffic activity within this area.

The pollutants tested here are oils and grease, the significant percentage roadway area carry traffic and oil and grease is often left on the road and is collected into the stormwater.

4.2. Collection Procedure

The collection of samples follows the procedures set out by New South Wales Health and the Division of Analytical laboratories. By following the collection procedures outlined in this document it ensures that the results presented are as accurate and correct as possible to provide validity to this research and feasibility analysis.

Bottles were provided by MidCoast Council and were cleaned and prepared prior to sample collection being undertaken.

The procedure for collection is as follows:

- Lid is kept on each sample bottle until the time of collection. Lid is to be kept away from anything that may contaminate the sample once removed
- Sample is not washed prior to collection
- Bottle is faced into the flow of water where possible
- Water must fill the entire container, no air gaps
- Ensure the lip is fastened correctly (not cross threaded)
- Samples are then transported in an insulated container, with ice to keep the samples between 1°C and 10°C to ensure samples do not alter or change prior to testing

- Samples are to be sent for testing within 24 hours of collection where possible.

This procedure is as per New South Wales Health guidelines (LABORATORIES 2010).

4.3. Samples

Samples were collected after a rainfall event on the 21st of June 2021. Each sample was collected in accordance with the above procedures, placed into an insulated and cooled container, transported to Council's NATA laboratory at Bootoowa.

As part of Council's testing procedure, a chain of responsibility form is used for each set of samples collected by council as part of its ongoing water sampling requirements. This form is attached in Appendix K.

Samples collected from the first location within Gloucester's industrial estate were the first samples collected. As mentioned, the samples collected here targeted metals and total dissolved solids. The samples collected is shown in Figure 21.

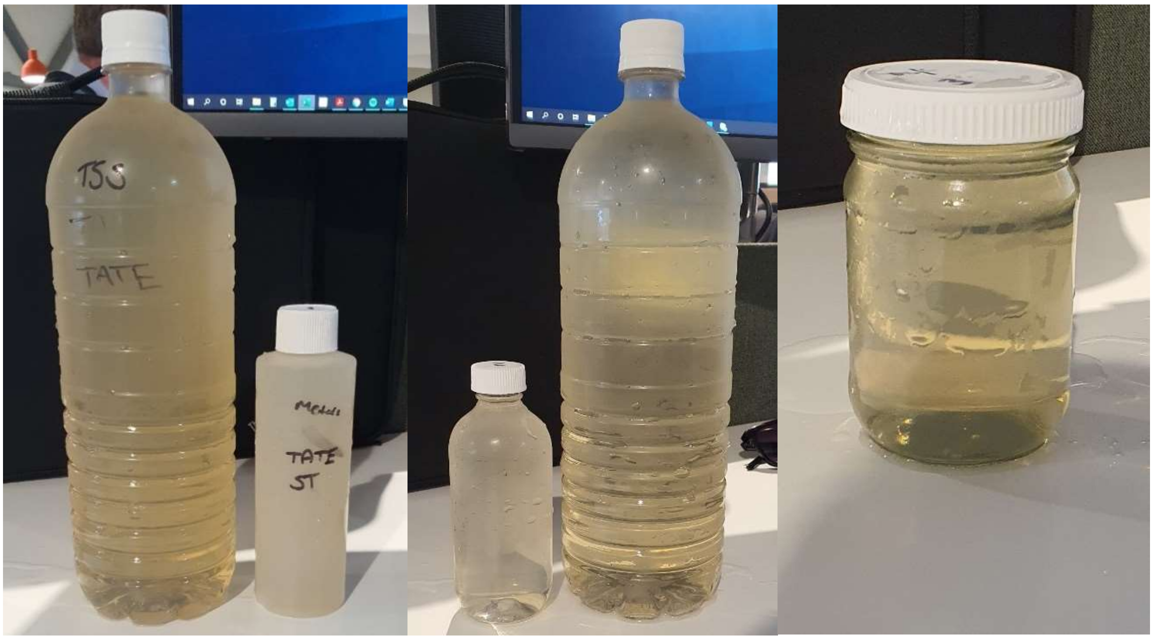

Figure 21 Samples collected from 3 locations

Figure 211 shows photographs of the samples as collected from the three described locations; the samples appear relatively clear with limited floating solids.

4.4. Results

Results were provided my MidCoast Council's laboratory and the results are presented in Table 7 .

Table 7 Water Collection Samples Results.

Sample	Sample	Lead Total mg/L	Zinc Total mg/L	Copper Total mg/L	Total Suspended Solids	Total Nitrogen	Total Phosphorus	Oil & Grease
Description	Date							
		mg/L	*mg/L*	*mg/L*	*mg/L*	*mg N/L*	*mg P/L*	*mg/L*
GSW1 - Tate Street	21/06/2021	0.0015	0.03	0.0084	16			
GSW2 - Church Street	21/06/2021				20	1.13	0.104	
GSW3 - Billabong Lane	21/06/2021							<10

Table 8 Stormwater Pollutants Compared to accepted values

Constituent	Units	Tested	Lower	Typical	Upper
Suspended Solids	mg/L	16-20	40	140	500
Lead	mg/L	0.0015	0.005	0.02	0.075
Zinc	mg/L	0.03	0.1	0.3	1
Copper	mg/L	0.0084	0.02	0.08	0.3
Nitrogen	mg/L	1.13	0.7	2	6
Phosphorus	mg/L	0.104	0.08	0.25	0.8
Oil and Grease	mg/L	<10	3	9.5	30

Table 8 shows the tested pollutants and how they compare to historically tested and associated lower, typical and upper concentrations.

4.5. Discussion

Water samples collected across the three sites provide a good variation and broad range of results for different expected pollutants within the urban stormwater catchment. The results provided from the collected samples indicate that most of the pollutants fall within or below the lower threshold for stormwater pollutants.

Values for suspended solids are significantly lower than any value, all of the metals (lead, copper and zinc) fall significantly below each of their lower threshold values, this indicates that metal pollutants are insignificant in this particular case.

The nutrient values collected (nitrogen and phosphorus) test within typical and lower thresholds, as the values are within typical ranges the treatment of nutrients through a wetland may provide sufficient reduction of pollutants that may allow for potable use of stormwater.

The three locations chosen for sample collection each have some form of treatment with gross pollutant traps and grassed swales this would provide additional treatment prior to the water reaching the outlet, this would suggest that potential higher values of pollutants are being collected from within the catchments, but treatments are removing pollutants as it makes its way down the catchment.

Pollutants pathogens, viruses and hydrocarbons were not tested as part of this study. As the collected stormwater will need to be transferred to Gloucester's existing treatment plant for final treatment and chlorination will kill pathogens and viruses thus meaning that even if they were found as part of any samples taken, the treatment of these pollutants would take part at council's existing treatment plant.

The weather during 2021 has seen higher than average rainfall values recorded across the catchment. In the preceding weeks before the samples were collected Gloucester experienced rainfall events that may have contributed to lower values of pollutants as recorded in the results. Any additional studies completed for urban stormwater collection within Gloucester will need to incorporate a rigorous water sampling program that collects samples over a significant time. This will provide sufficient information for the feasibility relating to water quality.

The results collected indicate that pollutant levels are low enough that with sufficient treatment through the use of a constructed wetland and additional treatment at the water treatment plant will allow for stormwater to be collected and used as part of Gloucester's drinking water network.

5. Parametric Study

A parametric study is designed to test variables and how they affect the final result. The purpose is to determine which variables change the final output and how they affect the other variables that are active within each test.

For the rainfall and runoff yield analysis a parametric study is used to determine the typical total annual outflow of the catchment and how the variables discussed above alter that result and ultimately determine a typical assumed average outflow that can be expected from the chosen catchment. This is then used to determine the feasibility of the urban stormwater collection for Gloucester and its feasibility in other locations.

As mentioned, the variables that affect runoff are primarily in relation to the percentage of pervious areas and the properties of those areas. The MUSIC software is able to use these variables in order to estimate runoff for a given year for a chosen rainfall input. The variables and their inputs are outlined below with modelling completed on each variable shown as part of the results.

5.1. Constant inputs

The catchment chosen for the significant portion of the parametric study is the catchment above the chosen location for the wetland. It is shown in Figure 22

Figure 22 Wetland Catchment (Council 2021b)

Table 9 and Table 10 outline the value chosen as static values that would not be likely to change depending on weather and other climate conditions.

Table 9 Constant Inputs for Parametric Study

Inputs			**Losses**		
Catchment - Roof	Catchment - Remainder	Impervious	Soil Depth	Soil Field Capacity	Groundwater Initial Depth
8.46 Ha	11.73 Ha	20.22%	94mm	70mm	10mm

The choice of catchment was made as discussed above, relating to locality of a treatment wetland, flood immunity and catchment topography. Roof water is separated in order to route runoff through a system of tanks with re-use requirements which will affect runoff. soil depth and capacity were chosen from research and Council's requirements as outlined above. The groundwater initial depth is taken from Council's requirements and an initial depth of 10mm is taken for all soil types.

These values will be used and repeated for the parametric study with results shown below.

5.2. Variable inputs

The following table outlines the value chosen as variable values that will change depending on weather and other climate conditions, producing the range of results as part of the study.

Table 10 Variable inputs for Parametric Study

Inputs	**Losses**				
Rainfall	Evapotranspiration	Tanks % Full	Soil % Full	Daily Recharge Rate	Daily Baseflow Rate
Low - High	Mean - High	0% - 100%	0% -100%	10% - 25%	10% - 25%

Rainfall will be broken into the three variables as discussed above, evapotranspiration will be taken from historical values and assumed values when rainfall is high, tanks and soil will be incrementally increased to assess the affect it has on runoff and finally daily recharge and baseflow rates will be changed from 10% to 25%.

The variables were modelled through the MUSIC software to determine total annual runoff and to assess the difference in results and compare them to determine whether it would be feasible to collect stormwater with great enough volume to look into potential reuse.

5.3. Results

Results are presented for a single variable in Table 11.

Table 11 Tabulated Results example High Rainfall, Empty Tanks

Inputs	**Losses**					**Outflow**	
Rainfall	Evapotranspiration	Tanks % Full	Soil % Full	Daily Recharge Rate	Daily Baseflow Rate	Flow ML/Year	Flow KL/Year
High	High	0%	100%	10%	10%	256.9	256900
High	High	0%	75%	10%	10%	255.3	255300
High	High	0%	50%	10%	10%	255	255000
High	High	0%	25%	10%	10%	254.9	254900
High	High	0%	0%	10%	10%	254.9	254900

Table 11 indicates typical results produced from MUSIC, this represents a single run of the parametric study, as can be seen the change in soil capacity provide a change in the overall outflow across the annual rainfall event chosen. It can be noted that the results are not significant across the five simulations of the MUSIC model. Complete results of the parametric study are provided in appendix E and F for complete catchments and the wetland catchment.

The following figures below show the full catchment parametric study consisting of high and low rainfall showing the affect the variables have of the total annual outflow for the Avon, Gloucester and total catchments. These figures indicate that the collection of the total catchment would be able to provide all of Gloucester's average annual water usage requirements.

Results for the wetland catchment are also shown in the following figures, it shows the complete parametric study across 100 individual modelling simulations per rainfall event.

