EFFICIENCY OF A DRY DETENTION BASIN WITH A BIOFILTER AS AN OUTLET (DDBBO) IN TREATING STORMWATER POLLUTANTS

A Thesis submitted by

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For the award of

MASTER OF ENGINEERING RESEARCH

2019

Abstract

Dry Detention Basin with a Biofilter as an Outlet (DDBBO) system is currently playing an essential role as Water Sensitive Urban Design (WSUD) measure due to its pleasing appearance and benefits in the management of peak flows, runoff volume, pollutant removal and groundwater recharge. Unfortunately, the effectiveness of this device and the environmental benefits when implemented in urban settings have not been appropriately evaluated and validated due to the lack of fieldwork data. Therefore, this study provided an exciting research opportunity to increase our knowledge in the performance treatment efficiency of this system under real storm events and specific site conditions as those presented in Toowoomba.

This study focused on assessing the effectiveness of a DDBBO system located in the suburb of Glenvale in Toowoomba for the removal of Total Nitrogen (TN), Total Phosphorous (TP) and Total Suspended Solids (TSS). The study obtained data for real storm events and developed models using eWater's MUSIC modelling software. The results have been compared with the objectives set out by the Australian legislation and verified with the findings from the literature. This study considered six storm events from which 36 samples were taken at the inlet and outlet of the DBBOO system via automatic sampling devices to subsequently being tested in the Laboratory. The results were then used to calculate the pollutant loads by applying three different mathematical techniques (regression, average and ratio estimator). The removal efficiency of the DDBBO was also analysed by implementing three different approaches (efficiency ratio, the summation of loads and regression). The results produced an average per cent removal efficiency of 58% for TSS, 17% for TP and 42% for TN that demonstrated that the DDBBO could facilitate the removal of pollutants. However, some negative values were reported for TN and TP for some of the individual sampled events. This may be explained due to denitrification processes generated by the organic decomposition of grass clipping as a result of maintenance activities and resettling and resuspension of sediment particles at the bottom of the DDBBO, which could not be picked up in the observed data for the selected events.

A longer-term monitoring program is recommended to be implemented to validate the performance of the DDBBO system.

The fieldwork results were compared against the results obtained from the MUSIC model developed for this study. The results showed that observed TSS and TN inflow concentrations were considerably lower than the lower deviation level set by the model. While, for TP, it was found that 50% of the samples were within the upper and lower levels and the remaining 50% fell below the lower deviation level. The model showed that the predicted removal efficiency for TSS was considerably higher than those figures reported in the field-observed study. While for TN and TP the model reported a better prediction. This study concluded that the TN, TSS and TP observed data were below the removal targets established by the legislation.

This study did demonstrate that the DDBBO at Glenvale could be effective at removing pollutant loads. However, the results from this study need to be used with caution as the number of samples fell below the minimum protocol (SQIDEP) requirements for stormwater quality treatment devices. Nevertheless, valuable information was gained in this study that could be used in future research projects that investigate DDBBO systems or similar structures in urban settings.

Certification of Thesis

This Thesis is entirely the work of Eduardo Mba except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

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Student and supervisor's signatures of endorsement are held at the University

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Acknowledgements

This project research involved a number of research activities such as sampling equipment installation, stormwater monitoring, water quality testing and analysis as well as programming and software modelling for which colleges, university staff and private organisations have guided me and made valuable contributions for me to complete this research project.

I would like to thank *Dr Ian Brodie,* and *Md Jahangir Alam* for the extraordinary support, guidance and patient provide during my academic journey, which made possible the success of this project. I would also like to extend my appreciation to all USQ staff members that contribute directly and indirectly to this project. Special thanks to *Friederike Susette Eberhard* USQ laboratory technical officer that provided valuable information for the operation and maintenance of laboratory testing equipment and *Chris Galligan* Workshop Coordinating officer that built the steel enclosure housing for the automatic samplers and equipment intended for the protection against vandalism and weather condition. I cannot forget to thank *Grant Millar,* external consultant, who provided valuable advice and information for the programming and operation of the sampling equipment.

I would also like to express my gratitude to Toowoomba Regional Council for providing financial assistance for testing of the stormwater samples

I would like to send a big “THANKS” to my family (*Eduardo, Mariluz, Paola A. & Carlos A.*), my supportive and amazing wife (*Catalina*) and my two beautiful kids (*Valentina & Emiliano*). This has been a stimulating, exciting and challenging journey that I would not have been able to accomplish and complete without your unconditional love, support and encouragement.

Finally, I would like to acknowledge that this research has been supported by Australian Commonwealth Government fee contribution through the Research Training Program Fee Offset scheme.

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LIST OF ABBREVIATIONS

Al	Aluminium
BCC	Brisbane City Council
Ca	Calcium
Cd	Cadmium
Cr	Chromium
CSTRs	Continuously Stirred Tank Reactors
Cu	Copper
DRAINS	Computer Software to Model Stormwater Drainage System
DDB	Dry Detention Basin
DDBBO	Dry Detention Basin with Biofilter as an Outlet
DWC	Dry Weather Concentration
EMC	Event Mean Concentration
EPA	Environment Protection Authority
ER	Efficiency Ratio
FAWB	Facility for Advancing Water Biofiltration
Fe	Iron
K	Potassium
Fe	Iron
Mn	Manganese
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
N	Nitrogen
NATA	National Association of Testing Authorities, Australia
$NH4^{+}$	Ammonium
Ni	Nickel
$NO3^{-}$	Nitrate
NTU	Nephelometric Turbidity Unit
P	Phosphorous
PAHs	Plocyclic Aromatic Hydrocarbons
Pb	Lead
PSD	Particle Size Distribution
QWQC 2009	Queensland Water Quality Guidelines 2009
ROL	Regression of Loads
SEQ	South East Queensland
SOL	Summation of Loads

SQU	Southern Queensland University
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorous
TRC	Toowoomba Regional Council
TSS	Total Suspended Solids
UK	United Kingdom
USA	United States of America
WQO	Water Quality Objective
WSUD	Water Sensitive Urban Design
Zn	Zinc

1 Introduction

1.1 Overview

In the past, the objective of stormwater management in Australia was mainly focused on flood mitigation. The aim was to build a system that conveyed the stormwater runoff from a developed urban area into the nearest waterbody as quickly and invisibly as possible. However, the extreme drought condition presented in Australia in the mid and late 1990s changed the national and local attitudes concerning water resources management. Nowadays, the efforts are focused on finding a long-term integrated approach, not just for water quality and ecological sustainability of our waterways, but also for stormwater harvesting and mitigation strategies (Mouritz et al., 1994, Davies, 1996, Melbourne Water, 2005, Argue et al., 2005, BCC, 2005, Zhang et al., 2015, Dhakal and Chevalier, 2016).

The runoff generated from urbanised areas in our cities and towns is mainly collected through underground and above-ground stormwater drainage systems, which subsequently are discharged into the waterways. This is placing increasing pressure on our waterways and its ecosystems. Hence, an integrated, innovative and sustainable approach to water management has been required to improve, protect and preserve the water cycle in terms of its water quality and hydrological benefits. In order to achieve that, a philosophical concept known as "Water Sensitive Urban Design" (WSUD) was introduced for the sustainable design and planning of our urban areas (Zhang et al., 2015). Although the concept was not created in Australia, it was originally introduced in Western Australia (Whelans, 1994), and it has successfully been implemented in the EEUU and Canada known as "Low Impact Development" (Zimmer, 2006) and the United Kingdom known as "Sustainable Drainage System" (Ellis et al., 2002).

Eutrophication is one of the top water quality concerns for the waterways and urban environments. In recent years, researchers have identified Total Nitrogen (TN), Total

Phosphorous (P) and Total Suspended Solids (TSS) as the primary pollutants responsible for the enrichment of the eutrophication process in waterbodies (Parker, 2010, Khan, 2009, Zarezadeh et al., 2018, Toor et al., 2017). These pollutants are generated from a variety of sources inclusive of the rainfall itself, and previous and impervious surfaces contained in different land uses such as urbanisation, forestry, agriculture, mining and other industries. Hence, considerable emphasis has currently been placed on the development of best management practice to mitigate and reduce pollutants discharges from those sources into the receiving environment. Bioretention system also referred as “rain gardens”, “biofilters” or “biofiltration”, has become one of the most commonly non-proprietary systems used for the removal of TN, TP and TSS pollutants from the stormwater runoff. Biofilters treat the polluted urban runoff through biologically processes carried out by the vegetation and biofilms present within the filter media. Even though extensive research studies have been undertaken, in both laboratory and field studies to test its performance in runoff retention and pollutant removal, the results have been remarkably variables.

In some cases, significant removal efficiencies were documented, but in other cases, the reported removal efficiencies were surprisingly lower than expected or predicted through the use of computer program such as the Model for Urban Stormwater Improvement Conceptualisation “MUSIC” (eWater, 2017, Water by Design, 2015b, Imteaz et al., 2013, Fletcher, 2013, Water by Design, 2010b). This highlights the complexity and challenges faced in the design, construction and maintenance of biofilters and the effect that they have on the overall performance and lifespan of the system.

The guidelines used to assist planners, designers, engineers, contractors and landowners have significantly evolved since the introduction of biofilter systems in the 1990s. This is evident in the “Technical Bioretention Guidelines” prepared by Water by Design (2014) and the “Review of Bioretention System Research and Design” paper prepared by Roy-Poirier et al. (2010). Biofilters are currently playing a vital role in the implementation of WSUD as they are aesthetically pleasing and reported to achieve a number of environmental sustainable outcomes and benefits, such as management of peak flows, runoff volume and stormwater pollution as well as maintenance of groundwater recharge and stream baseflow (Roy-Poirier et al., 2010, Davis et al., 2009, Davis et al., 2006, de Macedo et al., 2019).

The primary focus of this fieldwork investigation is to identify the knowledge gap existing with regard to the removal performance efficiency of critical pollutants within the stormwater runoff through a Dry Detention Basin, which has a Biofilter as an Outlet (Referred as a DDBBO in this document). Biofilters are receiving increasing interest due to their flexibility, small footprint, and landscape improvements, such as aesthetic enhancement (Hatt et al., 2009, Shafique, 2016). However, to date, performance data for biofilters is limited to the laboratory-scale, with few studies reporting on field-scale testing (Dietz and Clausen, 2006, Shafique, 2016). Furthermore, no study has currently been undertaken in Australia to validate the effectiveness of placing biofilters as an outlet in detention basins facilities. Therefore, this study provided a new knowledge with regards to the performance of DDBBO systems for reducing or/and mitigating the hydrologic impacts and water quality effects generated by urban surfaces in the receiving environment, especially under specific conditions such as weather, environment, soil characteristic and even topography as presented in Toowoomba City.

The uniqueness of this project research was centred on the basis that no sufficient on-field testing has been performed in Toowoomba and/or Australia that helps to validate the benefits of incorporating DDBBO system in term of hydrological and water quality improvements for the receiving waterways.

The biofilter lifespan is another of the major concerns for this DDBBO system due to the high content of suspended solids produced by detention condition as it has been widely documented (Weiss et al., 2006, Shammaa et al., 2002). No sufficient literature is currently available that can help designers to understand or predict the performance of DDBBO system as was proposed by Toowoomba Regional Council (TRC) on Sunset Drive, Glenvale. This study research mainly focused on two aspects:

- Assessing the effectiveness for the removal of pollutants, such as TSS, TN and TP under real storm events and then compared the results with the objectives established under the Queensland Best Practise Environmental Management Guidelines, State Planning Policy 07/2017- Healthy Water (DILGP, 2017) and findings from the literature review; and

- Comparing the monitored results against MUSIC software to determine the level of accuracy of the model to predict pollutant concentrations and removal efficiencies of DDBBO system under specific site condition and characteristics based on the recommendations provided by the eWater guidelines (eWater, 2017, Water by Design, 2010b) and local legislation requirements.