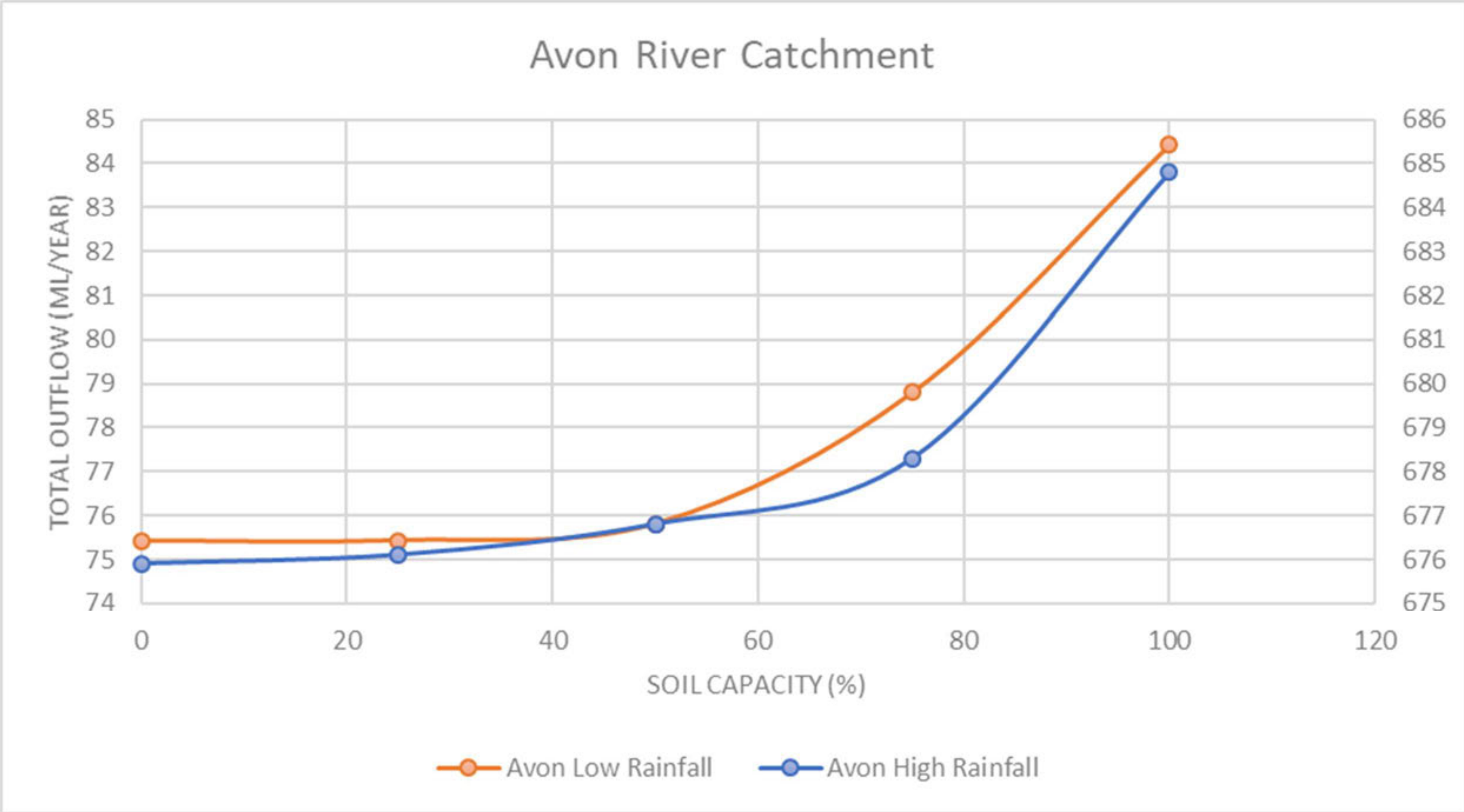

Figure 23 Discharge Relationship for Avon River Catchments

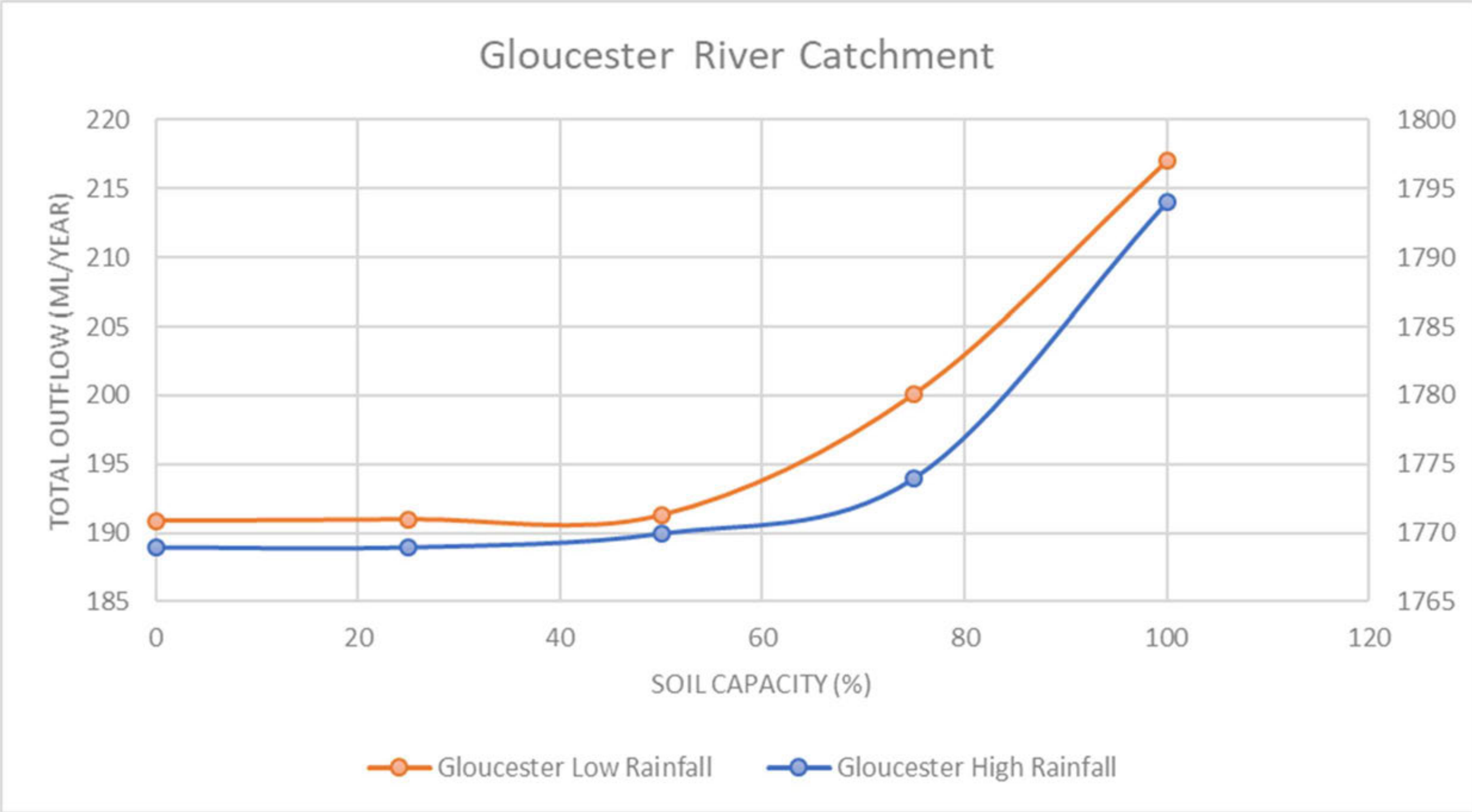

Figure 24 Discharge Relationship for Gloucester River Catchments

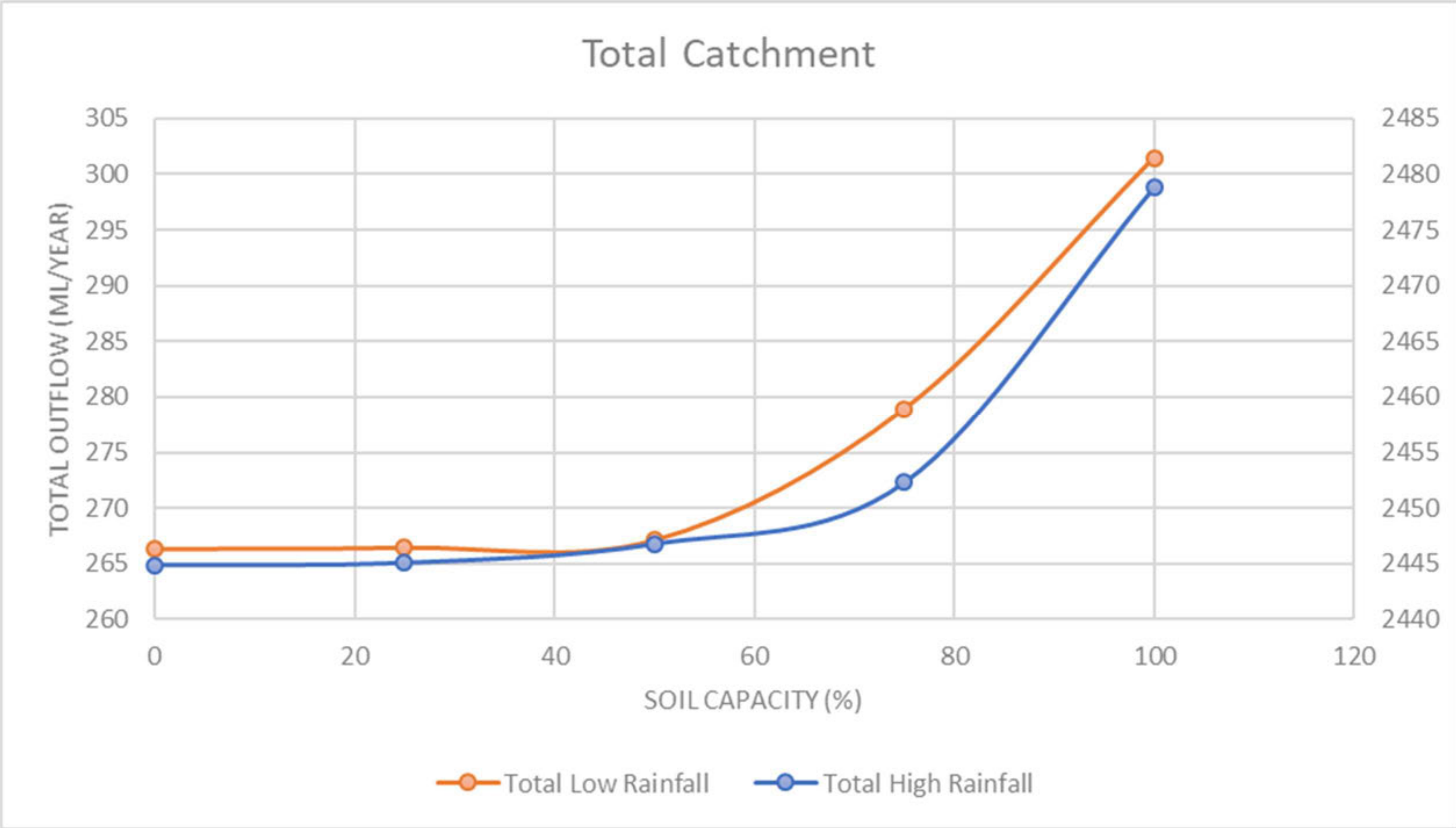

Figure 25 Discharge Relationships for Total Catchments

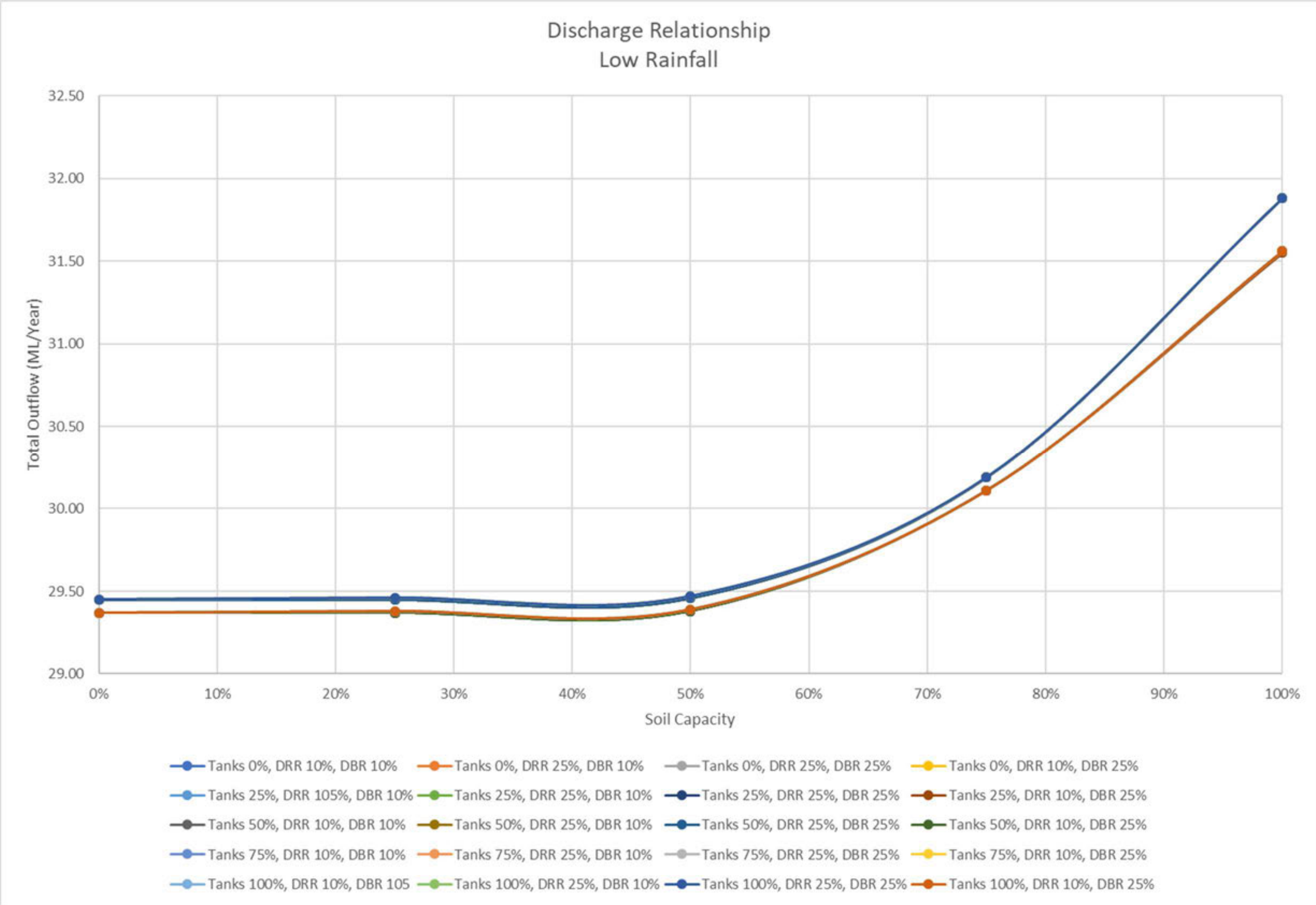

Figure 26 Discharge Relationship for Low Rainfall Wetland Catchment

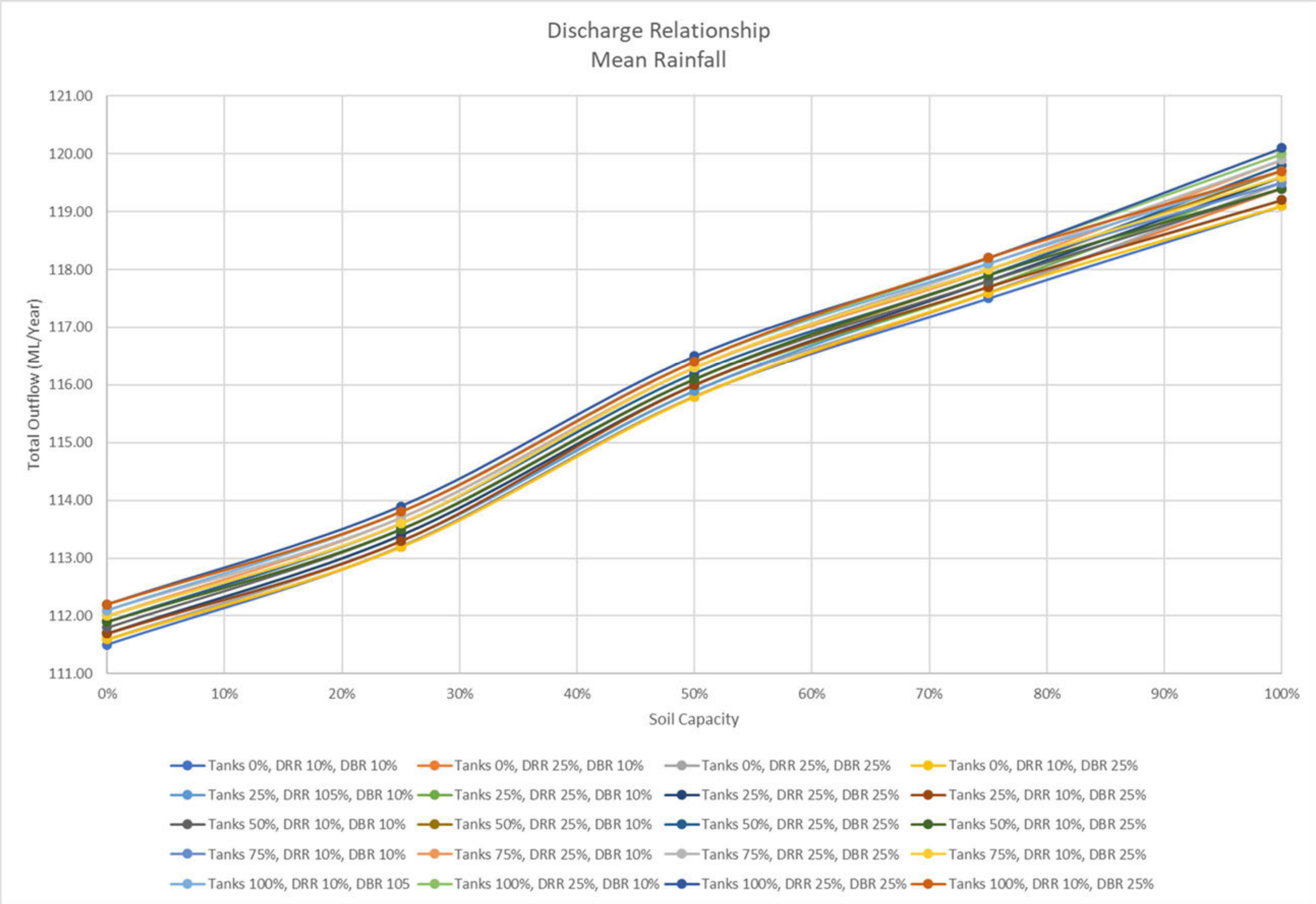

Figure 27 Discharge Relationship for Mean Rainfall Wetland Catchment

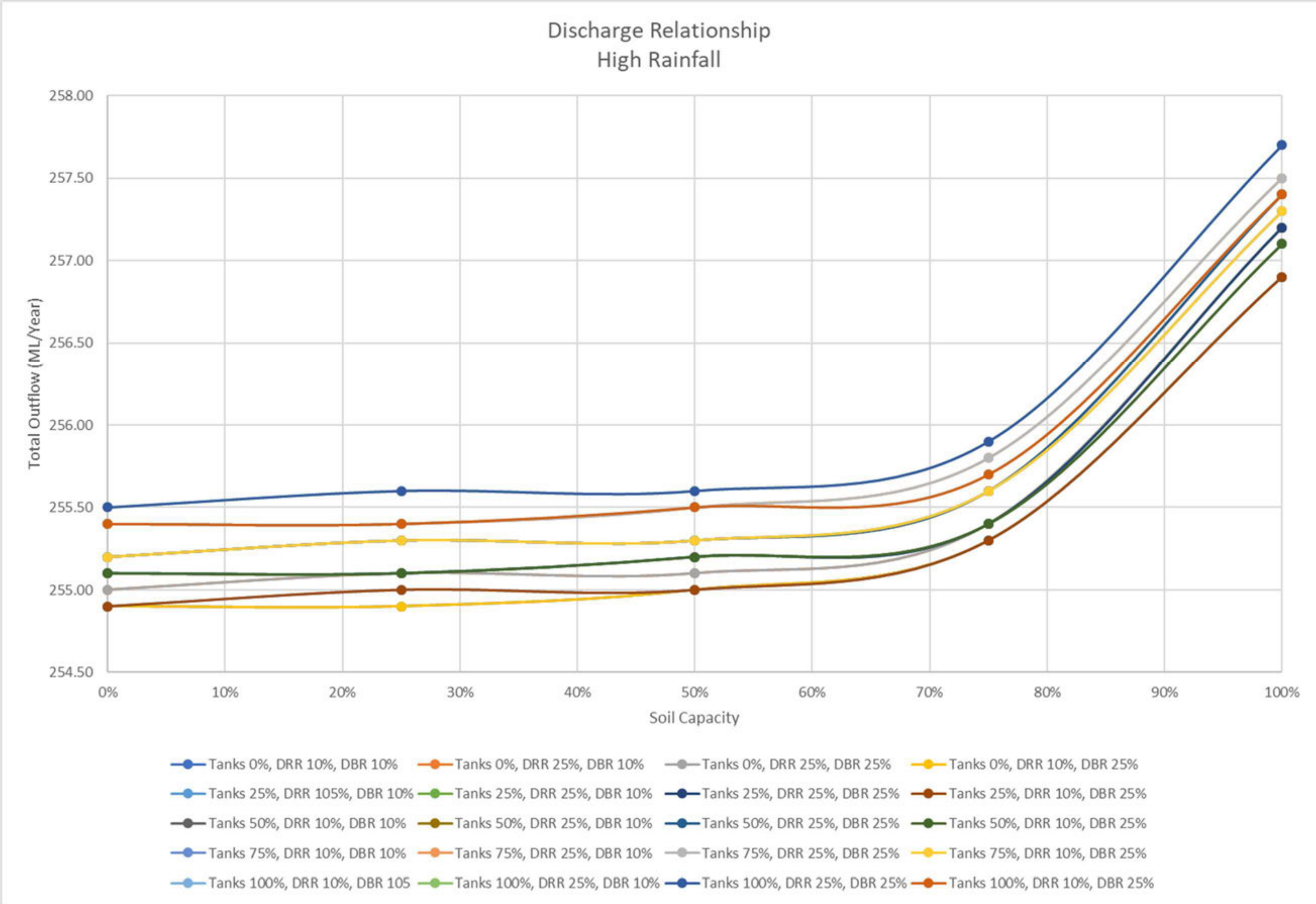

Figure 28 Discharge Relationship for High Rainfall Wetland Catchment

Figures 23-25 indicate the relationship between total annual outflow as soil capacity increases for the Avon, Gloucester and total catchment. As can be seen the individual plots have similar curves indicating that the increasing soil capacity does have a direct link to the outflow experienced for a given rainfall scenario.

Figures 26-28 show the relationship between total annual outflow as the soil capacity increases. This can be seen for low, mean and high historical rainfall events. The three figures show a definitive relationship between the soil capacity at the given time, the relationship between tank storage and groundwater properties appear to have little impact on the overall shape of each line on the graph indicating that soil and its capacity is the biggest driver of outflow for the chosen catchment.

Figure 26 shows a graph with 100 individual plots representing each of the parametric study's modelling scenarios. The graph only shows two lines plotted, however under close inspection it indicates that with such low rainfall events across an entire year the outflow is largely unaffected by groundwater, soil and tank storage.

From the results shown in Figure 27, mean rainfall data indicates that with an assumed soil capacity of 25% produces a yield between 113 and 114 ML/Year. This means that up to approximately 35% of Gloucester's water supply can be produced through the catchment in a typical rainfall year. Conversely during the lowest rainfall periods approximately 29.4ML/Year is collected from the catchment, while this represents a significant decrease in average yield it still represents approximately 10.7% of the annual water requirements.

5.4. Discussion

The greatest factor in runoff relationships is obviously rainfall, without significant rainfall across a catchment the total runoff will be significantly reduced.

The total Gloucester catchment analysis was able to determine that large stormwater runoff would be available for usage that far exceed the current demand for water. The significant associated costs and infrastructure to be able to collect all of this water make the collection of all runoff very unlikely and considered unfeasible. The use of transfer pumps and significant water storage areas along each of the catchments would create significant upfront costs as well as ongoing maintenance costs that make this option unrealistic given the usage requirements that Gloucester currently demands.