1.2 Problem Statement and Motivation of this Study

The runoff generated from urbanised areas in our cities and towns transport high concentrations of different pollutants that significantly affect the water quality, drainage patterns, existing ecosystem and aesthetic appearance of our receiving environments. Therefore, WSUD measures such as DDBBO have been implemented as a response to mitigate and reduce the increasing pressure that these harmful contaminants are placing into our waterways and ecosystems. In recent years, the DDBBO systems have been receiving increasing interest and attention due to their flexibility, small footprint, landscape improvements and its dual benefits to achieve stormwater quality and quantity outcomes. However, no sufficient on-field testing has currently been undertaken Australia to help to validate the benefits of incorporating these structures in term of hydrological and water quality improvements for the receiving waterways and environment. Besides, understanding the operation of the DDBBO can lead to more cost-effective management strategies and more consistent improved water quality discharges which in the long term would be translated in a significant benefit not just for the catchment and receiving waterways, but also for the human health and wellbeing. Therefore, the completion of a DDBBO system in Toowoomba in 2013 in the suburb of Glenvale provided an exciting research opportunity to develop and increase our knowledge and understanding about the effectiveness of DDBBO systems for the removal of targeted pollutants such as TP, TN and TSS as required by the legislation, especially under specific conditions such as weather, environment, soil characteristics and topography as those presented in Toowoomba.

1.3 Aims and Objectives

This study aims to provide a field validation study in Australia for the evaluation of the effectiveness of a DDBBO system located within Toowoomba city for the removal of the targeted pollutants set by the legislation such as TN, TP and TSS and compare the results against MUSIC software to assess the accuracy of the model to predict its performance.

The specific objectives of this study research were:

- To implement an effective stormwater monitoring program to assess the pollutant removal effectiveness of a DDBBO system under real storm events,
- To apply three (3) different load estimation techniques to determine the order of difference in magnitude between them, and
- To determine the outflow and inflow pollutant mean concentrations as well as the removal efficiency of the DDBBO and benchmark the results against the objectives established under the Queensland Best Practice Environmental Management Guidelines, State Planning Policy (SPP7/17), MUSIC model parameters and the local and global figures reported in the literature review.

1.4 The Novelty of the Study Research

The novelty of this study research was mainly centred on the basis that no sufficient on-field testing has been performed in Toowoomba and/or Australia that helps to validate the environmental benefits and treatment performance of DDBBO structures when those are installed in our urban settings. Therefore, the construction of a DDBBO system in the suburb of Glenvale in Toowoomba created an exciting and unique research opportunity to increase our understanding and knowledge of these systems in term of its water quality improvements for our receiving waterways, especially under specific site conditions such as those presented in Toowoomba such as weather, environment, soil characteristics and topography.

A chronological timeline of the current research undertaken for DDBBO or similar structures is briefly presented in *Table 1.1*.

Table 1.1 Chronological Research Timeline for DDBBO or Similar Structures.

Year	Author	Study Description
1993	Harper and Herr	Treatment Efficiencies of Detention with Filtration Systems. Orlando, Florida
2006	Weiss	Water Quality Performance of Dry Detention Ponds with Under-Drains. St. Paul, MN 55155: Minnesota Department of Transportation Research Services Section.
2009	Scholz and Kazemi Yazdi	Treatment of Road Runoff by a Combined Storm Water Treatment, Detention and Infiltration System
2015	Mba	Efficiency of Combined Dry Detention with a Biofilter as an Outlet (DDBBO) in Treating Stormwater Pollutants in Toowoomba, Queensland

1.5 Project scope

This study primarily objective is:

- Assessing the effectiveness of a DDBBO system for the removal of pollutants such as TN, TP and TSS under real storm events and comparing the results with objectives set by the Australian legislation and findings in the literature, and

- Assessing the performance of the DDBBO based on the fieldwork data and specific site conditions by using the MUSIC model.

The scope of the research project was as follows:

- The project research is limited to the Toowoomba region, which restricts the project outcome in term of regional and climatic parameters. However, the knowledge developed in relation to the performance of the DDBBO system and the MUSIC simulation process can be applicable in other regions around Queensland or other states and territories in Australia.

- The project research focused on chemical water quality parameters such as TN, TP and TSS. Other stormwater quality parameters such as microbiological process, hydrocarbon, heavy metals, and other environmental factors (seasonal and meteorological variations) were not considered in this study.

- A commercially available model known as MUSIC was used to predict stormwater quality removal targets of the DDBBO system based on the fieldwork data and the specific site conditions. MUSIC model does not currently have any specific node for DDBBO system. However, this study suggested the utilisation of the biofilter node as an alternative to facilitate the simulation of this combined system.

- The influence of land use was investigated only in relation to the MUSIC simulation process based on the current guidelines and recent research findings. No fieldwork was undertaken to validate the assumptions made in the MUSIC model. Further research will require to validate whether the used parameters are appropriate for the specific conditions presented in Toowoomba and provide advice on the most suitable figures to better predict the DDBBO performance.

- The parameters that were used for the MUSIC model were obtained from the default figures provided by MUSIC guidelines (eWater, 2017). The accuracy of these parameters will not be tested in this study as it is beyond the scope of this study research.

- The number of monitored storm events analysed in this study were below the current minimum protocol requirements (15 qualifying events) for assessing the removal efficiency of WSUD measures (Stormwater Australia, 2014). Therefore, the results shown in this study needs to be considered as preliminary only, and cautions need to be taken to no draw definitive conclusions about the performance of the DDBBO system.

- The biofilter area was identified to be undersized (0.12% of the total catchment) as described in the *Stormwater Management Plan Report* prepared by RMA (2010). For larger catchments (>10 Ha), the literature recommends that the filter area should be between 1.5% to 2% of the contributing catchment. WSUD guidelines also specify that a runoff routing model should be used to validate water quality targets set by the local authority, principally when the biofilters form part of a flood detention basin (Water by Design, 2014, Water by Design, 2010a, Water by Design, 2015b, eWater, 2017).

1.6 Thesis outline

The primary objectives of this study were:

- To assess the effectiveness of a DDBBO system located in the suburb of Glenvale in Toowoomba for the removal of pollutants such as TN, TP and TSS under real storm events and comparing the results with objectives set by the Australian legislation and findings in the literature; and

- To assess the performance removal efficiency of the DDBBO system and pollutant concentration predictions based on specific site conditions by using the MUSIC model.

The proposed framework of this dissertation is as follows:

Chapter 2 describes in details the relevant literature review regarding stormwater quality and hydrology of DDBBO systems or similar WSUD technologies and includes a review of the findings into the accuracy of the MUSIC model to predict pollutant concentrations and removal efficiency of WSUD technologies. This chapter provides in-depth knowledge of the reported efficiency of DDBBO systems for the removal of critical pollutants from stormwater runoff.

Chapter 3 provides a detail description of the study catchment, collection procedures, water testing methods and methodology adopted to assess the primary objectives set for this study.

Chapter 4 outlines the approach used to validate the water discharge relationship, the statistical analysis of the results and the different load estimation techniques and removal efficiency methods adopted to determine the effectiveness of the DDBBO system to remove stormwater pollutants. It also describes in detail the MUSIC modelling simulation process to assess the accuracy of this computer software to predict pollutant concentrations and removal performance of the DDBBO system under specific site conditions.

Chapter 5 summarises the conclusions and limitations drawn from the study and **Chapter 6** discusses recommendations for future research arising from this investigation.

2 Literature review

2.1 Introduction

WSUD is an approach to design and planning of the urban environment orientated to mitigate, reduce or minimise the harm and impacts caused by the urban stormwater runoff to rivers, creeks and waterways and its living ecosystem in term of water quality and hydrological impact (Zhang et al., 2015, Melbourne Water, 2005, Argue et al., 2005, Mouritz et al., 1994) . DDBBO system is currently playing an essential role as WSUD measure due to its pleasing appearance and benefits in the management of peak flows, runoff volume, pollutant removal and groundwater recharge (Hurley and Forman, 2011b).

In the following sections, it is provided with an overview of the existing planning, and design instruments in Queensland orientated to manage the urban water catchment, especially with regard to controlling the quality and quantity of the stormwater runoff discharging into our natural environments. In addition, an overview in relation to urbanisation impacts, pollutant sources and main pollutants of concerns in the urban catchment is presented to set the scenery for a more detailed review about biofilters and dry detention systems as separate treatment technologies to determine their progression in recent years as WSUD measures. This is followed by a review of the laboratory and field research findings of DDBBO systems or/and similar structures being implemented globally, which will help to identify the gap knowledge and to define whether the DDBBO system might bring any tangible benefits or improvement to our waterways.

Additionally, a research review of MUSIC modelling accuracy was undertaken as one of the primary goals of this study is to establish the level of accuracy of MUSIC to predict the removal efficiency of DDBBO systems. In the final section is discussed the conclusions and limitations to be drawn from this literature review.

2.2 Water Quality Objectives

In Australia, local and state governments have recognised the importance of incorporating the communities' water environmental values within the design and planning of the urban catchment. Thus, a series of guidelines, policies, assessment benchmark and measurement indicators have been set out to determine whether those environmental values are protected and whether new developments integrate and promote the relevant authorities interest and objectives in the delivering of a more sustainable built environment. This integrated water management approach set by the authorities incorporates sustainable strategies orientated to manage the urban water catchment by conserving and optimising the use potable water, providing opportunities for the reuse and recycling of different sources of water and controlling the water quality and quantity of the urban runoff discharging to the receiving environments (DILGP, 2017).

In Queensland, the State Planning Policy (SPP) 07/17 is the principal instrument used to ensure that planning of our urban environment is outcomes focused, efficient and accountable and expresses the state's interests in land use planning and development. The purpose of the SPP 07/17 and the state interest is mainly to ensure livable, sustainable and prosperous cities in Queensland by protecting their communities wellbeing and enhancing their natural resources, heritage and culture (DILGP, 2017). Queensland has a diverse range of waterways such as the Great Barrier Reef, Moreton Bay and the upland streams of the Great Diving range among others. Therefore, the DILGP (2017) is the mechanism implemented by local and state authorities to protect and enhance Queensland 's water quality and provide positive social and environmental outcomes in the planning of our cities. The stormwater design objectives set by SPP 07/17 are shown in

Figure 2.1. However, ANZECC (2000) guidelines provide additional concentrations triggers to those described in the DILGP (2017) such as heavy metals and

hydrocarbons to ensure that the protection of the environmental values can be achieved holistically.

Climatic region	Design objectives Reductions in mean annual load from unmitigated development (%)				
	Total suspended solids (TSS)	Total phosphorus (TP)	Total nitrogen (TN)	Gross pollutants >5mm	Waterway stability management
South East Queensland	80	60	45	90	Limit the peak 1-year ARI event discharge within the receiving waterway to the pre-development peak 1-year ARI discharge
Central Queensland (south)	85	60	45	90	
Central Queensland (north)	75	60	40[15]	90	
Cape York[14], wet tropics and dry tropics	80	60[16]	40	90	
Western Queensland[14]	85	60	45	90	

Figure 2.1 - Water quality design objectives for Queensland extracted from (DILGP, 2017)

2.3 Urban Stormwater Management & Behaviour

Due to urbanisation, the natural characteristics of the land changes introducing with it a variety of contaminants into the environment, which are mainly generated from the different industrial, agricultural, residential and commercial activities generated within the urban catchments. These contaminants accumulated on the surfaces in the form of litters, dust and soils, fertilisers, chemicals and pesticides, metals, oils and grease and lawn clipping, which subsequently are conveyed by the urban runoff to the natural receiving environment impacting the quality of the water bodies and its living ecosystems (McGrane, 2016, Valtanen et al., 2014).

In the past, the primary goal of urban stormwater management was orientated to flood mitigation as local authorities have been held liable and responsible for any flood damage caused by stormwater runoff. Traditionally, stormwater was transported as rapidly and invisibly as possible from the urban areas to the nearest waterways without the need of any treatment. However, the increasing pressure on the health of the waterways and its ecosystems raised the need to deal with both the quality and quantity of the stormwater runoff. Therefore, a water management approach known as WSUD that focuses on the sources of stormwater runoff and its contaminants was introduced, and its application has been increasing in recent year in the national and international contexts. The focus has been orientated on achieving sustainable ecological outcomes that provide social, economic and environmental benefits to the communities as demonstrated through the incorporation of water reuse, water recycles and stormwater harvesting schemes as part of the planning and design of urban development (Zhang et al., 2015, Parker, 2010, Argue et al., 2005).