The overall pattern from the parametric study is that the only variable other than rainfall that makes a significant difference in stormwater yield is the initial soil capacity. It can be seen on each of the six figures that generally as the capacity in the soil increases so does the yield in an exponential trend. The low rainfall relationship shows that during significant periods of low rainfall up to around 50% soil capacity almost no runoff occurs from pervious layers, as the soil capacity will be very low during these dry periods it can be assumed that only impervious surfaces will make it to the outlet. When the rainfall is high the ability of the soil to recharge itself becomes apparent with above 75% soil capacity seeing a significant spike in outflow. This would suggest that for that particular scenario the loss of water into the soil is enough to allow for water to be taken up by the soil until the soil reaches the 75% starting mark.

The mean rainfall figures indicate a relatively linear relationship between runoff and soil capacity, this would indicate that the volume of rainfall landing on the catchment provides enough water to enter the soil, as the capacity increases the runoff increases but as it is linear this indicates that the losses are equal to the runoff, therefore the capacity in the soil plays the most important role in the calculation of runoff.

The other input variables; tanks, daily recharge rates, daily baseflow rates provide very minimal changes to the total outflow and the graphs indicate that the overall relationship does not change significantly enough to consider any of those variables to substantially alter the final stormwater yield from a given scenario.

As a whole the parametric study has shown that pervious surfaces play a significant role in the final yield of a stormwater system while impervious layers provide the bulk of the flow certain scenarios will allow for pervious surfaces to make a significant contribution to overall outflow. The initial soil capacity is dependent on the previous year's rainfall particularly at the end of the previous year meaning that the runoff for the year will have a dependency on the rainfall from the previous year. This indicates that runoff and stormwater modelling through MUSIC are a continuous modelling technique where historical rainfall plays a significant part in the new year's stormwater runoff and collection potential.

It is to be noted that the parametric study considered water storage and reuse from residential tank storage however any additional measures such as detention basins or other water sensitive design measures that may affect the total runoff. if further investigation was to be completed for this site and others further research and modelling of these variable will be required to provide a more accurate assumption of total stormwater yield available for reuse.

6 Wetland design

The design of the wetland was completed using two methods, the first was a series of hand calculations to provide sizing details for the sediment basin and onto the macrophyte zone. The hand calculations have considered, pipe sizing for appropriate design flows, hi-flow bypass to protect the wetland in large storm events allowing excess flows to pass by saving the wetland from unnecessary damage. The second was a check using MUSIC software to ensure that the sizing of the wetland is appropriate for the removal of pollutants as tested as part of this project (BROWNING, G et al. 2017)

6.1. Design Rainfall and Discharge

According to the Wetland technical design guidelines the calculation of design rainfall and design flows is to be taken from the rational method of the Australian Rainfall and Runoff Guide. The guideline incorporates the use of the 1987 method and values so for this report the 1987 values will be deemed sufficient.

Rainfall intensities are collected from the bureau of meteorology and are tabulated in table 12.

Table 12 Design rainfall intensities for Gloucester using ARR 1987 Values (METEOROLOGY 2021a)

Location	Gloucester	**1987 Rainfall Intensities**					
Easting	151.95						
Northing	-32.025						
	ARI (mm/h)						
Duration	***1***	***2***	***5***	***10***	***20***	***50***	***100***
5	76.7	99.9	130	148	172	204	230
6	71.9	93.2	122	139	161	192	215
10	58.7	76.1	99.2	113	132	156	175
20	42.4	55	71.5	81.4	94.5	112	126
30	34.4	44.6	57.8	65.8	76.3	90.4	101

Rainfall intensities used in conjunction with catchment area and the coefficient of runoff will be able to estimate design discharges for the catchment above the wetland. The formula used for broad analysis of design discharges using the rational method is,

$$Q = CiA \qquad (2)$$

Where:

Q = Flow Rate (m^3/s)

C = coefficient of runoff

i = Rainfall intensity (mm/h)

A = Area of catchment (ha)

Equation 2 is the rational method for calculating flow rate incorporating runoff coefficients, rainfall intensities and catchment areas.

The coefficient of runoff is a value that incorporates landscape features, site slopes density of development to provide an estimated value to factor the flowrate of a particular catchment.

The Australian Rainfall and Runoff Guide has detailed steps to calculate frequency factors and runoff coefficients, detailed calculations are shown below. The time of concentration for an urban catchment of predominately piped urban catchment less than 500Ha can use the standard inlet time method (Government 2013a) this gives us a time of concentration of 15 minutes.

The guideline indicates that design inflow should be designed for a 1-year ARI with the bypass channel to handle up to a 100-year ARI for the protection of the wetland during large storm and flooding rainfall event. Using table 12 and 13 subbed into equation 2, results are presented in table 14.

Table 13 Calculated coefficient of runoff values (C) (GOVERNMENT 2013b)

C Runoff			
C10 Value	0.55		
ARI	1	50	100
Frequency Factor Fy	0.8	1.15	1.2
C Values	0.44	0.63	0.66

Table 14 Calculated design flows for wetland catchment (GOVERNMENT 2013b)

Area (ha)	**Time of Concentration (Tc)**	**I1 (mm/h)**	**I50 (mm/h)**	**I100 (mm/h)**	**C1**	**C50**	**C100**	**Q1 (m^3/s)**	**Q50 (m^3/s)**	**Q100 (m^3/s)**
20.19	15 Mins	46.4	122.8	138.5	0.44	0.63	0.66	***1.145***	***4.339***	***5.127***

6.2. Sediment Basin

Sediment basin is the first stage of a wetland, its purpose is to allow suitable time for the larger sediment to be removed from the incoming stormwater runoff. the wetland technical design manual provides details on how to calculate appropriate sizing for removal of sediment.

The design of a sediment basin can be calculated using the formula equation 3.

$$R = 1 - \left(1 + \frac{1}{n} \cdot \frac{Vs}{\frac{Q}{A}} \cdot \frac{de+d}{de+d*}\right)^{-n} \qquad (3)$$

Where:

R = Load Reduction Factor (90%)

Vs = Settling velocity = 0.011m/s

Q = Design Flow Rate = Q1 = $1.145 m^3/s$

De = Depth above permanent pool level = 0.3m

Dp = Permanent Pool Depth = 2.0m

D* = lesser of 1m typical depth or permanent depth so use 1.0m

The values for n are calculated using the wetland design manual. The equation relates to the flow of water through the sediment basin. The water will flow straight through a basin with a ratio of one width to 4 length, meaning a hydraulic efficiency of 0.41 which is used in determining the value for n.

The value for n to be used in equation 4 is as follows

$$n = \frac{1}{1-\lambda} \quad (4)$$

Value for n is calculated to be n = 1.69

Looking for a reduction of up to 90% requires a sediment basin surface area of approximately 292m^2 in order to remove sediment up to 125µm. this removal will be important for the overall efficiency of the wetland once water enters it from the sediment basin.

The location chosen is relatively long and narrow, following a localised natural drainage line so the decision was made to provide a length to width ratio of 1:4. This equates to a basin with dimensions of 8.5m wide and 34.5m long. For safety and accessibility the basin should have batters at a maximum of 1V2:H (Browning, Glenn et al. 2017) with this in mind and a depth of water of 2m, sizing is appropriate for safety and accessibility.

As the function of the basin is to collect sediment from water entering it during storms, a natural build-up of sediment will mean that the basin will need to be cleaned out from time to time. In order to assure the functionality of the basin it is recommended that the basin be cleaned every 5 years and sediment is to only be built up to approximately half of the sediment basin volume. (Browning, Glenn et al. 2017)

The volume of half of the sediment basin is calculated using the formula for a truncated pyramid, therefore the volume of a sediment basin 8m wide and 32m long is 68.11m^3. The build-up of sediment is given by the formula in equation 5.

$$V = ARL_0F_0 \quad (5)$$

Where:

A = Catchments area = 20.19Ha

R = pollutant removal = 90%

L_o = 0.6 (Browning, Glenn et al. 2017)

F_o = Frequency of maintenance = 5 Years

From equation 5 volume of sediment after 5 years V_5 = 54.51m^3, as the volume of half of the basin is 68.11m^3 is greater than the volume of the sediment, the basin is suitable.

6.3. Connection to the Macrophyte Zone

The structure connected the sediment basin to the macrophyte zone must be able to convey the design flow, the 1-year ARI flow of $1.145m^3/s$. This is achieved through the design of an overflow pit and connection pipes capable of carrying the flow. The weir flow conditions use the following equation to calculate perimeter of an outlet pit to pass the design flow of $1.145m^3/s$, with an assumed afflux of 0.3m with a blockage of 50%.

$$P = \frac{Qdes}{B.Cw.h^{\frac{3}{2}}} \tag{6}$$

Where:

P = Perimeter of the outlet (m)

Q = $1.145m^3/s$

B = Blockage = 50%

Cw = Factor = 1.66 (Browning, Glenn et al. 2017)

h = Afflux = 0.3m

Perimeter is calculated to be 8.40m.

The size of the outlet is calculated from equation 7, this is then used in conjunction with equation 6 to estimate a pit size. Outlet area is given by:

$$A = \frac{Qdes}{b.cd.\sqrt{2gh}} \tag{7}$$

Where:

A = Area of the Outlet (m^2)

B = Blockage 50%

Cd = 0.6

h = 0.3m

Calculated area is equal to $1.57m^2$, therefore a pit that is at least 8.4m around and $1.57m^2$. A square pit 2.5m by 2.5m is proposed which will satisfy both of the conditions allowing the required design flow to be collected and conveyed to the macrophyte zone. The pit is to be a letterbox grate, this will allow for large debris to be denied entry mitigating any significant blockages.

Now a connection pipe is to be sized to ensure the design flow can be conveyed. As the pipes will be submerged, the velocity can be estimated assuming coefficient K = 2 (Browning, Glenn et al. 2017), velocity is given by the equation.

$$V = \sqrt{gh} \tag{8}$$

Where

h = maximum available head, in this case the maximum is 0.5m which is the height of the bypass weir less the normal water level in the macrophyte zone.

So, velocity (V) is 2.21m/s, area can now be defined using the equation for flow rate of 1.145m^3/s.

$$Q = AV \text{ or } A = \frac{Q}{V} \tag{8}$$

Area is calculated to be 0.518m^2, this is approximately equivalent to two 450mm diameter concrete pipes, this will ensure that the volume of water is able to be conveyed into the macrophyte zone.

The final calculation relating to the connection is to design a high flow bypass weir. This plays an important role in protecting the macrophyte zone from excessive flows. For the purpose of this design the bypass will convey up to the 50-year ARI with the weir crest level set 0.3m above the permanent pool of the designed sediment basin.

Afflux is again assumed to be 0.3m, a length of weir is to be calculated to convey the above design flow. Using the following equation.

$$L = \frac{Q}{\left(Cw.H^{\frac{3}{2}}\right)} \tag{9}$$

Where

Q = 4.339m^3/s

Cw = 1.66

H = 0.3m

Length is calculated as 15.9m, the design will adopt 16m long. As the wetland is to be a long thin design, overall length of the overflow bypass will exceed 250m which will ensure that the channel has significantly more capacity than required.

6.4. Design of the Macrophyte Zone

An assumed size of macrophyte zone is adopted based on the geometry of the site to be a maximum of 6000m^2, this layout is based on the available space, level of pollutants found in testing and assumptions in comparison to the values provided by the Wetland Technical Design Manual.

The geography and geometry of the site indicates that the shape configuration is between Cases G and I (Browning, Glenn et al. 2017) this leads to an expected hydraulic efficiency of 0.6-0.7. The following inputs are as follows:

Aspect Ratio = 1 (Width) to 10 (Length)

Hydraulic Efficiency (λ) = 0.6-0.7

As the chosen catchment is a typical large lot residential, the wetland will need to be design for the removal of sediment and nutrients. The levels of heavy metals and oil and grease are considered small enough to be insignificant in the design of the wetland.

As the catchment location described by the Wetland Technical Design Guideline is very similar to the catchment chosen for the wetland location in this project the marsh zones and open water zones are described similarly below:

- The marsh zones to vary in depth over the length, the depth is to range from NWL to 0.4m below the permanent pool level, the shallow areas are to be located throughout the length of the wetland.
- A permanent water allowance is to be made to provide additional storage to minimise the volume of water lost prior to consumption.
- Depth of water in the open water zone is assumed to be 1.5m deep with a extended detention depth of 0.5m so a total depth of 2m.
- The zones are to be located perpendicular to the flow path to provide the best hydraulic efficiency.

For the safety of the public batter slopes are adopted as 1 vertical to 8 horizontal. This allows for the depth to be achieved.

To calculate the permanent pool volume, a number of factors need to be considered. According to constructed wetland design considerations (REF) the permanent storage volume (PSV) can use average annual rainfall, number of days rain per year and typical required reductions for pollutants to calculate a residence time of stormwater, thus providing a permanent storage volume that can provide sufficient pollutant reduction and be used as a water storage prior to final treatment at the water treatment plant.

Equation 10 below provides the permanent storage requirement.

$$Volume = CIAR \tag{10}$$

Where:

C = Runoff Coefficient = 0.55

I = Average Rainfall per day (mm/day)

A = Catchment area = 201896m^2

R = Longest Residence time for pollutant reduction

Residence time is given by figure 2.11.9 of Constructed wetland design considerations for total suspended solids, nitrogen and phosphorus. Council requires pollutant reductions to meet the following requirements:

- Total suspended solids = 70%
- Nitrogen = 40%
- Phosphorus = 40%

From figure 2.11.9 typical residence time for all pollutants is between 5 and 10 days, for this project a residence time of 7.5 days is adopted.

So using equation 10 total volume of the permanent pool is $6750m^3$ which is 6.75ML, as space is critical for this wetland, an extended detention wetland is to be adopted this allows for storage of water prior to the macrophyte zone which allows for a reduction in the shallow marsh area required. (HUNTER 2013) Storage area for extended wetland can be up to 50% of the wetland capacity which is stored above the wetland and deep pool sections. Up to 20% of the wetland area can be used for deep storage with the remainder split between marsh areas. With this consideration a deep pool storage area of $1200m^2$ and a depth of 1.5m is adopted with an additional 0.5m above the permanent pool level for extended storage thus providing sufficient storage for 7.5 days average rainfall.

For the pollutant removal and design checks, a MUSIC model was created to assess the macrophyte zone and its effectiveness to remove pollutants. For the purpose of the design, mean rainfall was used, with water diverted into the designed sediment basin, then into the wetland as sized. The results are shown below.

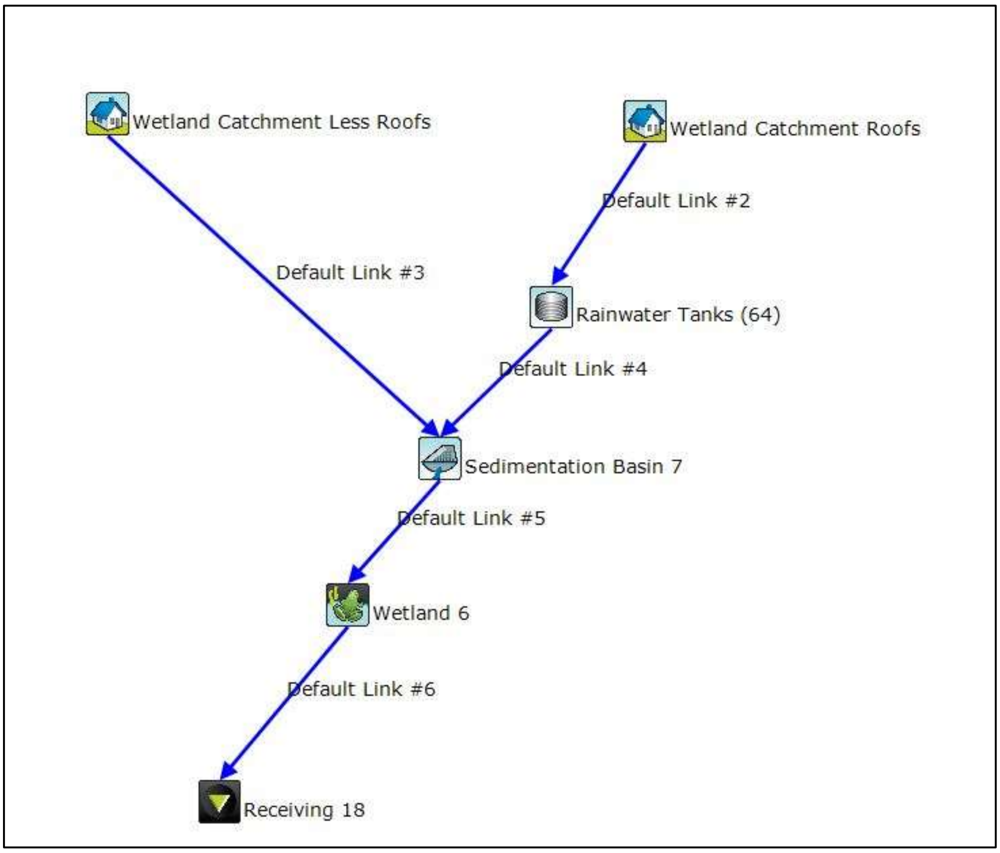

Figure 29 MUSIC Modelling Node Relationships

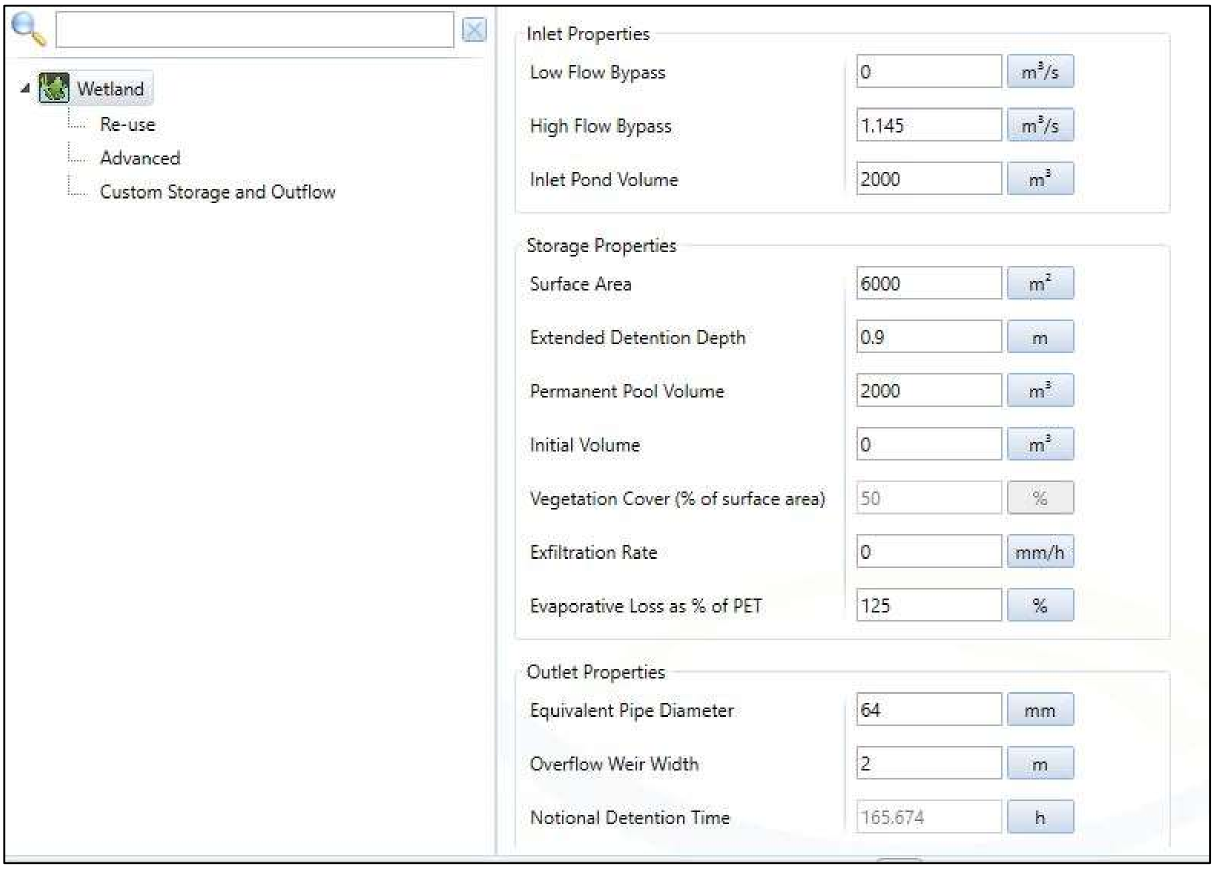

Figure 30 Wetland MUSIC Input Parameters

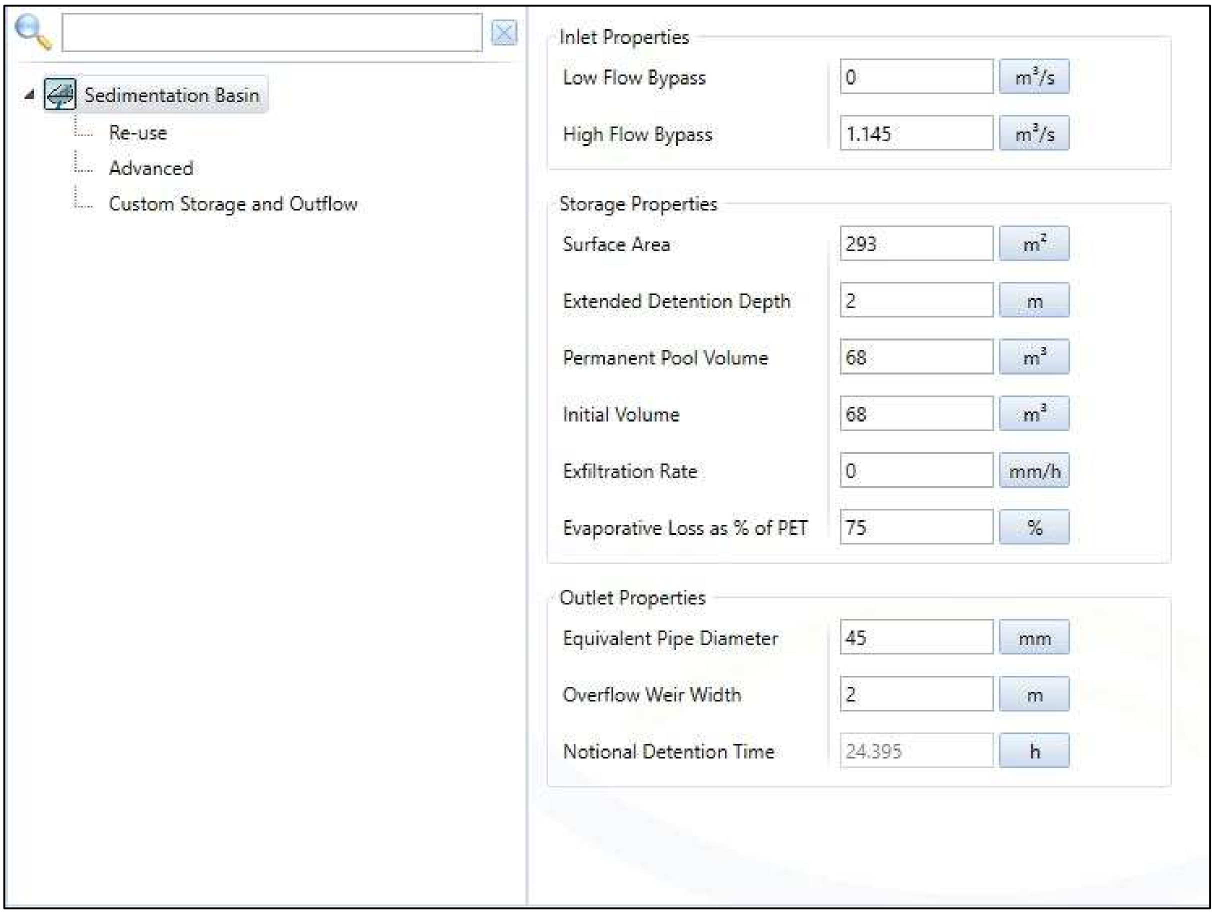

Figure 31 Sediment Basin MUSIC Input Parameters

Table 15 Results of Sediment Basin & Wetland Treatment

Latest Run : Treatment Train Effectiveness : Receiving 18

	Sources	Residual Load	% Reduction
Flow (ML/yr)	125.3	103.1	17.69
Total Suspended Solids (kg/yr)	1.148E+04	1056	90.8
Total Phosphorus (kg/yr)	23.25	8.355	64.06
Total Nitrogen (kg/yr)	280.7	131.1	53.29
Gross Pollutants (kg/yr)	3399	0	100

Figures 29 through 31 and table 15 show the MUSIC modelling scenario implemented for the treatment of pollutants collected from the chosen catchment. Input parameters for pollutant levels, exfiltration rates, evaporative loss were chosen as defaults from NSW guidelines for wetland and detention basin modelling using MUSIC (NSW 2019)

Results presented in Table 15Table 15 Results of Sediment Basin & Wetland Treatment show that total output of water is still exceeding 35% of the Gloucester supply demand requirements, with reductions in pollutants that meet and exceed the requirements of the Australian Drinking Water Guidelines (GOVERNMENT 2011). This indicates that with existing pollutant levels a detention basin and constructed wetland is a viable solution for water quality requirements.

Figure 32 Sediment Basin and Wetland Sketch

Figure 32 shows a concept sketch of the proposed sediment basin and wetland. It indicates that it can fit within the land chosen and is able to collect stormwater from the wetland catchment with a bypass channel to direct high flows around the wetland. With minimal disturbance to existing footpath, minimal remediation works would be required.

6.5. Design of the Macrophyte Zone Outlet

The purpose of the riser outlet is to ensure that a uniform notional detention time in the macrophyte zone, maximum discharge from the riser is given by the following equation:

$$Qmax = \frac{Extended\ Detention\ Storage\ Volume}{(Notional\ Detention\ Time)} \tag{11}$$

Extended detention time is calculated as total surface area by depth, depth chosen is 0.5m., therefore total extended detention storage is 3000m^2.

Notional detention time of 72 hours. So Q_{max} = 0.01157m^3/s or 11.5L/s.

Orifices are to be designed so that at any depth of inundation the flow rate allows for the macrophyte zone to drain in a chosen time frame, in this case 12 hours is chosen.

For the design of the discharge orifice sizes were chosen using the following equation

$$A = \frac{Q}{Cd\sqrt{2gh}} \tag{12}$$

Where:

Cd = Orifice discharge coefficient = 0.6

h = Depth of water (m)

A = Area of the Orifice

Q = Flow Rate required to drain the volume of the permanent pool within 12 hours

Orifices are located at 0.125m intervals along the riser length, located 0m, 0.125m, 0.250m and 0.375m above the permanent pool level. The orifice diameters chosen were 35mm and 30mm, the results are shown Table 16 and Figure 33.

Orifice Positions		0	0.125	0.25	0.375	0.5	
Orifice Diameter		55	30	30	30		
Number of Orifices		2	3	3	3		
Ext Det Depth	**Ex Detention Volume**	**Flow at Given Ext. Det. Depths (L/s)**				**Total Flow L/s**	**Not. Detention Time (Hrs)**
0	0	0.00				0.00	0
0.125	750	4.46	0.00			4.46	46.66
0.25	1500	6.31	1.99	0.00		8.31	50.16
0.375	2250	7.73	2.82	1.99	0.00	12.54	49.83
0.5	3000	8.93	3.45	2.82	1.99	17.19	48.47

Table 16 Orifice sizing spreadsheet (BROWNING, G et al. 2017)

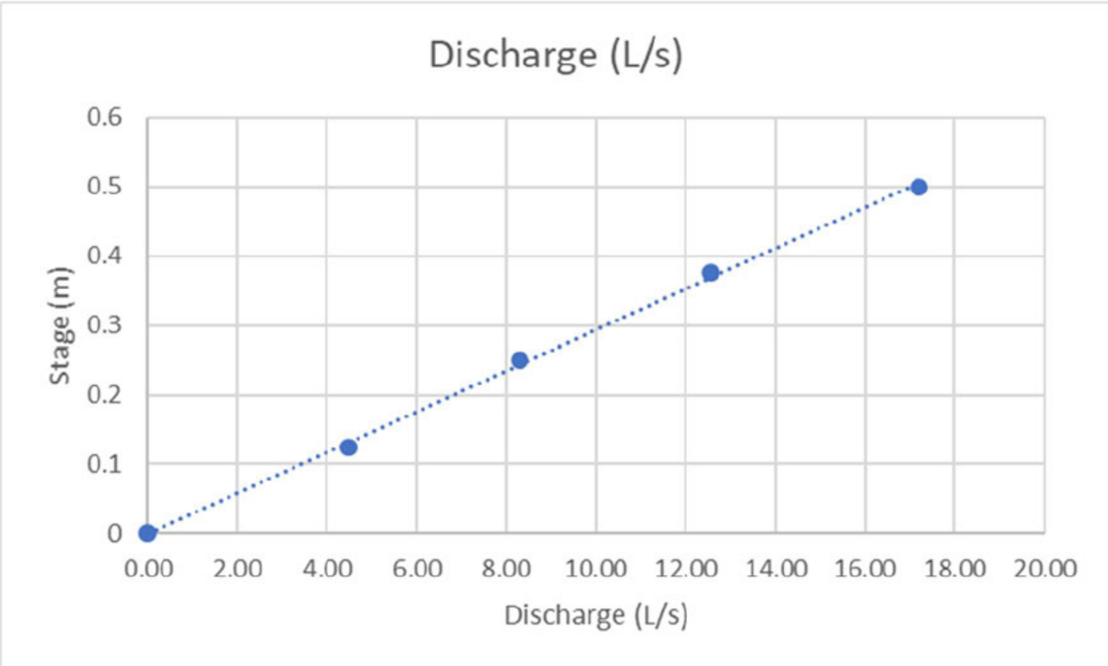

Figure 33 Riser discharge relationship.

As can be seen from Figure 33, the relationship of runoff is relatively linear and the orifices are designed to ensure that notional detention time is approximately 48 hours or higher, this ensures that detention times will be achieved for any volume of water within the Macrophyte zone. This will ensure that minimum treatment is achieved for all water entering the wetland.

6.6. Maintenance Drains

Maintenance of the wetland will be required to ensure its continued function to remove pollutants and sediment, in order to complete maintenance a drain needs to be installed to drain the wetland. The guideline suggests that the drain must be sized to drain the permanent pool of the macrophyte zone in 12 hours. Manning's equation is used to determine the flow rate and cross-sectional area of the pipe to achieve the desired drainage. Manning's equation is given in equation 13

$$Q = \frac{A.R^{\frac{2}{3}}.s^{\frac{1}{2}}}{n} \tag{13}$$

Where:

A = Cross sectional area of drain (m^2)

R = Hydraulic Radius (m)

S = Slope = 0.5%

n = 0.012

Q = 3375/(12*3.6) = 78.125L/s

From equation 13 a pipe diameter of 407.5mm is calculated, a 375mm pipe will provide a notional draining time of 15 hours, this is considered acceptable. An allowance for manual operation is done with a valve to achieve a similar drainage time. This is given be equation 12.

A nominal area of 0.0416m^2 equates to a pipe with 300mm diameter.

6.7. Discharge Pipe

Finally, the water needs to be discharged from the macrophyte zone into the receiving waters, the pipe needs to have sufficient capacity to convey the larger of the 2 values calculated above, this means that a 375mm pipe is chosen to discharge the required volume.

6.8. Plant Selection

The choice of plant life will be made through consultation with botanists and environmental consultants. Plant selection is based on climate and environment in which the plants are located, local zoysia species are a common choice due to their durability and resistance to damage during higher flows. As part of a final detail design of the wetland consultation will be made with appropriate parties to ensure that the plant life chosen fits the requirements as set out in this report.

6.9. Discussion

The location of the wetland zone created some constraints over potential sizing to achieve the desired treatment and pollutant removal, as shown above through the design and the MUSIC modelling the sediment basin and wetland are large enough to remove pollutants hold a significant volume of water within the constraints of the site. As the current water supply for Gloucester does not have a significant off river storage dam to hold water when discharges are occurring having a larger extended detention area can provide up to 6.5ML storage within the wetland. The discharge outlet will release water below the proposed wetland area, considerations for where this water is stored would need to be completed and constructed to provide an area for storage prior to final treatment and distribution within the network. This would need to consider as part of the design and construction of the off-stream storage dam that council are considering. With that considered approximately 35% of Gloucester's current supple demand can be met through the collection, treatment and discharge through the wetland.

The design of a wetland followed the design procedure outlined by Water by Design, this allows for water to bypass the wetland during high flow events thus protecting the basin and any associated plants, reducing overall costs and maintenance requirements.

The MUSIC model was able to indicate that removal of pollutants would reach desired outcomes. The sediment basin and wetland are able to remove the entirety of gross pollutants, approximately 85% of total suspended solids, a 54% of all nitrogen and 67% of phosphorus. This indicates that the chosen overall dimensions and residence times are appropriate and considered practical in the removal of these pollutants. The reduction targets as set out by MidCoast Council have been met and water treated through the wetland with further sanitation at the treatment plant is considered of a high enough quality to be consumed as potable water.

Overall, it can be concluded that a treatment train consisting of a sediment basin and a wetland is able to handle typical annual rainfall requirements and associated pollutants to provide a high quality of water treatment that can be considered for potable use as an offset and viable alternative to the existing water supply measures. With the construction of a large off stream storage dam within Council's plans this concept of a catchment and wetland can provide on average approximately a third of the annual average requirements for Gloucester's drinking water.

7 Cost Estimates

The purpose of a cost estimate is to provide an idea of the outlay of money required to construct a project and for its continued service for the chosen lifespan of a particular asset. For the purpose of this investigation the wetland will be functional for 20 years with maintenance scheduled to ensure its function for the duration of its functional life.

A cost estimate for the construction of the wetland and sediment basin is shown below. The calculated values are broad assumptions for earthworks requirements and would require detailed site survey, geotechnical investigations and final wetland design sizing's to ensure accuracy of a final estimate.

The cost estimate is taken from an example wetland costing completed by GHD with unit rates and approximate earthworks, pipes and aggregate values. (GHD 2009, 2010)

In order to provide an estimate a number of assumptions have been made that provide the basis for this estimate. They are as follows:

- Earthworks are only required to reach the invert level of the basin and wetland and no further assuming fall and terrain don't require excess excavation to achieve required depths.
- Pipe lengths and sizing, length of pipes connecting each zone are to be assumed to provide sufficient length to pass between each wall and provide flow to the following section of the wetland.
- Concrete and aggregate values are taken from example and reduced to suite this concept wetland design
- Aquatic plant life assumed planting is to be at $0.5m^2$ intervals across the wetland area thus providing 12,000 plants priced at $5.00 per plant.
- Maintenance will be split into 2 separate estimates. The first is the establishment years which is where the weed control and establishment of the plants is crucial. The second is after 2 years where establishment of the plants is already achieved, and routine maintenance is undertaken to ensure the continued function of the wetland and sediment basin.
- It is assumed that the wetland will be functional for 20 years so maintenance will be carried out across the lifespan of the proposed wetland.
- All existing stormwater infrastructure directing stormwater into the proposed wetland will not require repair, maintenance or upgrade as part of this construction.

An overall cost estimate is outlined in table 17, detailed cost estimates are shown in appendix J.