2.4 Hydrologic and Water Quality Impacts

In general terms, the changes in land use due to urbanisation means that trees and vegetation are removed, and impervious surfaces are increased, which reduces the amount of stormwater runoff infiltrating into the ground and introduces dramatic changes to the runoff in relation to the magnitude, pathways and timing to discharge into the receiving water bodies. The changes in the water-drainage patterns mainly influence the magnitude and extent of the flood risk and the depletion of aquifers as less water is available to replenish them (Liu, 2011, McGrane, 2016).

In a more technical view, urbanisation reduces the roughness coefficient and infiltration rate presented within the catchment, which subsequently reduces the time of concentration required for the runoff to travel from the hydraulically most distant point in the catchment to the outlet. This translates into changes in the peak runoff that in conjunction with climate change might intensify the risk of flooding, which leads to land degradation. For instance, Franczyk and Chang (2009) modelled a combination of climate and land cover changes for an urban catchment in Portland in the USA with the objective of determining which of those changes influence the mean runoff depths at the monthly, seasonal and annual scales. The results showed that the region would experience an increase of 1.2 C, 2% increase in the average annual precipitation and a 2.7 increase in mean annual runoff. They also found that projected climate change by 2040 and low-density urban area scenario represent the most significant change to mean annual runoff when compared with the other modelled scenarios suggested in the investigation.

Urbanisation does not only impact the quantity of the water, but also quality as the accumulated pollutants in the catchment surfaces are transported to the receiving environment by the runoff during rainfall (Aryal et al., 2016, Locatelli et al., 2017). The runoff can carry a mixture of contaminants including heavy metals, nutrients (i.e. nitrogen, phosphorous, sodium, among others), litter and other residues from roads. Liu et al. (2013) indicated that in addition to typical catchment characteristics such as land use and a fraction of impervious surfaces, other catchment characteristics such as impervious areas layout, urban form and site specifics have a significant influence on both, pollutant build-up and wash-off processes. In recent years, there has been an increasing focus on the sources, fluxes and fate of emerging priority pollutants such as herbicides, microbial contaminants, pharmaceutical and polycyclic aromatic hydrocarbons. Despite all of this, the impact of urbanisation on the natural hydrology is complex, and our collective understanding is still limited as shown by McGrane (2016) in a study investigation about the contribution of urbanisation to thermal insulation, for which it was found to have profound effects in precipitation dynamics in term of its intensity and variability. This precipitation changes affect the peak and volume of the runoff altering the catchments dynamics. McGrane (2016) undertook a review of the advancement and remaining challenges concerning urban hydrology, and they found that a 27% increase in warm season represents a 5.6% increase in rainfall precipitation, which highlights the influence of urbanisation not just in a local precipitation dynamics, but also a more regional scale.

Despite the advance and efforts to predict hydrologic dynamics and pollutant concentrations surrounding the urban water cycle and urban development, there is still existing some degree of limitations in our understanding and knowledge of the overall hydrological process. This has significantly increased our reliance on more sophisticated techniques, software and model structure that make the research process expensive, more difficult and arduous to pursuit (Van Niekerk et al., 2019, Murphy and Sprague, 2019, Luo et al., 2010, Prada et al., 2017).

2.5 Pollutant Sources

Stormwater runoff from urban areas is generated from a number of sources including roads, landscape surfaces, residential, commercial and industrial land uses. The accumulated pollutants are transported by stormwater runoff, which subsequently affects the water quality, drainage patterns, existing ecosystem, public health and the aesthetic appearance of our receiving waterbodies. The level of pollution and environmental degradation depend on the location and intensity of human activities within the catchment. In the past recent years, the adverse impacts originated by stormwater runoff on the waterways and its ecosystem have widely been studied and discussed by researchers (Liu et al., 2017, McGrane, 2016, Valtanen et al., 2014, Liping et al., 2013, Liu, 2011, Khan, 2009).

The primary pollutant sources encountered in the urban catchments are described in the subsequent sections.

2.5.1 Vehicular Traffic

It has widely been accepted that one of the most important causes of stormwater pollution in the urban environment is due to vehicular traffic. The pollutants generated by vehicles are primarily presented in the form of solids, liquids and gases, and its loads are directly related to traffic volume, pavement surfaces, driver habits and road characteristics such as the location of traffic lights, road layout and even road geometry (A. Liu et al, 2018, Liu et al., 2013).

Vehicle emissions comprise different pollutants including heavy metals, oil and grease, particulates from sources such as fuels, exhaust emission, brake pad and tire wears, and litters. Spillage of fuel, oil and lubricants have been discovered everywhere within the urban catchment, but they are more visible near to parking lots and traffic lights. Vehicle emissions contribute to the atmosphere in the form of gases and particulate matter. Even though larger solid particulates are directly deposited on the ground, the lighter fraction and gases accumulated in the atmosphere are also deposited on the ground by the rainfall and winds during the wet and dry periods to subsequently being conveyed into the waterbodies (Gunawardena, 2012, Hwang et al., 2018).

Liu (2011) indicated that even though vehicular traffic is one of the most critical pollutant contributors within the urban catchment, other factors such as land use can also be attributed to that. For instance, they found that industrial and commercial land uses can generate relatively more and various pollutant loads than residential land use mainly explained by the characteristic of the traffic volume. Gunawardena et al. (2013) studied ranking factors in term of their influence in heavy build-up metals, and he found that traffic volume was also the highest ranked factor for heavy metals build-up loads increase while the variability of the contaminant decrease.

2.5.2 Industrial and Commercial Processes

Contamination in industrial and commercial sites mainly arises if stored liquids or materials are spilled out or wash-off from the controlled sites or flushed into the ground following a storm event. The pollutant species and their concentration depend on the specific industrial process. However, the contaminants widely accepted as the primary concerns in industrial and commercial processes are total suspended solids, heavy metals, hydrocarbons, nutrients and organic substances. A small or repeated discharge of one of those contaminants over an extended period leads to contaminant accumulation in an aquifer or waterways causing sedimentation, algal blooms, lost of aquatic fauna and aesthetic damage (Liu, 2011).

2.5.3 **Lawns, plants and trees**

The urban landscape is another source of contaminants, and these are mainly introduced by lawn fertiliser, lawn clipping, leaf litter, recycled water used for irrigation and pet waste. Hobbie et al. (2014) suggested that leaf litters from plants and trees are one of the primary cause of deterioration and eutrophication process in waterbodies. They indicated that leaf litter decomposed more rapidly in the gutter than in nearby natural areas and litters have the potential to lose a high fraction of its initial P (from 27% to 80%) and a small fraction of its initial N (<10%) via leaching. They recommended that a careful selection of street tree species and timely removal of litterfall can significantly reduce nutrient fluxes into waterbodies.

Toor et al. (2017) suggested that anthropogenic activities and recycled water use mostly generate nutrients and sediment loading in residential catchments. They indicated that dry weather flows make significant contributions to TN and TP loads in highly irrigated catchments. Therefore, they questioned the classification of the land as urban as this does not accurately predict the potential underlying water problem in the urban catchments.

In a pollutant export study from six different land uses undertook by Line et al. (2002) in the upper Neuse River Basin catchment in North Caroline in the USA, they found that the higher N and P exports were due to high standards of lawn and turf maintenance undertaken for the landowners in those catchments. The study highlighted the critical role played by the urban landscape as a part of the overall urban water management.

2.5.4 **Erosion**

Nutrients deposited in pervious and impervious surfaces are subject to erosion and solid remobilisation due to the stormwater runoff, which is then transported to different levels of waterbodies. The most widely studied nutrients related to atmospheric deposition are those derivated from N and P due to their significant impacts inflict on the environment and its living ecosystem. Researchers have demonstrated that nutrients deposition due water erosion is highly correlated with land use characteristics, potential emission sources (i.e. anthropogenic activities, animal waste, ect.), stream banks, climatic conditions, vegetation, elevation and geographic locations. An elevated and unmanaged nutrient deposition source in an urban catchment can increase the risk of nutrient leaching and subsequent deterioration of the surrounding natural environment, and significant loss of aquatic life mainly due to eutrophication and sedimentation process in rivers and reservoirs (Liu, 2011, Lü et al., 2007).

Researchers have also found that changes in catchment hydrology due to urbanisation can result in an increase of peak flows and volume, which are translated in an increase in stream bank erosion (McGrane, 2016, Aryal et al., 2016, Valtanen et al., 2014). For instance, Nelson and Booth (2002) concluded that for a watershed in the USA the anthropogenic activities in the urban catchments are the cause of 50% increase in annual sediment yield, in which channel bank erosion accounts for 20%.

2.5.5 **Corrosion**

The leading cause of corrosion is due to acid rain and aggressive gases, which generated a significant amount of corrosion on fence, paints and gutters that will subsequently be washed off by the stormwater runoff causing severe problems to the receiving waterbodies. The corrosion rate is dependent on the material structure, available corrodible materials, the frequency and intensity of the exposure, the dry and wet frequency of the exposed surfaces, the character and structure of the materials and the maintenance practice (Petrucci et al., 2014, Sánchez et al., 2015). Researchers found that heavy metal concentrations in runoff from galvanised roofs are higher when compared to those generated from street surfaces (Wicke et al., 2014, Horváth and Buzás, 2013, Yu et al., 2014). For example, Charters et al. (2016) studied four different urban surfaces within a residential/institutional catchment in Christchurch in New Zeland. They found that roof catchment had the highest copper and zinc concentrations when compared with road surfaces and suggested that quantification and prediction of pollutant contributions from urban surfaces should take into account surface materials instead of being aggregated into more generalised categories such as land use.

2.6 Primary Pollutants in Urban Stormwater

With the current rate of human population growth, it is estimated that 83% of the population in the developed world and 53% of the developing world will live in urban areas by 2030. This will lead to more urbanisation processes that will continue inflicting significant alterations and changes to the catchment hydrologic and water quality in the waterways and aquifers impacting not just its living ecosystem, but also generating significant repercussions to the weather and climate conditions in the local and regional scales (McGrane, 2016).

Researchers around the world have suggested that the stormwater runoff and its point and non-point pollutant sources are the major contributors to aquifer depletion and water deterioration in the urban environment. Point pollutant sources can be easily identified and measured, and there is currently legislation in place to control and regulate its discharge. However, non-point pollutant sources continue to represent problems as they come from many diffuse sources, which are difficult to categorise, characterise and quantify due to its high variability from the different land use and atmospheric deposition and hydromodification processes. The impact of stormwater pollutants on receiving waterbodies depend on a number of factors such as the nature of the pollutants, their concentrations, a mixture of pollutants and their total loads. The primary pollutants of concerns that are analysed in this study are TSS, TN and TP. Arguably, These pollutants have widely been accepted as the primary pollutant to be removed and controlled in our receiving environment locally and internationally (Khan, 2009, Aryal et al., 2010, Parker, 2010, Fondriest Environmental, 2014).

2.6.1 Total Suspended Solids (TSS)

TSS is commonly used to measure the total mass of suspended sediments particle in the water, and it is reported in milligrams of solids per litre of water (mg/L). Researchers have found that TSS is the most significant non-point pollutant source present in urban waterbodies (Liu, 2011). The suspended particles are usually deposited on impervious and pervious surfaces through remobilisation process and/or originated by erosion of stream banks. These particles have adverse effects on aquatic life, as can be demonstrated by the presence of the following processes or indicators:

- *Algal Bloom:* This process blocks sunlight from reaching submerged vegetation, killing the plants and decreasing the amount of dissolved oxygen produced as the microbes require more oxygen to consume the bloom that dies off which creates hypoxic or even anoxic conditions. This bloom also releases harmful toxins that not only destroy aquatic life but also can affect human life (Khan, 2009, CSIRO, 1999).
- *Settleable solids:* High sedimentation rates can destroy fish habitat and spawning beds as they become buried the egg and embryo survival rate is reduced due to crusting over the egg and the oxygen supply reduction. This sediment deposition process also has effects in increasing the flood risk in some areas by pushing a volume of water due to sediment build-up (Khan, 2009, Zarezadeh et al., 2018).
- *Turbidity:* High turbidity rates can affect visibility and change feeding behaviours disrupting natural movement and migrations from aquatic life. Researchers have found that fine sediments can clog fish gill and lower

resistance to disease and parasites. Some fish can consume sediments that can alter the blood chemistry, which subsequently can threaten human life. Turbidity can also affect submerged plant growth as turbidity increase, the amount of light required by the vegetation decreases stopping the photosynthesis process depleting dissolved oxygen killing not just the vegetation, but either the organism that feeds on it and those that do not depend on it (Memon et al., 2014, Khan, 2009, CSIRO, 1999).

In addition, TSS plays a vital role in the stormwater quality as other pollutants such as heavy metals, nutrients, pathogens and hydrocarbons can be absorbed or attached to the solids particles that can harm and threaten aquatic life and even human health (Khan, 2009, Aryal et al., 2010, Parker, 2010, Fondriest Environmental, 2014, Liu, 2011, CSIRO, 1999).

2.6.2 **Nutrients**

Nutrients are needed to sustain living tissues, and this includes compounds such as N, P, Ca, K, Fe, Mn and carbon. N and P are the most important and abundant in the urban stormwater runoff. These come from both natural process and anthropogenic activities. Natural sources include weathering processes of rock, fixation of atmospheric N by leguminous plants, decomposition of organic material, and soil leaching. Anthropogenic sources come from washing cars, pet waste, vehicle emission, industrial processes, overflowing of sewer structures, fertiliser from lawn and agricultural activities (Khan, 2009, Parker, 2010, Liu et al., 2017).

Stormwater runoff transports nutrients in both particulate and dissolved forms. The excess of nutrients in water bodies can lead to an algal bloom, which decreases the content of dissolved oxygen due to the microbiological degradation of the dead vegetation. This process is referred to eutrophication, and it is considered a severe environmental problem which not just affect the living ecosystem causing harm to aquatic life and depleting waterbodies, but also can affect human health. Researchers found that a high presence of nitrate in the drinking water sources can cause severe diseases such as stomach cancer (Sandor et al., 2001, Keszei et al., 2013, Taneja et al., 2017).

A study undertaken by Huang et al. (2007) showed higher nutrients concentrations in the runoff generated from residential and parks land uses than those obtained from other land uses, and they suggested that this might be explained due to the high fertiliser application used by landowners in these type of land use.

2.6.3 Heavy Metals

Heavy metals present in the stormwater runoff have been given much attention due to their potential toxicity. The most common heavy metals reported by researchers in stormwater runoff are Pb, Cu, Zn, Ni, Cr, Al and Mn. All these pollutants can inflict a significant risk to human health, which limited the reuse of the stormwater as an alternative and reliable water source. These pollutants like nutrients are presented in the stormwater in both dissolved and particulate forms. Researchers have found that heavy metal concentrations are generally high in industrial and commercial land uses. In addition, to those, other anthropogenic and natural processes such as vehicle wear and emissions, fuel leakage, corrosion of metal surfaces and building siding and weathering are the primary source of heavy metals in stormwater (Ma et al., 2016, A. Liu et al, 2018, Valtanen et al., 2014, Gunawardena et al., 2013, Hares and Ward, 1999).

Sounthararajah et al. (2016) revealed in a batch and fixed bed column experiments that granular activated carbon filters are very effective for the removal of heavy metals such as Pb, Cu, Zn, Ni and Cd. Ma et al. (2016) investigated the removal efficiency of ponds for heavy metals such as Cu, Cr, Cd, Pb, Ni and Zn. They found that the concentrations varied considerably depending on the catchment type, with the highest concentration coming from industrial areas and the lowest from uncultivated and rural areas. They concluded that ponds could effectively remove heavy metals in particulate forms through sedimentation processes. However, they found that this efficiency steeply reduces with age.

It has widely been accepted that the major contributors to heavy metals are traffic vehicle. Gunawardena et al. (2013) undertook a comprehensive research study to identify traffic characteristics and climate factors in the production of heavy metals in the urban environment. They found that Zn is correlated with traffic volume and Pb, Cd and Ni and Cu are correlated with traffic congestion. They also found that Zn has the highest atmospheric deposition rate compared to other heavy metals. Huber et al. (2016) compiled and evaluated a database from six continents with the objective of characterising the occurrence and fate of heavy metal in eight traffic categories. The results showed that Zn concentrations are very variable for the different studied traffic areas compared with other heavy metals because of its presence in galvanised structures and car tyres. They also found that heavy metals concentrations in parking lots widely depend on their use and for roads with vehicles volume greater than 5,000 per day where found to be more polluted than highways due to the site-specific factors such as traffic signal.

2.7 Bioretention /Biofilters

Since its development and application two decades ago, the bioretention system has rapidly become most of the widely WSUD and best practice engineering measure used throughout Australia and many other parts of the world. Bioretention systems are defined as the process of improving stormwater runoff quality by filtering the water through biologically influenced media. Typical biofiltration consists of a vegetated swale or basin overlaying a sand based filter medium with a drainage pipe at the bottom. Stormwater runoff is generally diverted from a kerb or pipe into the biofiltration system, where it flows through dense vegetation to temporarily ponds on the surface before slowly filtering down through the filter media (de Macedo et al., 2019, Jiang et al., 2017, Winston et al., 2016, Shafique, 2016, Water by Design, 2014, Brown and Hunt, 2012, DeBusk et al., 2011, Roy-Poirier et al., 2010, Davis et al., 2009, BCC, 2003).

Depending on the design principles the treated flows are either infiltrated in underlying soils or collected in the underdrain system for conveyance to downstream waterways or storages for subsequent reuse. (Payne et al., 2015, BCC, 2003, GCCC, 2007).

The primary pollutants of concern in urban stormwater runoff are solids, heavy metals, biodegradable organics, nutrients (nitrogen and phosphorus), pathogenic micro-organisms, and organic micro-pollutants (Barbosa et al., 2012, Jiang et al., 2017, Liu et al., 2017, Liping et al., 2013). Suspended solids and heavy metals are found to be efficiently removed by this system as described in the research undertaken by Davis et al. (2009) and Blecken et al. (2009). However, research undertook by Brown et al. (2013) showed that the bioretention basins could efficiently remove particulate nitrogen, ammonium and nitrite. However, it was not very efficient for the removal of dissolved organic nitrogen and nitrate nitrogen due to leaching process, high N solubility in the runoff and strong dependence in the wetting and drying regime accounting only 9% of the net TN removal. Therefore, Hatt et al. (2009) recommended that the design of the bioretention basin should include mitigation to account for the harmful effect of drying on the biological activity which subsequently influences the long-term N removal capacity of the system. Brown et al. (2013) suggested that creating a denitrification condition for nitrate and preventing dissolved organic nitrogen leaching is critical for efficient N removal through the bioretention system. Zinger et al. (2013) suggested that the inclusion of a saturated zone within the filter media as well as the optimisation of the plant species selection can significantly increase and improve N removal efficiency in biofilters.

The findings from Davis et al. (2009) study showed that P removal from biofilters ranged from 70-85% and concluded that the P content of the filter media is critical to P removal performance. Dietz and Clausen (2005) also suggested that P leaching can be attributed to a disturbance of the filter media during the storm events. Study research undertook by Chahal et al. (2016) showed that compost-amended biofilters leach P, N and Cu and the increase in these concentrations occur at the beginning of the storm and the onset of a new storm.

2.7.1 **Filter Media**

The bioretention filter media consists of three free draining layers including mixes of gravel, sand, silt and organic matter, which are the filter media itself (400-600 mm deep), a transition layer (100 mm deep) and drainage layer (50 mm minimum under-drainage cover). The filter media is crucial for the support of the vegetation, and it is the mechanism by which the stormwater volume and discharge rate are controlled, and the runoff is infiltrated to be treated subsequently. In general, the filter media is recommended to be loamy sand with a low percentage of organic matter with low nutrient content and high permeability rate to ensure an increased water holding capacity (FAWB, 2009).

Bratieres et al. (2008) conducted a large-scale study to test the performance of biofilters, and they found that filter media with added organic matter reduced P treatment effectiveness. Bioretention basin operates by filtering runoff through planted filtration media and provides treatment through the biological uptake process, extended detention depth and the hydraulic conductivity of the filter media (Melbourne Water, 2005, FAWB, 2009, GCCC, 2007, BCC, 2005, Environment Australia, 2000). For a bioretention basin in a temperate climate with an extended detention depth of 100-300mm and surface area of approximately 2% of the impervious area of the contributing catchment will require a hydraulic conductivity between 100-300 mm/hr in order to meet best engineering practice targets. This configuration support plant growth without requiring too high land space. In warm and humid regions, the hydraulic conductivity of the filter media may need to be higher to achieve the required removal targets when using the same land space. A hydraulic conductivity higher than 300 mm/hr can create potential issues with watering requirements during the establishment of the vegetation, and a hydraulic conductivity higher than 600 mm/hr cannot support plant growth due to poor water retention and can also create potential issues with leaching of pollutants from the system. However, the guidelines suggest that by creating a submerged zone, the filter media can help to support plant survival. The guidelines also advise that the infiltration capacity of the bioretention basin will initially decline during the establishment phase of the vegetation as the filter media settle and compact, but as the plants grow and roots deepen the infiltration capacity of the filter starts to increase(FAWB, 2009).

Palmer et al. (2013) conducted a study to examine the capabilities of a filter media mixture of sand and compost enhanced with aluminium based drinking water treatment residuals to reduce nutrients. They found that the inclusion of the saturated zone in the filter media significantly reduced the nitrate concentration in the effluent from 33% to 71%. Therefore, they recommended that a saturated zone should be incorporated during the initial establishment phase to increase the efficiency of the system for the removal of TN.

Particle size distribution (PSD) is considered to be the second most crucial factor for the filter media after the hydraulic conductivity. PSD ensures that the filter media can provide the hydraulic conductivity required for the system to meet the removal targets. However, the recommended PSD ranges do not exclude the need for undertaking hydraulic testing to the media (FAWB, 2009).

Table 2.1 shows the optimal composition range (percentage w/w) recommended by (FAWB, 2009).

Soil Type	Percentage of Filter	Particle Size
Clay & Silt	< 3%	<0.05 mm
Very Fine Sand	5 - 30%	0.05 – 0.15 mm
Fine Sand	10 - 30%	0.15 – 0.25 mm
Medium to Coarse Sand	40 – 60 %	0.25 - 1.0 mm
Coarse Sand	7 – 10 %	1.0 – 2.0 mm
Fine Gravel	< 3 %	2.0 – 3.4 mm

Table 2.1 –Soil Type for Bioretention Basin Recommended by FAWB

Soil Type	Percentage of Filter	Particle Size
Clay & Silt	< 3%	<0.05 mm
Very Fine Sand	5 - 30%	0.05 – 0.15 mm
Fine Sand	10 - 30%	0.15 – 0.25 mm
Medium to Coarse Sand	40 – 60 %	0.25 - 1.0 mm
Coarse Sand	7 – 10 %	1.0 – 2.0 mm
Fine Gravel	< 3 %	2.0 – 3.4 mm

Clay and silt are essential for water retention and sorption of dissolved pollutant. However, they can substantially reduce the hydraulic conductivity of the filter media. The size fraction also influences the structural stability of the material. Therefore, FAWB recommends that clay and silt mix should not be less than 3% to minimise the risk of soil structural collapse(FAWB, 2009). For the organic matter and P contents, (FAWB) recommends values not higher than 5% (w/w) and 100mg/kg, respectively, as higher values can result in leaching problem (FAWB, 2009). Henderson et al. (2007) conducted a field study research of a bioretention basin to assess nutrients removal. They found that filter media without plants, can act as a source of pollutants, particularly for N. Therefore, they suggested that vegetated sand or/and vegetated sandy-loam provided the best overall treatment for the removal of P, N and carbon and displayed the minimal leaching process with the system.

The transition layer is another critical component of the filter media as this reduces the migration of smaller particles into receiv5ng waters bodies with can generate issues such as sediment deposition and eutrophication as previously discussed in this section (FAWB, 2009).

2.7.2 **Vegetation**

The vegetation is also a critical aspect for the removal of nutrients and transformation processes within the bioretention system. Vegetation provides surfaces in the plant root on which biofilms can grow due to organic breakdown process and also enhances the filter media functions by preventing erosion and continuously breaking up the soil through plant growth to prevent clogging and maintaining or/and improving its hydraulic conductivity. Researchers have found that plants can contribute to the overall reduction of the outflow volume via evapotranspiration with can also benefit local microclimate (Hatt et al., 2009, Payne et al., 2015, FAWB, 2009).