Item	Description	Total
1	Preliminaries and Site Establishment	
		$41,000.00
2	Earthworks	
		$217,400.00
3	Maintenance Tracks and Paths	
		$15,000.00
4	Sediment Pond	
		$21,060.00
5	Wetland Inlet	
		$38,549.00
6	Wetland outlet	
		$42,205.00
7	Landscaping	
		$77,300.00
8	Miscellaneous	
		$22,500.00
9	Maintenance	
		$132,000.00
	Sub-Total	$607,014.00
	Contingency (20%)	$121,402.80
	Total	$728,416.80

Table 17 Overall Cost estimate for the treatment of stormwater.

As can be seen from the table, an overall cost of approximately $600,000 for the construction and continued maintenance of the treatment area, a contingency of 20% is added to allow for adjustments to earthworks, and other civil construction components. It also provides a contingency for cost overruns during construction.

As there are a significant number of assumptions made as part of these estimates, an overall cost analysis is difficult to provide an accurate estimate for the overall cost of a constructed wetland to treat stormwater.

From the above cost estimates it can be concluded that a constructed wetland and sediment treatment basin are an effective and cost-effective solution to water quality treatment and would not pose a significant financial burden on the Council or the broader community whilst providing a solution to water supply concerns.

8 Conclusions and Recommendations

The aim of this project was to investigate and determine the feasibility of urban stormwater collection for potable reuse. As there is becoming an ever-increasing urgency for alternative water supplies for potable use there is a need to investigate alternatives. Urban stormwater collection for potable use is a relatively unknown entity with limited research or regulations, this project aimed to provide additional knowledge of urban stormwater with quality, yield and treatment options to assess its suitability as an alternative into the future.

By completing water sampling and testing of urban stormwater, it was discovered that samples from the Gloucester urban catchment generally produce pollutants of low concentrations across metals, nutrients and suspended solids. These values indicate that the water quality of most stormwater from Gloucester is of a quality that is suitable for drinking with appropriate continued treatment. It can be concluded that water collected from appropriate catchments can be used as an alternative to typical water supplies.

Stormwater yield was able to indicate that the entire catchment of Gloucester is able to typically provide enough water to service an entire years worth of water supply for Gloucester. Analysis of the catchments indicated that developing a system to collect all stormwater from the total catchment is impractical due to topography constraints and significant stormwater reconstruction and associated costs. The stormwater yield calculations were able to indicate that the collection of stormwater from urban areas is able to provide a significant runoff with typically higher volumes due to impervious percentages. With a suitable topography and sufficient rainfall urban stormwater collection can be used as an alternative.

The selection of a smaller catchment of approximately 20Ha provided a catchment of mostly residential homes and a high school agricultural farm. Testing of stormwater from this area indicated low rates on nitrogen and phosphorus. A parametric study using MUSIC software testing rainfall, soil and groundwater characteristics were able to indicate that for the mostly clay based soils that no variable has a significant impact on the final output of runoff. it can be concluded that for a smaller catchment with typical clay-based soils with low infiltration rates can provide an offset of total supply with typical values for Gloucester reaching approximately 35% of the annual demand.

The selection of a treatment area utilising existing infrastructure to direct stormwater from a single catchment under gravity to a proposed wetland area was chosen. By utilising guidelines and worked examples, a sediment basin to collect larger particles and a wetland to remove additional pollutants within the sizing constraints of the chosen location was designed. The sediment basin and wetland were then validated using the MUSIC software to ensure appropriate pollutant reductions were achieved. The software was able to validate the sizing and produce reductions to meet Council's water sensitive design requirements and meet drinking water requirements. This was able to demonstrate that a wetland can provide treatment to a level that meets requirements for drinking water with additional treatment at water treatment plants to meet drinking water requirements

In conclusion, by testing stormwater, completing yield and parametric analysis on catchments and designing an appropriate treatment, stormwater can be collected from the Gloucester urban drainage network and be treated to an appropriate standard that can be used as an alternative to existing potable supplies.

This project aimed to test quality, volume and treatment of stormwater. Through the testing, and analysis it can be confirmed that urban stormwater is an alternative subject to pollutant testing and appropriate yield.

9 Future Work

To further the research and modelling of this project, additional and significant testing of stormwater across a number of locations and time periods to provide a clearer picture of the all pollutants within collected stormwater from the site will be required.

With climate change affecting weather patterns and future rainfall, additional calculations and analysis of rainfall will be needed to ensure that the chosen catchments will be able to provide sufficient yield into the future to assess its feasibility into the future.

Research further into current documentation of stormwater and potable sources with a potential to look at how changes to the current regulations can provide additional guidance and planning legislation to allow for the collection of stormwater for drinking with appropriate controls.

Finally completing analysis on other sites with differing catchment, rainfall and soil characteristics to provide further data relating to the feasibility of stormwater collection.

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Appendix A Project Specification

ENG4111/4112 Research Project

Project Specification

For: Nicholas Kellner

Title: Urban Stormwater Collection for potable use, a feasibility study for Gloucester NSW

Major: Civil Engineering

Supervisors: Kamrun Nahar

Enrollment: ENG4111 – EXT S1, 2021

ENG4112 – EXT S2, 2021

Project Aim: To research, investigate, design and determine the feasibility of an urban stormwater collection scheme for Gloucester NSW.

Program: Version 1, 17th March 2021

1. Research urban stormwater collection, quality concerns, typical pollutants found in stormwater, treatment options for removal, typical yields, losses etc.
2. Conduct initial background research on the 3 important deliverables for stormwater; *yield, quality & treatment.*
    a. *Yield:* Calculate catchment areas, investigate runoff rates (impervious, pervious areas, pipe losses, different infiltration rates)
    b. *Quality:* Collect stormwater samples from some unique sites, determine the pollutants located in each sample and their values.
    c. *Treatment:* Using the yield and quality requirements for the system, design a suitable natural wetland to hold the runoff and provide treatment for pollutants found. Determine the size and types of natural filtration to remove said pollutants.
3. Design a model to incorporate scenarios for different run-off rates, infiltration rates, pipe losses etc.
4. Complete a parametric study using software to compare the discharge from several scenarios, parameters may include:
    a. Infiltration
    b. Losses
    c. Friction
    d. Other parameters found through research
5. Process and evaluate experimental data.
6. Design a suitable location for wetland, pumps and pipelines from various stormwater outlets to single location for initial treatment.
7. Write up results and produce the dissertation.

If time and resource permit:

8. Complete a cost estimate from baseline values
9. Investigate the possibility of stormwater collection at other localities in the Council area.

Appendix B Project Resources

Project Resources

Software

1) Drains/Music
    i) Model and estimate discharge
    ii) MidCoast Council have several licences for use
    iii) No Associated Costs
2) AutoCad
    i) Design of water storage/wetland treatment area
    ii) MidCoast Council have several licences for use
    iii) No Associated Costs
3) Microsoft Office 365
    i) Database, modelling & write up of dissertation
    ii) MidCoast Council have several licences for use
    iii) No Associated Costs
4) Zoom
    i) Communication with supervisor and laboratory
    ii) MidCoast Council have several licences for use
    iii) No Associated Costs
5) GIS
    i) Catchment area calculations, Stormwater network
    ii) MidCoast Council have several licences for use
    iii) No Associated Costs

Equipment

1) Sample Kits
    i) Water sampling for quality considerations
    ii) MidCoast Council have several kits
    iii) Tests will be completed by Council laboratory ($300 Approx. Each)
    iv) Possibly 6 tests required for potential areas of concern

Data

1) Rainfall
    i) Bureau of Meteorology (Historical Rainfall)
2) Catchment Areas
    i) Council mapping services (GIS)
3) Suitable Locality for treatment wetlands or similar
    i) Council mapping services (GIS)

Contingencies

1) Lack of rainfall for stormwater sampling
    i) Have allowed for a large window for sampling (7-8 weeks)
    ii) If no rain falls for the duration of the project, council historical data and pollutants found through research will provide sufficient data to design a treatment pond.
2) Time Constraints
    i) Have allowed significant time for research, sampling, analysis and design to ensure that the dissertation can be completed on time

Appendix C Risk Assessment

UNIVERSITY OF SOUTHERN QUEENSLAND

University of Southern Queensland

USQ Safety Risk Management System

Read Only View

Close

Develop as new RMP

Version 2.0

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2021_5700	*Approval Requested*	[redacted]	[redacted]	[redacted]	[redacted]

Assessment Title:	Urban Stormwater Collection for Potable use, a feasibility study for Gloucester, NSW	**Assessment Date:**	22/06/2021
Workplace (Division/Faculty/Section):	204060 - School of Civil Engineering and Surveying	**Review Date:**	3/08/2021 (5 years maximum)

Approver:	*Supervisor: (for notification of Risk Assessment only)*
Kamrun Nahar;	Kamrun Nahar;

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Sample Collection, testing and modelling		
Why is it being conducted?	As part of research project ENG4111 and ENG4112.		
Where is it being conducted?	Collection of stormwater samples and their testing. Modelling of catchments and discharge		
Course code (if applicable)	ENG4111	**Chemical Name (if applicable)**	NA

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Nicholas Kellner
Equipment	Sample Kits, Computers
Environment	Roadside, stormwater outlets, laboratory, office
Other	

Briefly explain the procedure/process

process will be the collection of water samples from outlets of stormwater at culverts, gross pollutants traps. The samples will be tested at a laboratory, the catchments and water quality modelling will be completed from the office.

Assessment Team - who is conducting the assessment?

Assessor(s): Nicholas Kellner

Others consulted: (eg elected health and safety representative, other personnel exposed to risks)

Risk Matrix

Probability	Consequence				
	Insignificant No Injury 0-$5K	Minor First Aid $5K-$50K	Moderate Med Treatment $50K-$100K	Major Serious Injury $100K-$250K	Catastrophic Death More than $250K
Almost Certain 1 in 2	M	H	E	E	E
Likely 1 in 100	M	H	H	E	E
Possible 1 in 1,000	L	M	H	H	H
Unlikely 1 in 10,000	L	L	M	M	M
Rare 1 in 1,000,000	L	L	L	L	L

Recommended Action Guide	
Extreme:	E= Extreme Risk – Task ***MUST NOT*** proceed
High:	H = High Risk – Special Procedures Required (Contact USQSafe) Approval by VC only
Medium:	M= Medium Risk - A Risk Management Plan/Safe Work Method Statement is required
Low:	L= Low Risk - Manage by routine procedures.

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 2b	Step 3			Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard without existing controls in place?	*Consequence:* What is the harm that can be caused by the hazard without existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level			*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
					Probability	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*catastrophic*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Working Near a road	Impact from a vehicle	Catastropl	Appropriate PPE	Possib	High	☐	Spotter, traffic control, PPE	Catastı	Rare	Low	☑
2	Working on an embankment	Tripping and falling	Major	Appropriate PPE	Possib	High	☐	Spotter, alternative locations for sample collection	Major	Rare	Low	☑
3	Collection of water samples	Unable to collect samples due to weather	Minor	Significant window for collection	Unlike	Low	☑					☐
4	Laboratory not available	Not able to have samples tested	Insignifica	Ensure significant window for testing	Possib	Low	☑					☐
5	Inadequate time to complete project	Failure to complete project, repeat the subject	Minor	Ensure planning and resources are available, complete work regularly	Unlike	Low	☑					☐

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*
1	Spotter, traffic control, PPE	☐	PPE, Spotter	Nicholas Kellner	7/06/2021
2	Spotter, alternative locations for sample collection	☐	Maps, drainage plans	Nicholas Kellner	7/06/2021

Supporting Attachments

View Attachments

Click here to attach a file

Step 6 – Request Approval

Drafters Name:	*Nicholas Kellner*	*Draft Date:*	*22/06/2021*
Drafters Comments:	*The risk management plan above outlines the risks involved in this project, with the controls in place and others to be implemented I believe that this can be completed safely and on time.*		

Assessment Approval: **All risks are marked as ALARP** 0

Maximum Residual Risk Level: **Low - Manager/Supervisor Approval Required** 1

Document Status:	*Approval Requested*

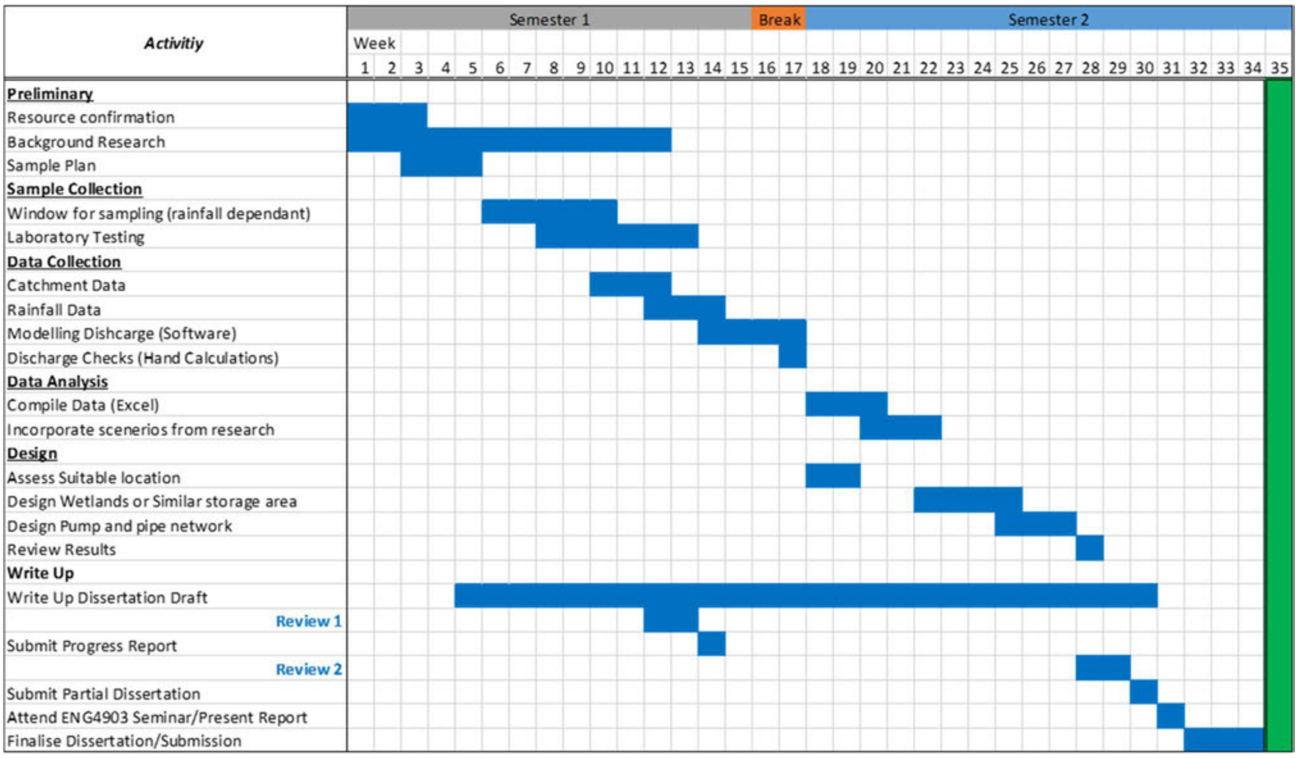
Step 6 – Approval

Approvers Name:	*Kamrun Nahar*	*Approvers Position Title:*	
Approvers Comments:			

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision:		*Approve / Reject Date:*		*Document Status:*	*Approval Requested*

Appendix D Project Plan


Activitiy
Semester 1
Break
Semester 2
Week
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Preliminary
Resource confirmation
Background Research
Sample Plan
Sample Collection
Window for sampling (rainfall dependant)
Laboratory Testing
Data Collection
Catchment Data
Rainfall Data
Modelling Dishcarge (Software)
Discharge Checks (Hand Calculations)
Data Analysis
Compile Data (Excel)
Incorporate scenerios from research
Design
Assess Suitable location
Design Wetlands or Similar storage area
Design Pump and pipe network
Review Results
Write Up
Write Up Dissertation Draft
Review 1
Submit Progress Report
Review 2
Submit Partial Dissertation
Attend ENG4903 Seminar/Present Report
Finalise Dissertation/Submission

Appendix E Full Catchment Parametric Study

	Inputs	Losses					Outflow	
Catchment	Rainfall	Evapotranspiration	Tanks % Full	Soil % Full	Daily Recharge Rate	Daily Baseflow Rate	Flow ML/Year	Flow KL/Year
Avon	High	High	0	0	10	10	675.9	675900
Avon	High	High	25	25	10	10	676.1	676100
Avon	High	High	50	50	10	10	676.8	676800
Avon	High	High	75	75	10	10	678.3	678300
Avon	High	High	100	100	10	10	684.8	684800
Avon	Low	Mean	0	0	10	10	75.42	75420
Avon	Low	Mean	25	25	10	10	75.43	75430
Avon	Low	Mean	50	50	10	10	75.81	75810
Avon	Low	Mean	75	75	10	10	78.8	78800
Avon	Low	Mean	100	100	10	10	84.43	84430
Avon	Mean	Mean	0	0	10	10	283.7	283700
Avon	Mean	Mean	25	25	10	10	290.1	290100
Avon	Mean	Mean	50	50	10	10	300.2	300200
Avon	Mean	Mean	75	75	10	10	307	307000
Avon	Mean	High	100	100	10	10	313.2	313200
Gloucester	High	High	0	0	10	10	1769	1769000
Gloucester	High	High	25	25	10	10	1769	1769000
Gloucester	High	High	50	50	10	10	1770	1770000
Gloucester	High	High	75	75	10	10	1774	1774000
Gloucester	High	High	100	100	10	10	1794	1794000
Gloucester	Low	Mean	0	0	10	10	190.9	190900
Gloucester	Low	Mean	25	25	10	10	191	191000
Gloucester	Low	Mean	50	50	10	10	191.3	191300
Gloucester	Low	Mean	75	75	10	10	200.1	200100

Gloucester	Low	Mean	100	100	10	10	217	217000
Gloucester	Mean	Mean	0	0	10	10	736.1	736100
Gloucester	Mean	Mean	25	25	10	10	755.7	755700
Gloucester	Mean	Mean	50	50	10	10	787.2	787200
Gloucester	Mean	Mean	75	75	10	10	808.3	808300
Gloucester	Mean	High	100	100	10	10	827.1	827100
Total	High	High	0	0	10	10	2444.9	2444900
Total	High	High	25	25	10	10	2445.1	2445100
Total	High	High	50	50	10	10	2446.8	2446800
Total	High	High	75	75	10	10	2452.3	2452300
Total	High	High	100	100	10	10	2478.8	2478800
Total	Low	Mean	0	0	10	10	266.32	266320
Total	Low	Mean	25	25	10	10	266.43	266430
Total	Low	Mean	50	50	10	10	267.11	267110
Total	Low	Mean	75	75	10	10	278.9	278900
Total	Low	Mean	100	100	10	10	301.43	301430
Total	Mean	Mean	0	0	10	10	1019.8	1019800
Total	Mean	Mean	25	25	10	10	1045.8	1045800
Total	Mean	Mean	50	50	10	10	1087.4	1087400
Total	Mean	Mean	75	75	10	10	1115.3	1115300
Total	Mean	High	100	100	10	10	1140.3	1140300

Appendix F Wetland Catchment Full Parametric Study

Inputs	Losses					Outflow	
Rainfall	Evapotranspiration	Tanks % Full	Soil % Full	Daily Recharge Rate	Daily Baseflow Rate	Flow ML/Year	Flow KL/Year
High	High	0%	100%	10%	10%	256.9	256900
High	High	0%	75%	10%	10%	255.3	255300
High	High	0%	50%	10%	10%	255	255000
High	High	0%	25%	10%	10%	254.9	254900
High	High	0%	0%	10%	10%	254.9	254900
High	High	0%	100%	25%	10%	257.2	257200
High	High	0%	75%	25%	10%	255.4	255400
High	High	0%	50%	25%	10%	255.1	255100
High	High	0%	25%	25%	10%	255.1	255100
High	High	0%	0%	25%	10%	255	255000
High	High	0%	100%	25%	25%	257.2	257200
High	High	0%	75%	25%	25%	255.4	255400
High	High	0%	50%	25%	25%	255.1	255100
High	High	0%	25%	25%	25%	255.1	255100
High	High	0%	0%	25%	25%	255	255000
High	High	0%	100%	10%	25%	256.9	256900
High	High	0%	75%	10%	25%	255.3	255300
High	High	0%	50%	10%	25%	255	255000
High	High	0%	25%	10%	25%	254.9	254900
High	High	0%	0%	10%	25%	254.9	254900
High	High	25%	100%	10%	10%	256.9	256900
High	High	25%	75%	10%	10%	255.3	255300
High	High	25%	50%	10%	10%	255	255000
High	High	25%	25%	10%	10%	255	255000

High	High	25%	0%	10%	10%	254.9	254900
High	High	25%	100%	25%	10%	257.2	257200
High	High	25%	75%	25%	10%	255.4	255400
High	High	25%	50%	25%	10%	255.2	255200
High	High	25%	25%	25%	10%	255.1	255100
High	High	25%	0%	25%	10%	255.1	255100
High	High	25%	100%	25%	25%	257.2	257200
High	High	25%	75%	25%	25%	255.4	255400
High	High	25%	50%	25%	25%	255.2	255200
High	High	25%	25%	25%	25%	255.1	255100
High	High	25%	0%	25%	25%	255.1	255100
High	High	25%	100%	10%	25%	256.9	256900
High	High	25%	75%	10%	25%	255.3	255300
High	High	25%	50%	10%	25%	255	255000
High	High	25%	25%	10%	25%	255	255000
High	High	25%	0%	10%	25%	254.9	254900
High	High	50%	100%	10%	10%	257.1	257100
High	High	50%	75%	10%	10%	255.4	255400
High	High	50%	50%	10%	10%	255.2	255200
High	High	50%	25%	10%	10%	255.1	255100
High	High	50%	0%	10%	10%	255.1	255100
High	High	50%	100%	25%	10%	257.4	257400
High	High	50%	75%	25%	10%	255.6	255600
High	High	50%	50%	25%	10%	255.3	255300
High	High	50%	25%	25%	10%	255.3	255300
High	High	50%	0%	25%	10%	255.2	255200
High	High	50%	100%	25%	25%	257.4	257400
High	High	50%	75%	25%	25%	255.6	255600
High	High	50%	50%	25%	25%	255.3	255300

High	High	50%	25%	25%	25%	255.3	255300
High	High	50%	0%	25%	25%	255.2	255200
High	High	50%	100%	10%	25%	257.1	257100
High	High	50%	75%	10%	25%	255.4	255400
High	High	50%	50%	10%	25%	255.2	255200
High	High	50%	25%	10%	25%	255.1	255100
High	High	50%	0%	10%	25%	255.1	255100
High	High	75%	100%	10%	10%	257.3	257300
High	High	75%	75%	10%	10%	255.6	255600
High	High	75%	50%	10%	10%	255.3	255300
High	High	75%	25%	10%	10%	255.3	255300
High	High	75%	0%	10%	10%	255.2	255200
High	High	75%	100%	25%	10%	257.5	257500
High	High	75%	75%	25%	10%	255.8	255800
High	High	75%	50%	25%	10%	255.5	255500
High	High	75%	25%	25%	10%	255.4	255400
High	High	75%	0%	25%	10%	255.4	255400
High	High	75%	100%	25%	25%	257.5	257500
High	High	75%	75%	25%	25%	255.8	255800
High	High	75%	50%	25%	25%	255.5	255500
High	High	75%	25%	25%	25%	255.4	255400
High	High	75%	0%	25%	25%	255.4	255400
High	High	75%	100%	10%	25%	257.3	257300
High	High	75%	75%	10%	25%	255.6	255600
High	High	75%	50%	10%	25%	255.3	255300
High	High	75%	25%	10%	25%	255.3	255300
High	High	75%	0%	10%	25%	255.2	255200
High	High	100%	100%	10%	10%	257.4	257400
High	High	100%	75%	10%	10%	255.7	255700

High	High	100%	50%	10%	10%	255.5	255500
High	High	100%	25%	10%	10%	255.4	255400
High	High	100%	0%	10%	10%	255.4	255400
High	High	100%	100%	25%	10%	257.7	257700
High	High	100%	75%	25%	10%	255.9	255900
High	High	100%	50%	25%	10%	255.6	255600
High	High	100%	25%	25%	10%	255.6	255600
High	High	100%	0%	25%	10%	255.5	255500
High	High	100%	100%	25%	25%	257.7	257700
High	High	100%	75%	25%	25%	255.9	255900
High	High	100%	50%	25%	25%	255.6	255600
High	High	100%	25%	25%	25%	255.6	255600
High	High	100%	0%	25%	25%	255.5	255500
High	High	100%	100%	10%	25%	257.4	257400
High	High	100%	75%	10%	25%	255.7	255700
High	High	100%	50%	10%	25%	255.5	255500
High	High	100%	25%	10%	25%	255.4	255400
High	High	100%	0%	10%	25%	255.4	255400
Low	Mean	0%	100%	10%	10%	31.55	31550
Low	Mean	0%	75%	10%	10%	30.11	30110
Low	Mean	0%	50%	10%	10%	29.38	29380
Low	Mean	0%	25%	10%	10%	29.37	29370
Low	Mean	0%	0%	10%	10%	29.37	29370
Low	Mean	0%	100%	25%	10%	31.88	31880
Low	Mean	0%	75%	25%	10%	30.19	30190
Low	Mean	0%	50%	25%	10%	29.46	29460
Low	Mean	0%	25%	25%	10%	29.45	29450
Low	Mean	0%	0%	25%	10%	29.45	29450

Low	Mean	0%	100%	25%	25%	31.88	31880
Low	Mean	0%	75%	25%	25%	30.19	30190
Low	Mean	0%	50%	25%	25%	29.46	29460
Low	Mean	0%	25%	25%	25%	29.45	29450
Low	Mean	0%	0%	25%	25%	29.45	29450
Low	Mean	0%	100%	10%	25%	31.55	31550
Low	Mean	0%	75%	10%	25%	30.11	30110
Low	Mean	0%	50%	10%	25%	29.38	29380
Low	Mean	0%	25%	10%	25%	29.37	29370
Low	Mean	0%	0%	10%	25%	29.37	29370
Low	Mean	25%	100%	10%	10%	31.55	31550
Low	Mean	25%	75%	10%	10%	30.11	30110
Low	Mean	25%	50%	10%	10%	29.38	29380
Low	Mean	25%	25%	10%	10%	29.37	29370
Low	Mean	25%	0%	10%	10%	29.37	29370
Low	Mean	25%	100%	25%	10%	31.88	31880
Low	Mean	25%	75%	25%	10%	30.19	30190
Low	Mean	25%	50%	25%	10%	29.46	29460
Low	Mean	25%	25%	25%	10%	29.45	29450
Low	Mean	25%	0%	25%	10%	29.45	29450
Low	Mean	25%	100%	25%	25%	31.88	31880
Low	Mean	25%	75%	25%	25%	30.19	30190
Low	Mean	25%	50%	25%	25%	29.46	29460
Low	Mean	25%	25%	25%	25%	29.45	29450
Low	Mean	25%	0%	25%	25%	29.45	29450
Low	Mean	25%	100%	10%	25%	31.55	31550
Low	Mean	25%	75%	10%	25%	30.11	30110
Low	Mean	25%	50%	10%	25%	29.38	29380
Low	Mean	25%	25%	10%	25%	29.37	29370

Low	Mean	25%	0%	10%	25%	29.37	29370
Low	Mean	50%	100%	10%	10%	31.56	31560
Low	Mean	50%	75%	10%	10%	30.11	30110
Low	Mean	50%	50%	10%	10%	29.38	29380
Low	Mean	50%	25%	10%	10%	29.37	29370
Low	Mean	50%	0%	10%	10%	29.37	29370
Low	Mean	50%	100%	25%	10%	31.88	31880
Low	Mean	50%	75%	25%	10%	30.19	30190
Low	Mean	50%	50%	25%	10%	29.46	29460
Low	Mean	50%	25%	25%	10%	29.45	29450
Low	Mean	50%	0%	25%	10%	29.45	29450
Low	Mean	50%	100%	25%	25%	31.88	31880
Low	Mean	50%	75%	25%	25%	30.19	30190
Low	Mean	50%	50%	25%	25%	29.46	29460
Low	Mean	50%	25%	25%	25%	29.45	29450
Low	Mean	50%	0%	25%	25%	29.45	29450
Low	Mean	50%	100%	10%	25%	31.56	31560
Low	Mean	50%	75%	10%	25%	30.11	30110
Low	Mean	50%	50%	10%	25%	29.38	29380
Low	Mean	50%	25%	10%	25%	29.37	29370
Low	Mean	50%	0%	10%	25%	29.37	29370
Low	Mean	75%	100%	10%	10%	31.56	31560
Low	Mean	75%	75%	10%	10%	30.11	30110
Low	Mean	75%	50%	10%	10%	29.39	29390
Low	Mean	75%	25%	10%	10%	29.38	29380
Low	Mean	75%	0%	10%	10%	29.37	29370
Low	Mean	75%	100%	25%	10%	31.88	31880
Low	Mean	75%	75%	25%	10%	30.19	30190
Low	Mean	75%	50%	25%	10%	29.47	29470

Low	Mean	75%	25%	25%	10%	29.46	29460
Low	Mean	75%	0%	25%	10%	29.45	29450
Low	Mean	75%	100%	25%	25%	31.88	31880
Low	Mean	75%	75%	25%	25%	30.19	30190
Low	Mean	75%	50%	25%	25%	29.47	29470
Low	Mean	75%	25%	25%	25%	29.46	29460
Low	Mean	75%	0%	25%	25%	29.45	29450
Low	Mean	75%	100%	10%	25%	31.56	31560
Low	Mean	75%	75%	10%	25%	30.11	30110
Low	Mean	75%	50%	10%	25%	29.39	29390
Low	Mean	75%	25%	10%	25%	29.38	29380
Low	Mean	75%	0%	10%	25%	29.37	29370
Low	Mean	100%	100%	10%	10%	31.56	31560
Low	Mean	100%	75%	10%	10%	30.11	30110
Low	Mean	100%	50%	10%	10%	29.39	29390
Low	Mean	100%	25%	10%	10%	29.38	29380
Low	Mean	100%	0%	10%	10%	29.37	29370
Low	Mean	100%	100%	25%	10%	31.88	31880
Low	Mean	100%	75%	25%	10%	30.19	30190
Low	Mean	100%	50%	25%	10%	29.47	29470
Low	Mean	100%	25%	25%	10%	29.46	29460
Low	Mean	100%	0%	25%	10%	29.45	29450
Low	Mean	100%	100%	25%	25%	31.88	31880
Low	Mean	100%	75%	25%	25%	30.19	30190
Low	Mean	100%	50%	25%	25%	29.47	29470
Low	Mean	100%	25%	25%	25%	29.46	29460
Low	Mean	100%	0%	25%	25%	29.45	29450
Low	Mean	100%	100%	10%	25%	31.56	31560
Low	Mean	100%	75%	10%	25%	30.11	30110

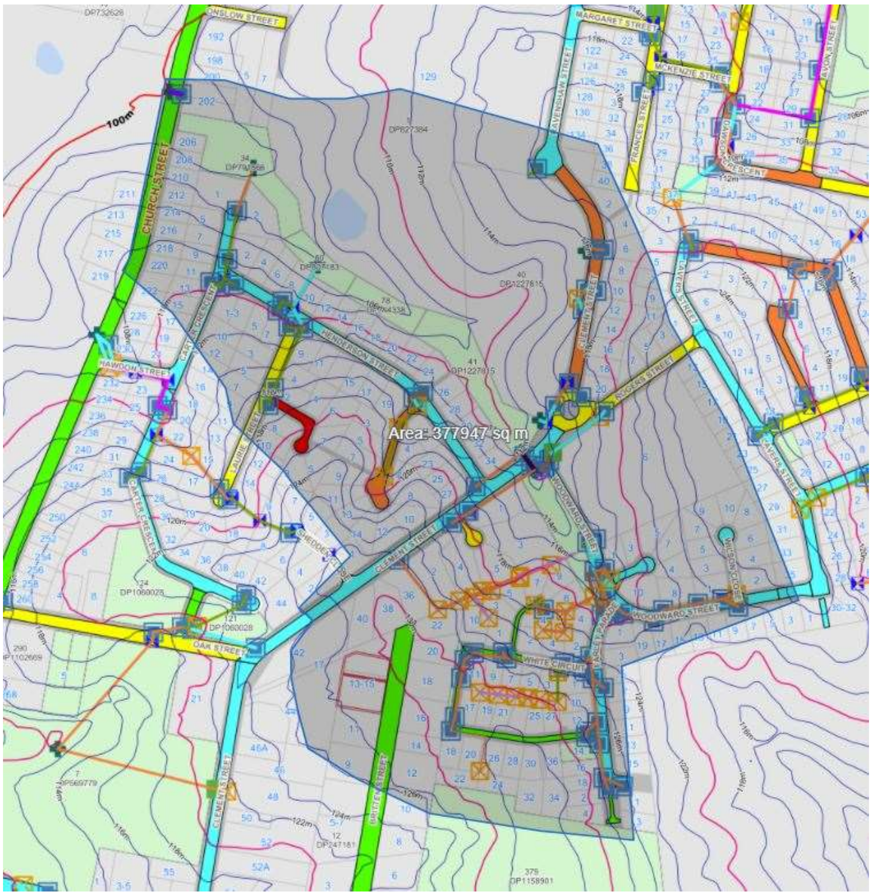
Low	Mean	100%	50%	10%	25%	29.39	29390
Low	Mean	100%	25%	10%	25%	29.38	29380
Low	Mean	100%	0%	10%	25%	29.37	29370
Mean	Mean	0%	100%	10%	10%	119.1	119100
Mean	Mean	0%	75%	10%	10%	117.5	117500
Mean	Mean	0%	50%	10%	10%	115.8	115800
Mean	Mean	0%	25%	10%	10%	113.2	113200
Mean	Mean	0%	0%	10%	10%	111.5	111500
Mean	Mean	0%	100%	25%	10%	119.4	119400
Mean	Mean	0%	75%	25%	10%	117.6	117600
Mean	Mean	0%	50%	25%	10%	115.8	115800
Mean	Mean	0%	25%	25%	10%	113.2	113200
Mean	Mean	0%	0%	25%	10%	111.6	111600
Mean	Mean	0%	100%	25%	25%	119.5	119500
Mean	Mean	0%	75%	25%	25%	117.6	117600
Mean	Mean	0%	50%	25%	25%	115.9	115900
Mean	Mean	0%	25%	25%	25%	113.3	113300
Mean	Mean	0%	0%	25%	25%	111.6	111600
Mean	Mean	0%	100%	10%	25%	119.1	119100
Mean	Mean	0%	75%	10%	25%	117.6	117600
Mean	Mean	0%	50%	10%	25%	115.8	115800
Mean	Mean	0%	25%	10%	25%	113.2	113200
Mean	Mean	0%	0%	10%	25%	111.6	111600
Mean	Mean	25%	100%	10%	10%	119.2	119200
Mean	Mean	25%	75%	10%	10%	117.7	117700
Mean	Mean	25%	50%	10%	10%	115.9	115900
Mean	Mean	25%	25%	10%	10%	113.3	113300
Mean	Mean	25%	0%	10%	10%	111.7	111700