Zhang et al. (2011) undertook a laboratory study and found that planted biofilters with submerged zone performed better for N removal when compared with those no planted with a submerged zone. They also found that P removal efficiency of the system with a submerged zone can significantly increase regardless of the presence and type of vegetation. They suggested that the increase in the system performance was due to the submerged zone as this increases the denitrification processes and enhances plant growth. Payne et al. (2015) recommended in their guidelines that raising the outlet to create a submerged zone can bring significant benefits to the biofilter as this provides moisture to plants, prolonged retention and enhance the pollutant performance of the system.

A large-scale study in Melbourne conducted by Bratieres et al. (2008), which consisted in testing the performance removal efficiency of bioretention basin for TP, TN and TSS demonstrated that vegetation selection is critical for the removal of N. They found that *Carex appressa* and Melal*euca ericifolia* were the best performer plant species in the study. They suggested that an optimal biofilters design should at least capture 2% of the catchment runoff and be planted with *C apressa* or *M. ericifolia*. Henderson et al. (2007) found that sandy loam media offers the best support for vigorous plant growth, even without the inclusion of organic matter to the filter media. They concluded that plant selection could significantly increase the overall performance of biofilters for the removal of those pollutants.

Chandrasena et al. (2014) investigated in a laboratory scale the E. Coli removal performance of biofilters. They found that the performance efficiency of this system is profoundly influenced by the plant presence and species type, the presence of a submerged zone and duration of dry periods. However, they concluded that the most critical factor for E. Coli removal in biofilters was due to vegetation selection for which the best performer plant species (Leptospermum, continentale, Melaleuca incana or Palmetto buffalo) were associated with lower infiltration rates. Payne et al. (2015) demonstrated that vegetation influences the effectiveness of biofilters and serve multiple roles in aspects such as water quality uptake, transformation to organic form, carbon provision to microbes, transpiration reducing stormwater volume, establishment of the filter media, preservation and enhancement of the infiltration rates, cooling to the surrounding environment, and amenity and aesthetics.

2.7.3 **Sizing**

Sizing is vital to determine the treatment capacity, the sediment rates, pollutants accumulation and the moisture regime to support not just plant grow, but also the biofilms communities. Sizing of a biofilter needs to take into consideration aspects such as biofilter area, extended detention depth and hydraulic conductivity of the filter media, which influences its infiltration capacity and its overall pollutant removal efficiency (FAWB, 2008, FAWB, 2009). WSUD guidelines in Australia recommend that as a starting point, a bioretention sizing should have at least a surfaces area equivalent to 2% (4% for Queensland) of the contributing impervious catchment, an extended detention depth between 100 – 300 mm and hydraulic conductivity of 100 – 300 mm/hr in order to meet regulatory load reductions targets. Guidelines also suggest that even though there is some flexibility to deviate and offset some of these design parameters, it is crucial no too deviate too far outside the recommended values as this can bring problems such as drought conditions, clogging and sediment accumulation, or even risk to public safety and aquatic life. (FAWB, 2008, Parker, 2010, Payne et al., 2015, BCC, 2003, BCC, 2005, GCCC, 2007).

Undersized bio-basin (<1% of the contributing impervious catchment) can increase the risk fo clogging and reduce the lifespan of the system. Therefore, to reduce these risks, it is recommended to install a pre-treatment system such as forebay and vegetated swale with the objective to capture sediments and protect the system against scour due to high flows. Oversized bio basin can increase the risk of the system to drying out and plant death due o insufficient flow and moisture (Deletic et al., 2015).

2.7.4 Maintenance and Operation

Bioretention basins are often preserved by regularly incorporating maintenance activities. These activities mainly consist of undertaking pruning, mulching, watering and liming. Vegetation is essential to the aesthetic appeal of bio-system and is crucial for the overall performance of the system. Therefore, a rapid plant establishment sometimes requires the basin to be limed. In other cases, due to the low presence of P, basins may also require the use of fertiliser to ensure plants growth and survival. Australian Guidelines currently recommend that watering must be undertaken every 2 or 3 days for a period of no less than a month or even more frequently in some locations to ensure plant survival. The frequency of these activities is seasonally influenced, with more frequent maintenance activities undertaken during the summer than in winter. The removal of mulch and the top layer of the filter soil is critical to reducing of the risk of clogging (Melbourne Water, 2013, Payne et al., 2015, Water by Design, 2015a). Hunt and Lord (2006) investigated two set of bioretention cells for 12 months, and they found that improperly constructed and maintained bioretention basins can have negative impacts in the overall removal pollutant effectiveness of this system.

Water by Design (2015a) defined in their guidelines the cost and activities required for maintaining a variety of bioretention basin types. They also defined four types of bioretention basins as shown in Figure 2.2 to Figure 2.5.

Figure 2.2 - Bioretention street trees (obtained from guide to the cost of maintaining bioretention basin prepared by Water by Design)

Figure 2.3 – A streetscape biorientation system (obtained from guide to the cost of maintaining bioretention basin prepared by Water by Design)

Figure 2.4 - Precinct scale bioretention basins (obtained from guide to the cost of maintaining bioretention basin prepared by Water by Design)

Figure 2.5 - Large biorientation basin (obtained from guide to the cost of maintaining bioretention basin prepared by Water by Design)

2.8 Dry Detention Basin

In Australia, many urban centres are equipped with detention and retention ponds for flood attenuation and water quality improvement. Detention ponds are surface storage basins whose outlets are restricted by some means such as an orifice, plate or outlet pipe to detain the stormwater runoff for an adequated period to allow particles and associated pollutant to settle. These are referred to as "dry system" when the pond dries out after a storm event and as "wet system" when a permanent pool of water is left to treat, detain and release stormwater runoff at a set rate. Dry detention ponds are traditionally the most suitable stormwater best management practice used to provide flow control and as a pre-treatment device of other WSUD measures such as wetland system and/or bioretention basin. They generally require large areas and are placed at the end of the WSUD treatment trains. They can also provide a dual-use such as parking lot, sporting field playground and any other multi-use area suitable within the urban environment due to its nature of retaining water for a relatively short period (Sharkey, 2007, Argue et al., 2005, Mouritz et al., 1994, GCCC, 2007, BCC, 2005, Environment Australia, 2000).

Research has found dry detention as a very effective mechanism to reduce nutrients and metals from urban catchment by up to 80% ((Keßler et al., 2017). However, other research studies have found a little benefit for the improvements of water quality, mainly due to scoring issues presented at the bottom of the basin and sediment resuspension by the next rain event if inadequate maintenance is provided to the system (Caroline Fortunato, 2005, Weiss et al., 2006, Sébastian et al., 2015). On the other hand, wet systems have been extensively monitored under a wide range of conditions. Researchers have found that wet systems can remove between 60% to 70% TSS, 60% to 70% nutrients and 60% to 95% heavy metals. There are a variety of processes responsible for the pollutant removal effectiveness of these systems, but physical sedimentation is considered to be the most significant removal mechanism used by this system. Recent research results have also shown that further enhancement can be achieved for this system by incorporating chemical, biological and advanced physical processes. Dry and wet detention ponds are currently considered to be the most suitable solution in areas where groundwater is vulnerable or when dual-use benefits can be provided such as flood attenuation/control and human recreation (Caroline Fortunato, 2005, Shammaa et al., 2002, Weiss et al., 2006).

In summary, dry detention ponds are an effective measure for reducing and controlling the energy associated with the stormwater discharge by helping to stabilise degraded receiving water habitat, peak flow control and replenishment of groundwater. However, they are not an effective measure for the treatment of stormwater runoff. On the other hand, wet ponds are very effective not just as a flow control measure but also for the removal of the nutrients, which translate in further improvement and enhancement of the receiving environment (Pitt, 2003, Pezzaniti et al., 2012).

2.8.1 **Sizing**

As discussed in the previous section, detention basin and /or ponds are an important WSUD feature. Therefore, sizing them correctly is crucial for achieving the purpose and intent of its design. In Australia today, there exist many computer-based mathematical modelling packages to study catchment runoff and help engineers and designer to better estimate the sizing requirements of these units within the urban environment (Van der Sterren et al., 2008). The sizing mainly depends on the inflow and outflow hydrographs which are a function of the upstream runoff and the attenuation obtained by the hydraulic and hydrologic routing. DRAINS is the most common software package used in Australia to determine the size of a detention pond (O'Loughlin and Stack, 2017). The hydrologic method used in DRAINS involves the principles of conservation of mass and storage-discharge relationship, while the hydraulic method consists of the analysis of hydraulic grade line and flows. Correct sizing is an essential process because if the basin is too small, this can overtop frequently damaging the structure or even causing flooding downstream. If the basin is too large, this can create unnecessary construction over cost and can alter natural environmental drainage system (Sharkey, 2007, QUDM, 2017, O'Loughlin and Stack, 2017).

Abrishamchi et al. (2010) simulated a conventional detention basin against a two compartment basin to predict the discharge of heavy metal, and the found that the use of two compartments basin could reduce the volume requirements by half when compared with a conventional design.

Park et al. (2014) investigated the detention volume and area demand for a district located in Ulsan in South Korea to attenuate the development outflow peaks for Q2, Q10 and Q100 years design storms. They studied three multi-staged detention basins by using the US Environmental Protection Agency's Storm Water Management Model (EPA-SWMM5) and compared them based on the construction and land costs requirements. They also analysed the benefits associated with using the basin as recreational and parking facilities. They validated their design by applying historical data, and they found that the basin sizes were slightly higher than the actual size needed. They found that multi-use detention basin for Q2 yields 37.4% benefits, while for Q10 was 22.8%. The results also showed that the multi-staged detention basin design for Q2 is the most cost-effective design in the study.

2.8.2 Treatment effectiveness

Dry detention ponds are the most common stormwater treatment practices used for flow control and water treatment in urban environments internationally and nationally. Research studies have found variable pollutant removal efficiencies for dry and wet detention systems. For instance, Birch et al. (2006) examined a detention basin adjacent to a significant motorway in Sydney, and they found that the basin was moderately efficient for the removal of TSS, trace metals, (Cu, Mn, Pb & Zn), nutrients (TKN & TN) and faecal coliform from stormwater runoff. They also noticed that the basin was a source of Fe, Ni and Cr during some periods of high flows, which was considered to be as a result of leaching process due to the material settled at the base of the system. Weiss et al. (2006) investigated three detention basins equipped with underdrains and single inlet and outlet structures in Minnesota, USA. The results showed that dry detention basins with underdrains are an effective alternative for water quality control reporting removal efficiencies of 88% for TSS, 58% for TP, 52% dissolved P and 81% for volatile suspended solids. Abrishamchi et al. (2010) simulated a single compartment detention basin against two compartment basins to predict the discharge of toxic metals, Cu and Zn and the results showed that the use of two compartment treatment could significantly reduce the discharge frequency of these metals into the receiving environment. Pezzaniti et al. (2012) studied a detention basin located on the expressway in Adelaide, Australia. They concluded that the average load reductions varied for as little as 18% for TDS up to 77% for TP and Pb.

Cu concentration was also detected at the inflow. However, no concentrations were detected at the outflow. The average reductions for Zn and Pb were more than 50% on more than 80% occasions. Belizario et al. (2016) investigated a detention basin for an agriculture catchment located next to a motorway in Portugal. They determined that the basin have a functional capacity for retention of Cr, Cu and Zn with a removal efficiency above 95%. However, they noticed that the basin removal capacity was reduced for rainfall intensities greater than 29.4mm and duration of 6 hours concluding that a significant amount of pollutants were discharged into the waterways for those conditions. Morse et al. (2017) monitored two wet basins and two dry basins. They concluded that at watershed scale wet detention basin was capable of denitrifying 58% of the incoming dissolved inorganic N. While, a dry detention basin can only denitrify 1%.

2.9 DDBBO & similar treatment technologies

A DDBBO system is for this research study a *"Dry Detention Basin with a Biofilter and/or Infiltration System used as an Outlet*". There are not currently detailed guidelines or sufficient laboratory or/and field validation studies in Australian and overseas that can help engineers and designers to understand in more detail the removal efficiency performance of the DDBBO system and promote their use. In Australia, a brief technical approach has been outlined in the "Bioretention Technical Design Guidelines" prepared by Water by Design (2014). This is the only current document that addresses and provides a recommended approach for the construction and operation of DDBBO systems.