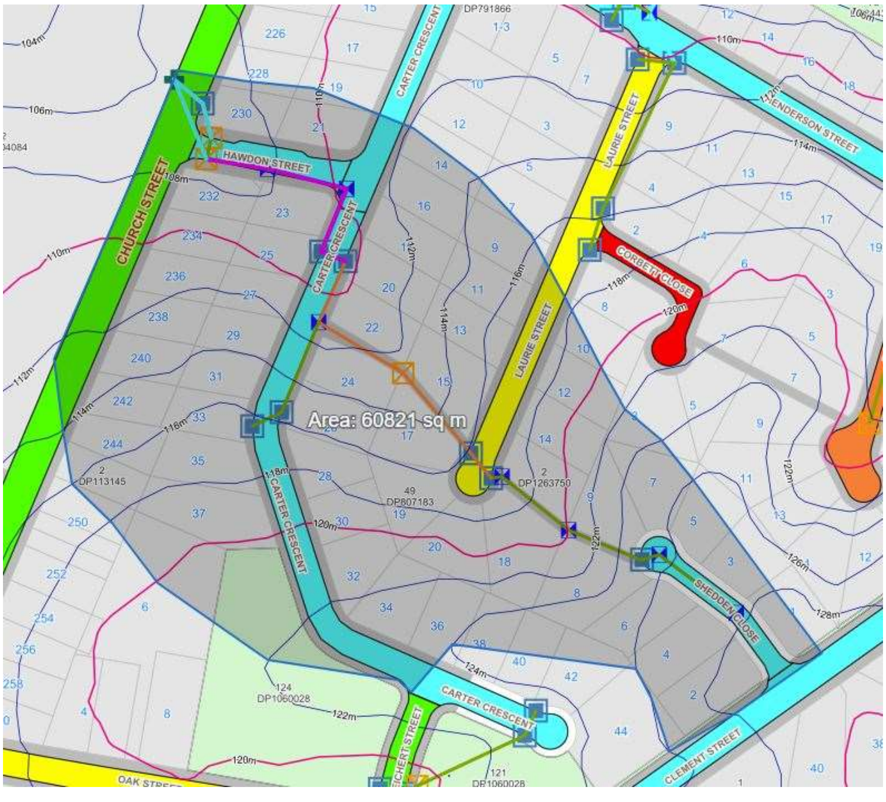
Mean	Mean	25%	100%	25%	10%	119.6	119600
Mean	Mean	25%	75%	25%	10%	117.7	117700
Mean	Mean	25%	50%	25%	10%	116	116000
Mean	Mean	25%	25%	25%	10%	113.4	113400
Mean	Mean	25%	0%	25%	10%	111.7	111700
Mean	Mean	25%	100%	25%	25%	119.6	119600
Mean	Mean	25%	75%	25%	25%	117.8	117800
Mean	Mean	25%	50%	25%	25%	116	116000
Mean	Mean	25%	25%	25%	25%	113.4	113400
Mean	Mean	25%	0%	25%	25%	111.7	111700
Mean	Mean	25%	100%	10%	25%	119.2	119200
Mean	Mean	25%	75%	10%	25%	117.7	117700
Mean	Mean	25%	50%	10%	25%	116	116000
Mean	Mean	25%	25%	10%	25%	113.3	113300
Mean	Mean	25%	0%	10%	25%	111.7	111700
Mean	Mean	50%	100%	10%	10%	119.4	119400
Mean	Mean	50%	75%	10%	10%	117.8	117800
Mean	Mean	50%	50%	10%	10%	116.1	116100
Mean	Mean	50%	25%	10%	10%	113.5	113500
Mean	Mean	50%	0%	10%	10%	111.8	111800
Mean	Mean	50%	100%	25%	10%	119.7	119700
Mean	Mean	50%	75%	25%	10%	117.9	117900
Mean	Mean	50%	50%	25%	10%	116.1	116100
Mean	Mean	50%	25%	25%	10%	113.5	113500
Mean	Mean	50%	0%	25%	10%	111.9	111900
Mean	Mean	50%	100%	25%	25%	119.8	119800
Mean	Mean	50%	75%	25%	25%	117.9	117900
Mean	Mean	50%	50%	25%	25%	116.2	116200
Mean	Mean	50%	25%	25%	25%	113.6	113600

Mean	Mean	50%	0%	25%	25%	111.9	111900
Mean	Mean	50%	100%	10%	25%	119.4	119400
Mean	Mean	50%	75%	10%	25%	117.9	117900
Mean	Mean	50%	50%	10%	25%	116.1	116100
Mean	Mean	50%	25%	10%	25%	113.5	113500
Mean	Mean	50%	0%	10%	25%	111.9	111900
Mean	Mean	75%	100%	10%	10%	119.5	119500
Mean	Mean	75%	75%	10%	10%	118	118000
Mean	Mean	75%	50%	10%	10%	116.3	116300
Mean	Mean	75%	25%	10%	10%	113.6	113600
Mean	Mean	75%	0%	10%	10%	112	112000
Mean	Mean	75%	100%	25%	10%	119.9	119900
Mean	Mean	75%	75%	25%	10%	118	118000
Mean	Mean	75%	50%	25%	10%	116.3	116300
Mean	Mean	75%	25%	25%	10%	113.7	113700
Mean	Mean	75%	0%	25%	10%	112	112000
Mean	Mean	75%	100%	25%	25%	119.9	119900
Mean	Mean	75%	75%	25%	25%	118.1	118100
Mean	Mean	75%	50%	25%	25%	116.3	116300
Mean	Mean	75%	25%	25%	25%	113.7	113700
Mean	Mean	75%	0%	25%	25%	112.1	112100
Mean	Mean	75%	100%	10%	25%	119.6	119600
Mean	Mean	75%	75%	10%	25%	118	118000
Mean	Mean	75%	50%	10%	25%	116.3	116300
Mean	Mean	75%	25%	10%	25%	113.6	113600
Mean	Mean	75%	0%	10%	25%	112	112000
Mean	Mean	100%	100%	10%	10%	119.7	119700
Mean	Mean	100%	75%	10%	10%	118.1	118100
Mean	Mean	100%	50%	10%	10%	116.4	116400

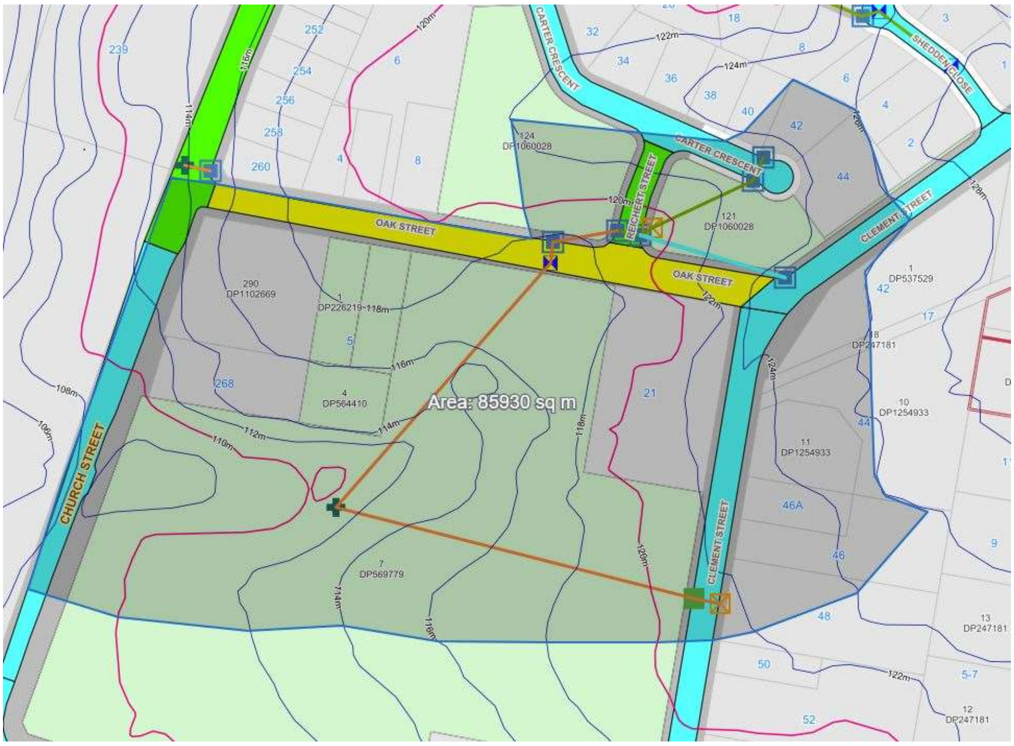
Mean	Mean	100%	25%	10%	10%	113.8	113800
Mean	Mean	100%	0%	10%	10%	112.1	112100
Mean	Mean	100%	100%	25%	10%	120	120000
Mean	Mean	100%	75%	25%	10%	118.2	118200
Mean	Mean	100%	50%	25%	10%	116.4	116400
Mean	Mean	100%	25%	25%	10%	113.8	113800
Mean	Mean	100%	0%	25%	10%	112.2	112200
Mean	Mean	100%	100%	25%	25%	120.1	120100
Mean	Mean	100%	75%	25%	25%	118.2	118200
Mean	Mean	100%	50%	25%	25%	116.5	116500
Mean	Mean	100%	25%	25%	25%	113.9	113900
Mean	Mean	100%	0%	25%	25%	112.2	112200
Mean	Mean	100%	100%	10%	25%	119.7	119700
Mean	Mean	100%	75%	10%	25%	118.2	118200
Mean	Mean	100%	50%	10%	25%	116.4	116400
Mean	Mean	100%	25%	10%	25%	113.8	113800
Mean	Mean	100%	0%	10%	25%	112.2	112200

Appendix G Gloucester River Catchments

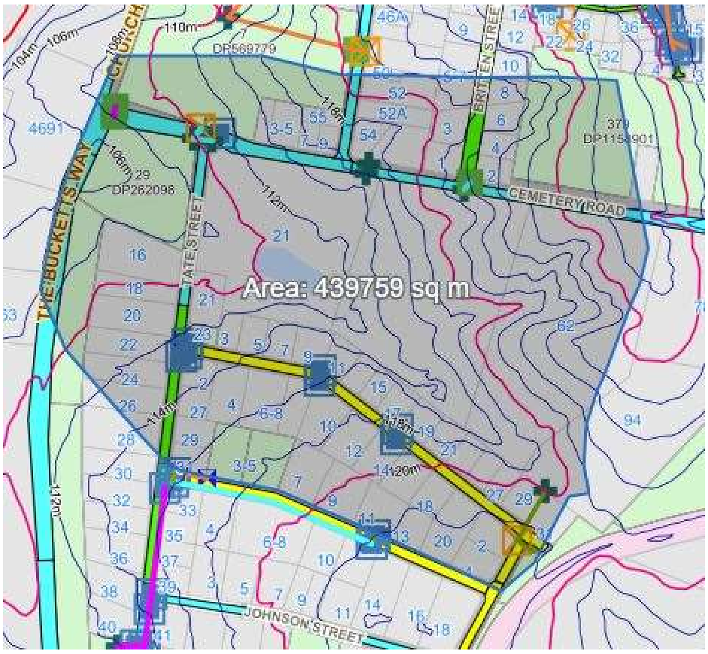

Area: 377947 sq m

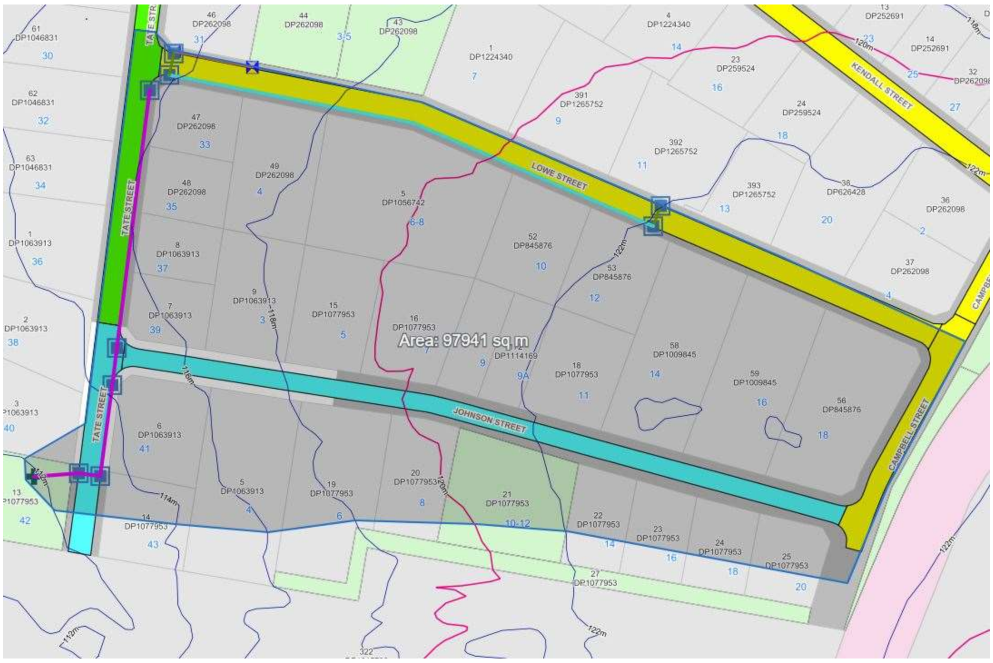

Area: 60821 sq m
CHURCH STREET
HAWDON STREET
CARTER CRESCENT
LAURIE STREET
CORBETT CLOSE
HENDERSON STREET
SHEDDEN CLOSE
CLEMENT STREET
OAK STREET

Area: 10807 sq m
OAK STREET
CARTER CRESCENT
DP116307
250
252
254
256
258
260
239
124
DP1060028
120m
122m



Area: 85930 sq m
OAK STREET
CHURCH STREET
CLEMENT STREET
CARTER CRESCENT
REICHERT STREET
SHEDDEN CLOSE
124
DP1060028
121
DP1060028
290
DP1102669
1
DP226219
4
DP564410
7
DP569779
11
DP1254933
10
DP1254933
1
DP537529
18
DP247181
13
DP247181
12
DP247181

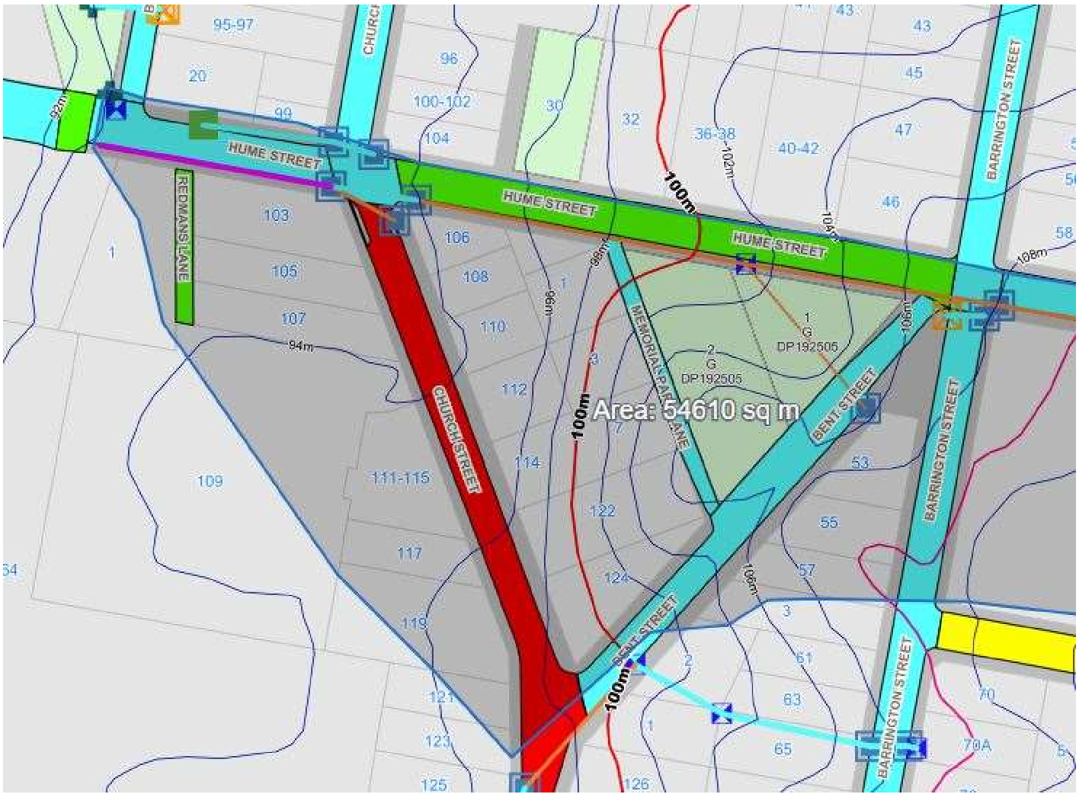

Area: 439759 sq m
TATE STREET
CEMETERY ROAD
JOHNSON STREET
THE BUCKETTS WAY
BRITTEN STREET


Area: 97941 sq m
TATE STREET
LOWE STREET
JOHNSON STREET
CAMPBELL STREET
KENDALL STREET

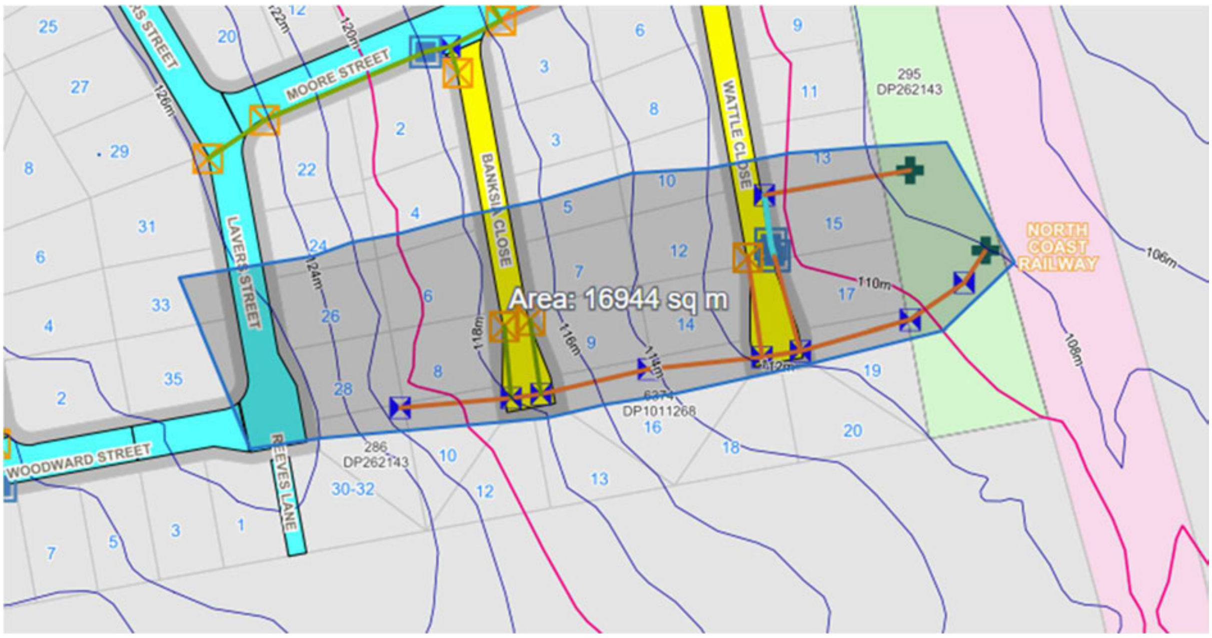

Area: 138860 sq m
HAY STREET
ONSLOW STREET
CHURCH STREET
RAVENSHAW STREET
MARGARET STREET
PHILIP STREET
DP116312
DP827384
DP1160548
166-182
100m
104m
106m
108m
110m
112m
116m
118m