In a more international context, similar technologies have been monitored and documented throughout Florida and Minnesota in the United States of America (USA). For example, Harper and Herr (1993) conducted a field and laboratory investigation from April 1992 to January 1993 in a detention basin equipped with a side bank filtration system located in Debary, Florida. They determined that the combined system have a removal efficiency ranging from 49-87% for TP and 97-

100% for TSS. However, no net removal efficiencies were found for TN during the six months study period. They suggested that even though the filter system may have trapped particles, subsequent decomposition processes within the media resulted in an increased concentration of soluble inorganic species of nitrogen and orthophosphorus at the underdrain outflow.

Weiss et al. (2006) undertook a field and laboratory investigation for three DDBs equipped with an underdrain system located near Mankato city in Minnesota in the USA. These structures were monitored from May 2004 to November 2004 and May 2005 to August 2005. They demonstrated that the removal efficiencies for a total of twelve storm events were 88% for TSS and 58% for TP. Scholz and Kazemi Yazdi (2009) investigated a combined detention and infiltration system located in the University of Edinburg in the United Kingdom (UK). The investigation proved promising removal efficiencies for TSS (83%), Nitrate-N (32%) and orthophosphate phosphorous (47%). They suggested that the most critical removal process presented within the system were biological degradation, sedimentation and infiltration.

As this literature review demonstrates, there is not sufficient laboratory or/and field validation studies of DDBBO system that can permit researchers and the industry, in general, to understand the performance of DDBBO system and promote their use. Even though few similar technologies have been investigated and monitored, there is still existing limited knowledge about the effectiveness and efficiency of the DDBBO systems to remove key pollutants from stormwater runoff, especially under the Australian weather and climate conditions.

2.10 MUSIC

2.10.1 Introduction

There is an increasing interest in improving the quality of stormwater runoff generated in our urban environment in recent years. The modelling of the stormwater runoff quality has presented to be very difficult and highly dependent on factors such as catchment characteristic, weather, climate and environmental conditions. The pollutants contained within the stormwater runoff can only be predicted with an acceptable level of accuracy as long as extensive field measurement data is gathered for the different urban land uses. MUSIC modelling is becoming one of the most widely used software in Australia to predicts the expected load generation and to assess the effectiveness of stormwater treatment strategies for the removal of the pollutant targets set by the legislation. Unfortunately, only a few research studies have investigated into the accuracy of the model to predict the pollutant loads and reductions of a functioning catchment and WSUD measures (Imteaz et al., 2013).

MUSIC is a physically based stochastic model as it calculates the generation of stormwater pollutants such as gross pollutants, TSS, TN and TP for an urban catchment. MUSIC just not predict the quantity of runoff, but also simulates the quality based on catchment land use (eWater, 2017).

The inability for designers and engineers to obtain a complete set of data required to reproduce an accurate and reliable historical pollutographs has made MUSIC model a widely used conceptual analysis tool as it only requires few input data, for which most of them are provided as defaults from experimental and soil conditions investigated in Brisbane and Melbourne (Imteaz et al., 2013, Fletcher, 2013, eWater, 2017).

2.10.2 **The Accuracy of MUSIC Model**

MUSIC is currently one of the most common model package used by engineers and designer in Australia, and in recent years its use has been extended to the UK. Currently, only a few studies have been undertaken to analyse the accuracy of the MUSIC model in relation to pollutant generation and flow due to the limited availability and reliability of water quality data. MUSIC utilises the results from Duncan (1999) and Fletcher (2004) as default parameters to determine the pollutant loading according to the catchment characteristics.

However, those parameters are from studies undertook in Melbourne and Brisbane sites. Therefore, the data, in theory, should not be used in another urban catchment outside of those regions as this will not be a correct representation of the specific conditions of such catchments (eWater, 2017). However, due to lack of adequate and reliable data in Australia, designer and engineers require to keep using this data to be able to run the model until more data becomes available to calibrate and validate the current information (Van der Sterren et al., 2008, Dotto et al., 2011a). Dotto et al. (2009) investigated the MUSIC model with the objective to calibrate and undertake a sensitivity analysis to evaluate the uncertainty with regard to flow and water quality. They found that the calibration parameters of the rainfall/runoff model were not sensitive for 11 out of 13 studied parameters suggesting that the model could be simplified without losing accuracy. However, for the water quality, they suggested that at least six months of rainfall data and water quality testing are required to produce reliable predictions.

A report prepared by Fletcher (2013) analysed the accuracy of the MUSIC model by comparing field results obtained from a bioretention and detention basins and replicating the basins' catchment into MUSIC. The results showed that on average the field results for TN, TP, TSS and gross pollutant had lower concentrations than those reported by the model in the order of 61%, 48%, 56% and 35%, respectively. They also suggested that there was a tendency by the MUSIC model to overestimate the pollutant concentrations for small storms.

Imteaz et al. (2013) investigated the accuracy of MUSIC Model for different constructed stormwater treatment options based on several field measurements collected from the literature in Australia, Sweden, New Zeland and Scotland. The experimental results concluded that MUSIC could simulate flow conditions with reasonable accuracy. However, the results also showed that the removal efficiencies of TSS, TN and TP varies, and such discrepancies may be explained due to leaching process presented within the system, insufficient or inaccurate data availability, missing variables related to vegetation such as density and type, and the increase of TSS retention due to vegetation or the existence of loose topsoil. They concluded that the MUSIC model needs to be used with caution as in some cases the model overestimate the treatment capacity of the system and in other cases, it can underestimate it. They suggested that the model should be used as a sensitivity analysis to evaluate the shape and dimension of the system. However, a further comparison of the experimental results would require a strict quality control and data collection process.

2.11 Literature review conclusion

Numerous papers and reports discuss the importance of controlling and treating stormwater runoff from urbanised area (Dhakal and Chevalier, 2016, Drapper, 2015, Valtanen et al., 2014, Liu et al., 2012, Erik and John, 2009, Van der Sterren et al., 2008, Zimmer, 2006). Biofilters and dry detention basins (DDBs) are stormwater treatment structures that have been widely installed as separate facilities to reduce or mitigate the adverse effects of untreated stormwater runoff into natural ecosystems. These structures have previously been studied and their performance and effectiveness for the removal of contaminants are well documented (Water by Design, 2014, Pezzaniti et al., 2012, Brown and Hunt, 2012, Luell et al., 2011, Hurley and Forman, 2011a, Roy-Poirier et al., 2010, Caroline Fortunato, 2005). However, there is not sufficient laboratory or/and field validation studies of DDBBO systems that can help engineers and designers to understand their performance and promote their use. Even though the investigation of similar technologies in the USA have shown promising results; there is not sufficient knowledge to predict the benefit of promoting such a system, especially under the Australian weather and climate conditions.

It was also found through this literature review that only a few studies have been undertaken to assess the accuracy of the MUSIC model to predict pollutant concentration and loading. This highlights the lack of research studies in assessing the MUSIC modelling prediction and proper field quality data in urban centres outside of Brisbane or Melbourne to allow us to validate the model. Most of the parameters used in MUSIC requires to be used as a default due to the insufficient field data, especially for mixed urban/rural catchment such as those presented at Glenvale in Toowoomba. Therefore, this study provides an exciting opportunity to compare the results obtained from a field observation against the model to determine its accuracy prediction level.

3 Material and Methods

3.1 Research Framework

The completion of DDBBO system in the suburb of Glenvale in Toowoomba in 2013 offered an exciting research opportunity to investigate and understand a bit more about the performance efficiency of this structure for the removal of critical pollutants from the urban stormwater runoff.

Two monitoring stations were installed at the DDBBO at the inflow and outflow with the objective of measuring the hydrology and water quality characteristics of this structures to subsequently be compared with the findings from the literature review as well as the MUSIC predictions obtained from the simulations process. This chapter mainly outlines the methodology used to assess the performance of the DDBBO system as follows:

- Procedures and equipment adopted to monitor stormwater quality and quantity.
- Laboratory methods used to analyse water quality parameters.
- Description of the different load estimation techniques.
- MUSIC model set up and adopted values.
- DRAINS Model set up to calibrate flow discharges.
- Monitoring sampling challenges.

Figure 3.1 shows all the task required to undertake this study, which is explained in further detail in subsequent sections.

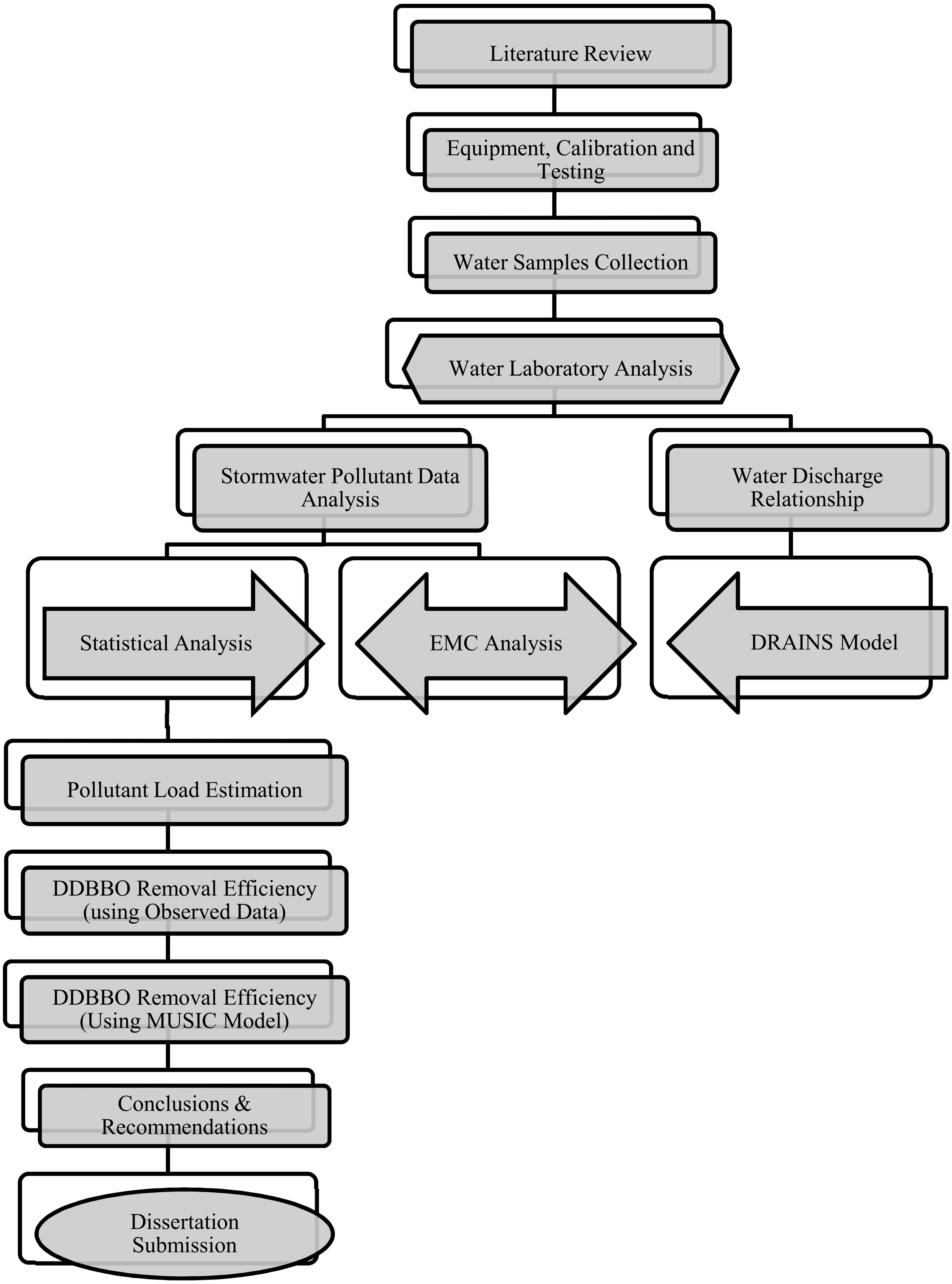


Figure 3.1 - Project research activities flowchart

3.2 Case Study Area

3.2.1 Site Selection

This study was undertaken as a response to insufficient field validation data and design guidelines that permit engineers and designers to understand the performance removal efficiency of DDBBO systems, especially under Australian weather and climate conditions. The study site was selected based on the completion of a DDBBO structure in Toowoomba city in 2013 by TRC. This structure provided an exciting research opportunity to develop and increase our knowledge and understanding about the effectiveness of DDBBO systems for the removal of key pollutants target as specified under the Queensland Urban Stormwater Quality Planning Guidelines (DERM, 2010) Best Practise Environmental Management Guidelines (CSIRO, 1999) and State Planning Policy 07/17 (DILGP, 2017).

3.2.2 Site Description

Toowoomba is known as "The Garden City" is a city located in Darling Down region in the South-East of Queensland at approximately 127 km west of Queensland's capital city of Brisbane. The city covers an area of approximately 498.1 km^2 and elevation of 700 m above sea-level (TRC, 2018a).

In recent years, Toowoomba has become one of the fastest growing town with an estimated population of approximately 118,000 at June 2017.(ID, 2017, BOM, 2018, TRC, 2018a) This city has been identified as the largest inland logistical centre and major inland port in the country. Its economic growth potential lays on retail, construction and development of energy sources in the Surat Basin and food processing as well as the development of Wellcamp airport and Second Range Crossing. It is also considered a major educational centre with more than 23 private and public schools, TAFE technical College and the presence of three major universities such as Southern Queensland University (SQU), University of Queensland (UQ) and Griffith University.

Toowoomba has a warm, humid subtropical climate with a cold, dry winter and warmer wetter summer. The daily maximum temperatures average 28 C in summer and 17 C in winter. The average annual rainfall, according to the Bureau of Meteorology, is 724mm. The majority of the rainfall falls from November to March, with January and February being the peak rainy months (BOM, 2018, TRC, 2018b).

The DDBBO system is located in Outlook Estate adjacent to Sunset Drive in the suburb of Glenvale in Toowoomba as shown in Figure 3.2. Glenvale is a rural/residential catchment located a proximately 6 km from the south-west of central Toowoomba.

Figure 3.2 - Locality plan of study area

This WSUD structure was constructed in early 2013, and the extent of the local catchment was determined by RMA Consultant Engineers using Toowoomba Regional Council's (TRC) Online Mapping information and detail design plan of surrounding subdivisions provided by TRC (RMA, 2010). The catchment was subdivided into four development stages as shown in Figure 3.3, and described in

Table 3.1.

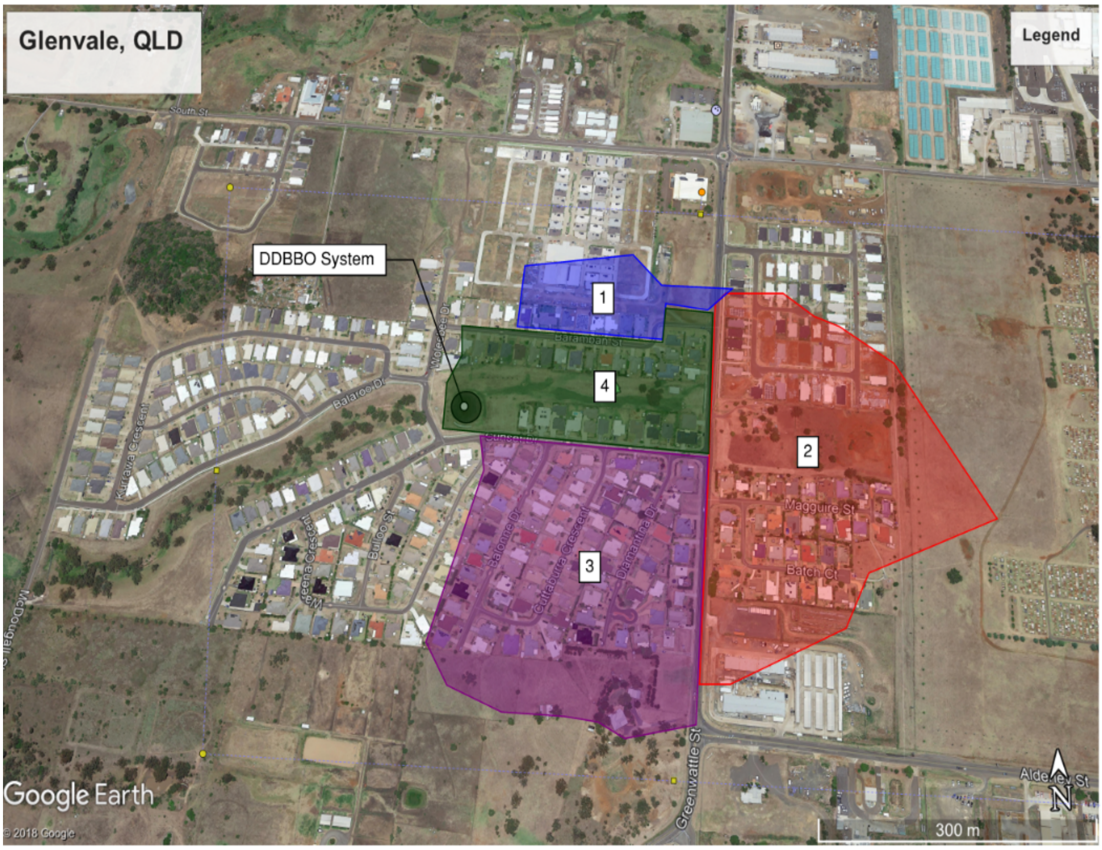


Figure 3.3 - Stormwater catchment plan showing four sub-catchments of the study area replicated from a stormwater report prepared by RMA (Project No 6065-revision dated on 20th December 2010)

Table 3.1 - Catchment characteristics obtained from RMA stormwater report No 6065(RMA, 2010)

Catchment	No of Developed Lots	Roof area		Balance Area		Total	
		Area (ha)	Imp. (%)	Area (ha)	Imp. (%)	Area (ha)	Imp. (%)
1	8	0.2	100	1.28	28	1.48	37
2	78	1.95	100	7.57	28	9.52	42
3	98	2.45	100	6.79	38	9.24	54
4	32	0.8	100	3.32	15	4.12	32

The stormwater management strategy for the catchment consisted of two vegetated swales with a combined total length of 280 m, a Dry detention basin (DDB) with a total volume of 2,784 m^3 and extended detention depth of 1.8 m, and a biofilter as an outlet with a total surface area of 160 m^2. The filter media has a total depth of 1.0 m, divided vertically into three layers. The upper layer is a 700-mm sandy loam filter media layer, the medium layer is a 100mm coarse sand transition layer, and the lower layer is a 200-mm coarse sand and gravel drainage layer. The biofilter is provided with a field inlet pit with an overflow level located at 200 mm above the filter surface level to accommodate the extended detention depth required by this system. One longitudinal slotted 150 mm diameter PVC and thirteen transversal slotted 100 mm diameter PVC underdrains pipes are located in the drainage layer, which conveys the treated water to a centred inlet pit, to subsequently be discharged downstream to a stormwater channel. A biofilter cross-section detail and layout plans are shown in Figure 3.4 and Figure 3.5.

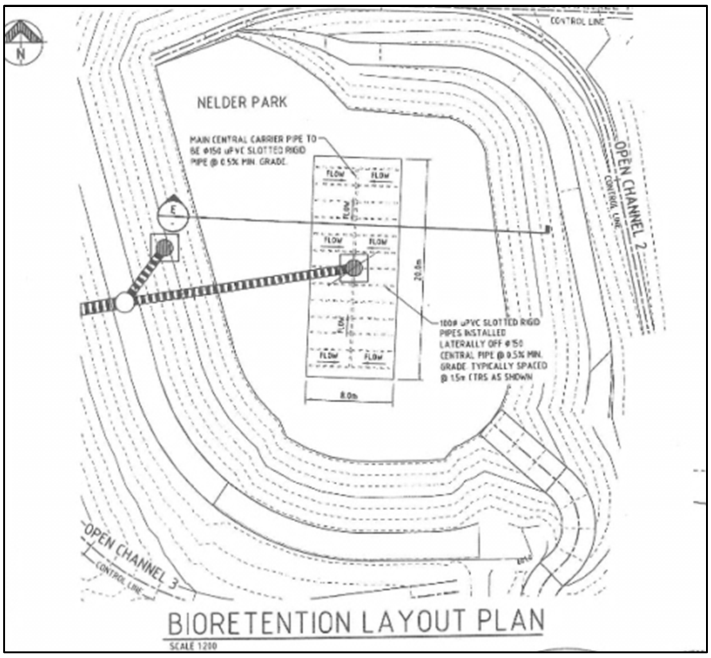


Figure 3.4 - Detention basin and biofilter layout plans obtained extracted from engineering documentation prepared by RMA engineers (drawings No 101472-001 & 006 revision 2 dated 21st April 2011) (RMA, 2011)

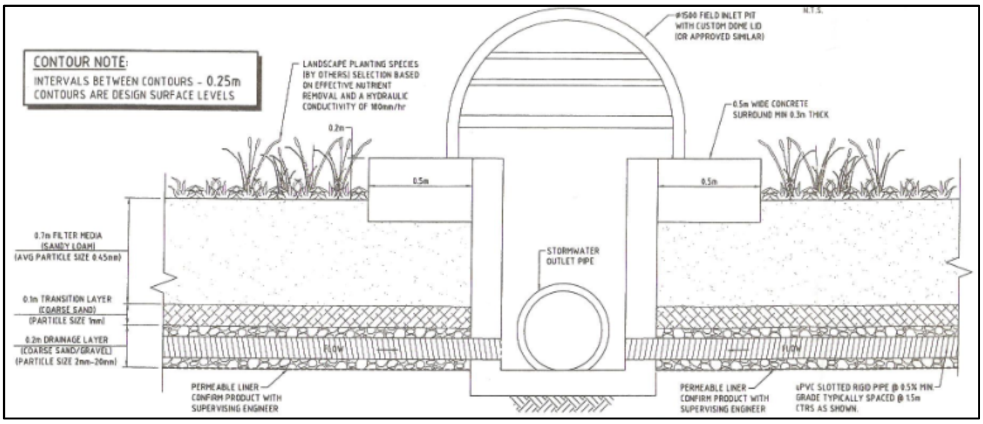


Figure 3.5 - Biofilter cross section detail obtained from drawings prepared by RMA engineers (Drawing No 101472-006 Revision 2 dated 21st April 2011)(RMA, 2011)

3.3 Hydrologic and Water Quality Data

3.3.1 Rainfall

The performance of WSUD systems depends mostly on the rainfall characteristic, and identifying those characteristics is very important in the overall design process. Due to the timeframe and scope of works defined for this project research and the issues presented during the sample collection process to be discussed in subsequent sections, it was only possible to monitor seven storm events during the summer season of which six were only used due to insufficient information to measure the removal efficiency of the DDBBO system. The storm events were monitored from 13th December 2014 to 22nd May 2015 providing five months and ten days for the sampling collection phase. Most of the storm events presented during this period were monitored, but water samplings were only conducted on the six storms with the rainfall characteristics shown in Table 3.2.

Due to duration and the number of sampled events, the validity of the data set and statistical analysis show in the subsequent sections may impose some limitation to this study as these fell well below the minimum protocol (SQIDEP) requirements for stormwater quality treatment devices. The protocol requires at least 15 samples to be collected in a period not less than a year but due to time constraints, programming of sampler units and sampling difficulties. Unfortunately, it was not possible to meet such requirements.

Table 3.2 - Selected storm events features.

Storm Events	Total Rainfall (mm)	ADP (hr)	Rainfall duration (min)	I (mm/hr)	Peak I_6 (mm/hr)
18.02.2015	1.8	-	1	3.60	8.00
21.02.2015	4.4	7	5	0.86	6.00
27.02.2015	11.2	66	3	3.73	24.00
26.03.2015	3.8	8	2	1.73	10.00
02.04.2015	2.2	8	1	2.20	2.00
03.04.2015	5.4	3	14	0.38	6.00
01.05.2015	113.4	576	18	6.23	28.00

3.3.2 **Field Measurements**

Two monitoring stations were installed at a DDBBO system located in the suburb of Glenvale in Toowoomba to measure the stormwater inflows and outflows, not only to analyse water flows but also to assess water quality concentrations of TP, TN and TSS. The monitoring stations were placed at two locations that did not generate any disruption for the treatment system, TRC park and maintenance crew and residents in the area.