Area: 22482 sq m
PHILIP STREET
HAY STREET
CHURCH STREET
RAVENSHAW STREET
DP605302
SP100862
DP192505
100m

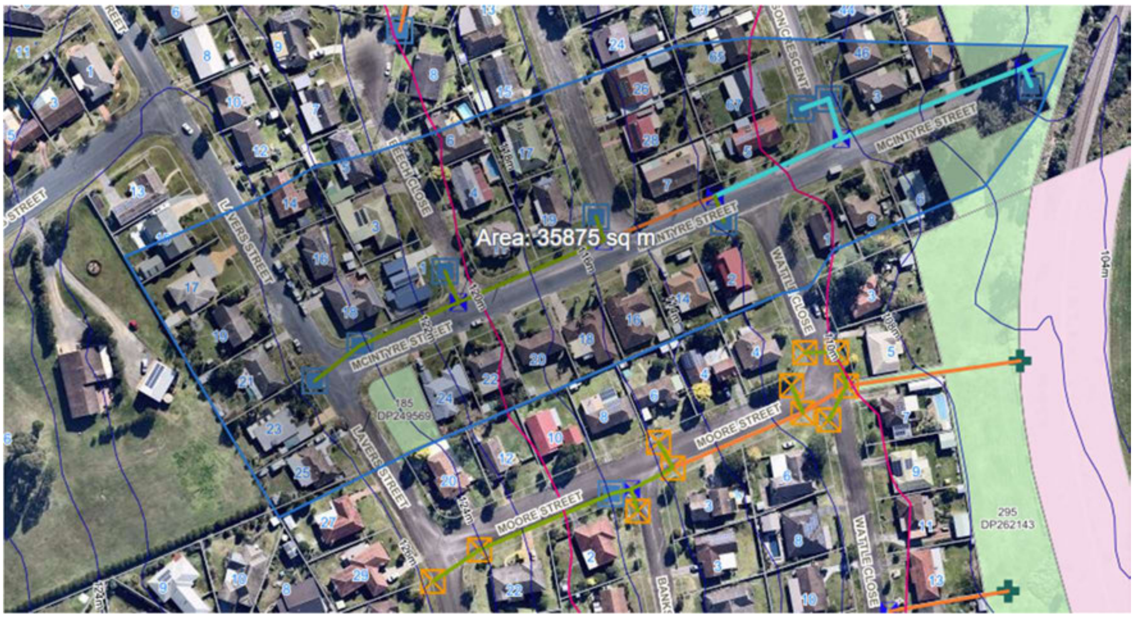

Area: 78258 sq m
CHURCH STREET
BARRINGTON STREET
ELLIOT STREET
GREGSON STREET
PHILIP STREET
100m


Area: 54610 sq m
HUME STREET
REDMANS LANE
CHURCH STREET
MEMORIAL PARK LANE
BENT STREET
BARRINGTON STREET
100m

Appendix H Avon River Catchments


MOORE STREET
LAVERS STREET
BANKSIA CLOSE
WATTLE CLOSE
Area: 16944 sq m
NORTH COAST RAILWAY
WOODWARD STREET
REEVES LANE
295
DP262143
286
DP262143
DP1011268
110m
106m
108m
118m
116m
124m
120m
126m


Area: 18074 sq m
MOORE STREET
LAVERS STREET
BANKSIA CLOSE
WATTLE CLOSE
MCINTYRE STREET
295
DP262143


Area: 35875 sq m
MCINTYRE STREET
MOORE STREET
LAVERS STREET
WATTLE CLOSE
BEECH CLOSE
DP249569
295
DP262143


Area: 65057 sq m
MARGARET STREET
MCKENZIE STREET
AVON STREET
RAVENSHAW STREET
FRANCES STREET
DAWSON CRESCENT
MAPLE CLOSE
PINE CLOSE
ROGERS STREET
LAVERS STREET
CLEMENTS STREET
DP248399
DP550217


Area: 157774 sq m
PHILIP STREET
HAY STREET
RAVENSHAW STREET
FRANCES STREET
MARGARET STREET
MCKENZIE STREET
DAWSON CRESCENT
AVON STREET
MAPLE CLOSE
PINE CLOSE
179
DP248399
100m


Area: 35835 sq m
PHILIP STREET
RAVENSHAW STREET
HAY STREET
AVON STREET
RAILWAY STREET
100m


Area: 196042 sq m
HUME STREET
ELLIOT STREET
GREGSON STREET
PHILIP STREET
100m


Area: 80300 sq m
QUEEN STREET
DENISON STREET
KING STREET
HUME STREET
RAILWAY STREET
100m

Appendix I Catchment Percentages

Catchment	**Gloucester**			**1**
Area	m^2	377947	Ha	37.79
Area Less Roof		293326	Ha	**29.33**
Grass	m^2	256198	Ha	25.62
Road	m^2	37128	Ha	3.71
Roof	m^2	84621	Ha	**8.46**
Total Catchment				
Impervious	%	12.66		
Pervious	%	87.34		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**2**
Area	m^2	60821	Ha	6.08
Area Less Roof		42919.38	Ha	**4.29**
Grass	m^2	34861.08	Ha	3.49
Road	m^2	8058.3	Ha	0.81
Roof	m^2	17901.63	Ha	**1.79**
Total Catchment				
Impervious	%	18.78		
Pervious	%	81.22		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**3**
Area	m^2	10807	Ha	1.08
Area Less Roof		8226.695	Ha	**0.82**
Grass	m^2	7154.995	Ha	0.72
Road	m^2	1071.7	Ha	0.11
Roof	m^2	2580.305	Ha	**0.26**
Total Catchment				
Impervious	%	13.03		
Pervious	%	86.97		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**4**
Area	m^2	85930	Ha	8.59
Area Less Roof		78639.22	Ha	**7.86**
Grass	m^2	35367.22	Ha	3.54
Road	m^2	43272	Ha	4.33
Roof	m^2	7290.78	Ha	**0.73**
Total Catchment				
Impervious	%	55.03		
Pervious	%	44.97		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**5**
Area	m^2	439759	Ha	43.98
Area Less Roof		326643.1	Ha	**32.66**
Grass	m^2	300132	Ha	30.01
Road	m^2	26511.1	Ha	2.65
Roof	m^2	113116	Ha	**11.31**
Total Catchment				
Impervious	%	8.12		
Pervious	%	91.88		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**6**
Area	m^2	97941	Ha	9.79
Area Less Roof		42285.68	Ha	**4.23**
Grass	m^2	27254.18	Ha	2.73
Road	m^2	15031.5	Ha	1.50
Roof	m^2	55655.32	Ha	**5.57**
Total Catchment				
Impervious	%	35.55		
Pervious	%	64.45		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**7**
Area	m^2	138860	Ha	13.89
Area Less Roof		117870	Ha	**11.79**
Grass	m^2	102161	Ha	10.22
Road	m^2	15709	Ha	1.57
Roof	m^2	20989.96	Ha	**2.10**
Total Catchment				
Impervious	%	13.33		
Pervious	%	86.67		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**8**
Area	m^2	22482	Ha	2.25
Area Less Roof		15623.05	Ha	**1.56**
Grass	m^2	13377.05	Ha	1.34
Road	m^2	2246	Ha	0.22
Roof	m^2	6858.95	Ha	**0.69**
Total Catchment				
Impervious	%	14.38		
Pervious	%	85.62		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**9**
Area	m^2	78258	Ha	7.83
Area Less Roof		56701.92	Ha	**5.67**
Grass	m^2	40032.72	Ha	4.00
Road	m^2	16669.2	Ha	1.67
Roof	m^2	21556.08	Ha	**2.16**
Total Catchment				
Impervious	%	29.40		
Pervious	%	70.60		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Gloucester**			**10**
Area	m^2	54610	Ha	5.46
Area Less Roof		47012.34	Ha	**4.70**
Grass	m^2	27052.34	Ha	2.71
Road	m^2	19960	Ha	2.00
Roof	m^2	7597.66	Ha	**0.76**
Total Catchment				
Impervious	%	42.46		
Pervious	%	57.54		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**1**
Area	m^2	16944	Ha	1.69
Area Less Roof		12445.1	Ha	**1.24**
Grass	m^2	10138.1	Ha	1.01
Road	m^2	2307	Ha	0.23
Roof	m^2	8355.1	Ha	**0.84**
Total Catchment				
Impervious	%	18.54		
Pervious	%	81.46		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**3**
Area	m^2	35875	Ha	3.59
Area Less Roof		26140.91	Ha	**2.61**
Grass	m^2	18856.91	Ha	1.89
Road	m^2	7284	Ha	0.73
Roof	m^2	18077.61	Ha	**1.81**
Total Catchment				
Impervious	%	27.86		
Pervious	%	72.14		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**4**
Area	m^2	65057	Ha	6.51
Area Less Roof		49855.24	Ha	**4.99**
Grass	m^2	40673.84	Ha	4.07
Road	m^2	9181.4	Ha	0.92
Roof	m^2	28231.84	Ha	**2.82**
Total Catchment				
Impervious	%	18.42		
Pervious	%	81.58		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**5**
Area	m^2	157774	Ha	15.78
Area Less Roof		121849.9	Ha	**12.18**
Grass	m^2	101302.4	Ha	10.13
Road	m^2	20547.5	Ha	2.05
Roof	m^2	66716.26	Ha	**6.67**
Total Catchment				
Impervious	%	16.86		
Pervious	%	83.14		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**6**
Area	m^2	35835	Ha	3.58
Area Less Roof		18196.75	Ha	**1.82**
Grass	m^2	9113.25	Ha	0.91
Road	m^2	9083.5	Ha	0.91
Roof	m^2	7559.25	Ha	**0.76**
Total Catchment				
Impervious	%	49.92		
Pervious	%	50.08		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**7**
Area	m^2	196042	Ha	19.60
Area Less Roof		138265.4	Ha	**13.83**
Grass	m^2	110593.3	Ha	11.06
Road	m^2	27672.1	Ha	2.77
Roof	m^2	107299.3	Ha	**10.73**
Total Catchment				
Impervious	%	20.01		
Pervious	%	79.99		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Catchment	**Avon**			**8**
Area	m^2	80300	Ha	8.03
Area Less Roof		57895.35	Ha	**5.79**
Grass	m^2	41608.65	Ha	4.16
Road	m^2	16286.7	Ha	1.63
Roof	m^2	41608.65	Ha	**4.16**
Total Catchment				
Impervious	%	28.13		
Pervious	%	71.87		
Total - Roof				
Impervious	%	100.00		
Pervious	%	0.00		

Appendix J Cost Estimates

Item	Description	Quantity	Unit	Rate	Total
1	**Preliminaries and Site Establishment**				
1.1	Site Setup, Insurances, Plans, OHS, Environment, Setout all permits and audits to complete work	1	Item	$22,000.00	$22,000.00
1.2	Geotechnical Investigation	1	Item	$5,000.00	$5,000.00
1.3	Signage	1	Item	$1,000.00	$1,000.00
1.4	Access for vehicles	1	Item	$2,000.00	$2,000.00
1.5	Traffic management	1	Item	$5,000.00	$5,000.00
1.6	Tree and vegetation Clearing	1	Item	$6,000.00	$6,000.00
2	**Earthworks**				
2.1	Strip and stockpile topsoil off site	2000	m^3	$12.00	$24,000.00
2.2	Strip and stockpile topsoil on site	2000	m^3	$4.00	$8,000.00
2.3	Cut to spoil	9450	m^3	$12.00	$113,400.00
2.4	Trim and Compact Subgrade	6000	m^2	$2.00	$12,000.00
2.5	Supply and Place and Compact 600mm Clay Liner	6000	m^3	$10.00	$60,000.00
3	**Maintenance Tracks and Paths**				
3.1	Nominal value	1	Item	$15,000.00	$15,000.00
4	**Sediment Pond**				
4.1	Supply and place 300mm Thick rock	90	m^3	$84.00	$7,560.00
4.2	Supply and place 600mm Graded Rock	180	m^3	$75.00	$13,500.00
5	**Wetland Inlet**				
5.1	Excavation for Drainage Structures	100	m^3	$35.00	$3,500.00
5.2	Sediment Pond Diversion Pit	1	Each	$15,000.00	$15,000.00
5.3	Supply and install 450mm RCP Class 2	15	m	$170.00	$2,550.00
5.4	Supply and install 600mm Graded rock	126	m^3	$84.00	$10,584.00
5.5	Supply and install 200mm thick concrete maintenance pad	25	m^3	$240.00	$6,000.00
5.6	*Endwall*				
5.6.1	Supply and place 900mm Large toe rock	5	m^2	$100.00	$500.00
5.6.2	Supply and Place 150mm thick shot rock bedding	2	m^3	$50.00	$100.00
5.6.3	Supply and Place fine Crushed Rock	2	m^3	$80.00	$160.00
5.6.4	Supply and install Geotextile	5	m^2	$3.00	$15.00
5.6.5	Supply and install geogrid	5	m^2	$3.00	$15.00
5.6.6	Supply and install 200mm thick concrete cut off wall SL82 Mesh	0.5	m^3	$250.00	$125.00

6	**Wetland Inlet**				
6.1	Excavation for Drainage Structures	100	m^3	$40.00	$4,000.00
6.2	Supply and install 375mm RCP	8	m	$250.00	$2,000.00
6.3	Supply and install wetland outlet concrete pit	1	Each	$25,000.00	$25,000.00
6.4	Supply and install junction pit with valve and orifice plate	1	Each	$10,000.00	$10,000.00
6.5	Supply and place 50mm thick concrete blinding	1	m^3	$290.00	$290.00
6.6	*End Wall*				
6.6.1	Supply and place 900mm Large toe rock	5	m^2	$100.00	$500.00
6.6.2	Supply and Place 150mm thick shot rock bedding	2	m^3	$50.00	$100.00
6.6.3	Supply and Place fine Crushed Rock	2	m^3	$80.00	$160.00
6.6.4	Supply and install Geotextile	5	m^2	$3.00	$15.00
6.6.5	Supply and install geogrid	5	m^2	$3.00	$15.00
6.6.6	Supply and install 200mm thick concrete cut off wall SL82 Mesh	0.5	m^3	$250.00	$125.00
7	**Landscaping**				
7.1	Supply and install large woody debris/stump	10	Each	$750.00	$7,500.00
7.2	Supply and install platic post for large woody debris	36	m	$50.00	$1,800.00
7.3	Reinstate topsoil to wetland zone	2000	m^3	$4.00	$8,000.00
7.4	Wetland Plants	12000	each	$5.00	$60,000.00
8	**Miscellaneous**				
8.1	Reinstate footpath	75	m^3	$300.00	$22,500.00
9	**Maintenance**				
9.1	First 2 Years of Maintenance	2	Each	$6,500.00	$13,000.00
9.2	Following 20 years maintenance	20	Each	$1,950.00	$39,000.00
9.3	Sediment Basin Cleanout every 5 years	4	Each	$20,000.00	$80,000.00
	Sub-Total				**$607,014.00**
	Contingency (20%)				**$121,402.80**
	Total				**$728,416.80**

Appendix K Sample Collection Form

Sample Collection Sheet

MIDCOAST council

Form No: BLANK_SCS | Version No: 3
Issue Date: 28 October 2020 | Review Date: As Required
Responsible Officer: Senior Chemist/Senior Microbiologist
Authorised by: Co-ordinator Scientific Services

DATE: 21/6/2021
WEATHER: overcast

LIMS NUMBERS:

SAMPLE TYPE:

- [ ] SEWER INCIDENT
- [ ] REPEAT RETICULATED WATER
- [ ] RETICULATED WATER
- [x] OTHER WATER
- [ ] TRADE WASTE
- [ ] OTHER

Emailed & saved
By_______
Date_______

GSW1 - Tate street Gloucester, Collected at outlet to the southern end, collecting Industrial stormwater

GSW2 - Church street Gloucester, Collected at outlet of Grass swale south of Gloucester High school Ag Farm

GSW3 - Billabong lane Gloucester. Collected at outlet between Campbell's Engineering & Carpark, collecting SW to King street.

ANALYSIS: 2x TSS, 1 x Nutrients, 1 x oils and Grease 1 x metals (lead zinc copper)

CHAIN OF CUSTODY.

SAMPLE COLLECTED BY:

NAME: Nicholas Kellner | DATE: 21/6/21
SIGNATURE: [redacted] | TIME: 3:15pm

SAMPLE TRANSPORTED BY:

NAME: | DATE:
SIGNATURE: | TIME:

SAMPLE RECEIVED AT THE LABORATORY BY:

NAME: | DATE:
SIGNATURE: | TIME:

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