The monitoring stations consisted of a custom-made housing enclosure to protect the equipment from weather and vandalism. The housing enclosures were located at locations near to the inlet and outlet of the DDBBO system as shown in Figure 3.6. Signs were located in the housing enclosure with the objective of informing residents about the project research and reduce or mitigate the risk of vandalism. Rain gauges also were installed at the top of each housing enclosure with the purpose of recording rainfall data and compared data results. This was also considered as a backup plan to ensure that rainfall data was available for the data analysis process.

V- notch weirs were installed at the open channel and stormwater chamber located at the inlet and outlet of the DDBBO system, respectively. CS451 pressure transducers from *Campbell Scientific* were used to measure the height of the water passing over the weirs. Further details of the weirs and pressure transducers equipment are provided in sections 3.3.3 and 3.4, respectively. These flow measurements were used to create the hydrographs to determine inflow/outflow volumes (L/s).

PVS4120D-CSA units from *Campbell Scientific* were selected to collect the water samples that were then assessed to obtain pollutant concentrations so different load estimations could be determined and compared. For further detail of the water samplers used in this project refer to section 3.4.2 Automatic water Sampler.

In summary, the monitoring stations consisted of similar components with a slight variation in the datalogger and rain gauge. Each station was equipped with a Campbell Scientific datalogger, which allowed the data to be downloaded directly to a computer. This activity was undertaken on a weekly basis to check for errors, power failure and any other unforeseen issue during the sample collection phase.

The monitoring stations were powered by two sealed rechargeable lead batteries 12V-7.0Ah. These batteries were replaced and recharged every two or three days with the objective of avoiding any power failure when the water samples collection was required. Section 3.4 shows the equipment used in the monitoring stations.

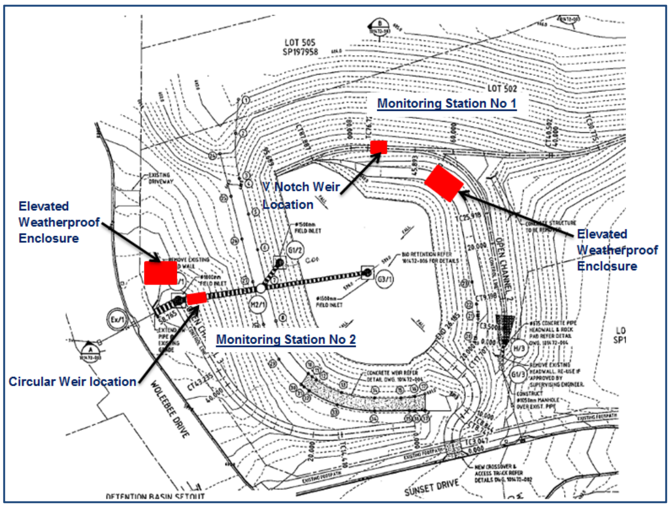


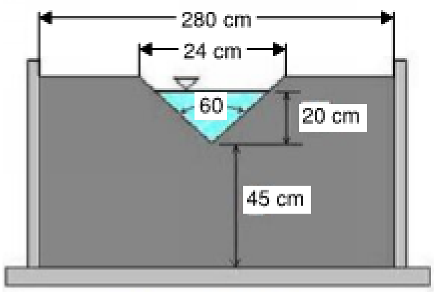
Figure 3.6 - Location of monitoring stations & equipment at DDBBO system at Glenvale (RMA, 2011).

3.3.3 **Flow Measurement**

Weir structures and pressure sensors at the inlet and outlet of the DDBBO were installed to measure the flows accurately. Weirs were placed at the open channel and within the stormwater pipe at the inlet and outlet, respectively. Weir locations are shown in Figure 3.6 to Figure 3.9. CS451 Pressure transducers were installed below the weir crest to record the height of the water passing over the sensors. The hydraulic head for the weir was corrected by accurately measuring the distance between the pressure transducer and the bottom of the V-notch. The data logger was then programmed to subtract these measurements as an offset with the purpose of obtaining a reading of 0 mm just before the stormwater runoff starts to run over the weir.

Discharge over the weir is proportional to the height of water built up on the upstream side of the weir. The weir equations used at the inlet and outlet locations of the DDBBO are shown in Figure 3.7, to Figure 3.9 (Marriott, 2016, Hardy, 1999).

For the monitoring station No 1, it was constructed a galvanised 60 degrees angle v-notch weir to measure the stormwater flows running into the DDBBO system as shown in Figure 3.7.



20cm < h < 0cm $\longrightarrow$ $Q\ (m^3/s) = 2.36\ Ce\ Tan\frac{\emptyset}{2}(h + K)^{2.5}$

Where,

Q: Discharge (m^3/s)

Ce: Discharge Coefficient

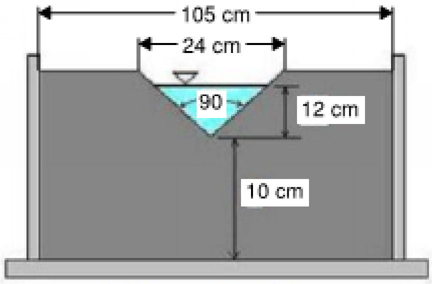
∅: Vertex angle of the triangular notch

K: Head correction factor (m)

h: Hydraulic head (m)

Figure 3.7 - 60-degree V-Notch weir used in monitoring station 1

For the station monitoring station 2, it was constructed a galvanised 90 degrees angle v-notch weir to measure the stormwater flows leaving the DDBBO system as shown in Figure 3.8.



12cm < h < 0cm $\longrightarrow$ $Q\ (m^3/s) = 1.36\ (h)^{2.48}$ (*v notch weir*)

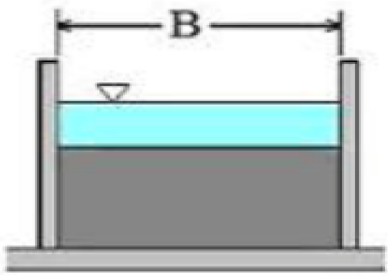
Where,

Q: Discharge (m^3/s)

h: Hydraulic head (m)

Figure 3.8 – 90-degree V-Notch weir used in monitoring station 2

The rectangular weir equations were included as part of the flow measurement calculations for both weirs for those cases in which the total hydraulic head of the weirs was exceeded. The equations are described in Figure 3.9 (Hardy, 1999).



Monitoring station 1 & 2: $\mathrm{Q\ (m^3/s) = 1.84\ B\ h^{1.5}}$

Where,

Q: Discharge (m^3/s)

h: Hydraulic head (m)

Figure 3.9 - Rectangular weir equation

The critical design parameters and assumptions used for the weir structures are listed below:

- The flow approaching the weir should be uniform and steady.
- The flow approaching the weir should be perpendicular to the notch opening.
- Weirs were placed, so at least the upstream channel was a minimum ten times the length of the weir crest.
- Bottom of the channel to the crest to be at least twice the depth of the hydraulic head being measured.
- The velocity of the stormwater flow approaching the weir needed to be no higher than 0.3 m/s.

3.3.4 **Water Sample Collection Process**

It was defined from the initial phase of the research project the utilisation of automatic water samplers as these are one of the most efficient and advanced methods nowadays to collect water samples. Campbell Scientific units were selected and installed at the inlet and outlet of the DDBBO system. These units were programmed via dataloggers to take samples based on a predefined volume of 1KL overtopping the weirs. The collected samples were stored in 24 litre plastic containers at each sample to subsequently being transferred to sample storage bottle provided by Southern Queensland University (SQU). These samples were collected from the field generally within 24 hrs of the sample being collected by the samplers and transported in eskies with ice to the laboratory of the Faculty of Engineering and Survey where they were kept in refrigerated conditions. A protocol sampling process was established with the assistant of the research supervisor (Dr Ian Brodie) with the objective of enhancing the collection process and avoid any error or confusion due to labelling and so on.

Storm events were followed via a weather app, and at the beginning of any storm event, a site project inspection was undertaken to make sure that the equipment and stations were in good conditions to conduct the water collection process of that specific storm event. This procedure helped to understand in more detail the site conditions and allowed to enhance the overall process continuously. Six random water samples (three per each monitoring station) of each selected storm event were then transported to the Toowoomba Regional Council (TRC) laboratory, which is a NATA accredited in accordance with the ISO/IEC 17025, for analysis of the TP, TN and TSS concentrations. The selected sample number was determined based on funding availability.

Additional stormwater testing was undertaken at the SQU laboratory with the objective to get familiar with the testing analysis technique and define whether any other correlation exists with the targeted pollutants under the legislation. The stormwater parameters analysed at the SQU lab were turbidity, TDS, Fluoride, Chloride, Nitrite, Nitrate, Bromide, Phosphate and Sulphate. Further detailed information is presented in *Appendix A – Project Research Supporting Information* and *Appendix B – TRC Water Sample Results.*

3.4 Equipment Used

3.4.1 Rain Gauge

Automatic electronic tipping bucket type pluviometers with 0.20 mm accuracy were used to monitor the storm events. These devices were installed at the selected inlet and outlet monitoring locations of the DDBBO system shown in Figure 3.10. These devices were attached to the dataloggers located at each monitoring station, and the recorded data was downloaded into a computer program to be analysed and processed as shown in *Appendix A – Project Research Supporting Information.* Photograph of Rain Gauge is given in Figure 3.10.

Figure 3.10 - Rain gauge

3.4.2 Automatic water Sampler

The automated sampler is a programmable electro-mechanical instrument capable of collecting single, series of grab samples or composited samples. PVS4120D-CSA unit from Campbell Scientific was selected to collect the water samples. These units are a lightweight, portable, battery-powered waters sampler that deposits its water samples into 24 containers. This includes a programmable controller with the 16-key intuitive touchpad. This unit also interfaced with a dataloggers and the pressure transducer that defined event measured conditions. An image of the used Campbell units installed at both monitoring stations is shown in Figure 3.11 (Campbell Scientific, 2011).

Figure 3.11– Portable discrete water sparaampler PVS4120D (images extracted from Campbell Scientific Website)

3.4.3 **Pressure Transducer**

A CS451 pressure transducer from Campbell Scientific was used to measure the height of the water passing over them at the weirs. The sensors were programmed, and the data was extracted by connecting the datalogger to the computer via a program (PW200) developed by Campbell Scientific. Photograph of a Rain Gauge is given in *Figure 3.12*.

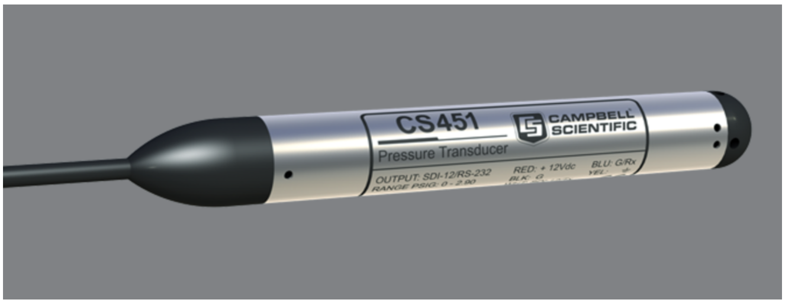


Figure 3.12 - Portable discrete water sampler PVS4120D (images extracted from Campbell Scientific Website)

3.4.4 **Dataloggers**

CR800 and CR200 dataloggers were used for the monitoring program. The CR800 is a datalogger designed for stand-alone operation in remote environments. This reads the inputs from sensors to subsequently transmit the data via communication peripheral and has the flexibility to be configured as a network or units. Photograph of a CR800 is given in

Figure 3.13.

Figure 3.13 - CR800 datalogger (images extracted from Campbell Scientific Website)

The CR200 is a low-cost unit, and it is mainly designed to measure a maximum of two sensors. Photograph of a CR800 is given in Figure 3.14.

Figure 3.14 - CR200 datalogger (images extracted from Campbell Scientific Website)

3.5 Data analysis

Determination of pollutants load is a crucial indicator to assess the level of impact that urban developments can generate to waterbodies and its ecosystem. Estimation of pollutant loads through monitoring is a very complex task that requires accurate measurement of both pollutant concentration and flow discharge, often based on a statistical approach.

Ideally, the most accurate approach to estimate pollutant load would be to sample very frequently and capture all the variability. Flow is relatively easy to measure, but concentration is expensive and, in most case, impossible to measure continuously.

For this study, the performance of the DDBBO system was assessed by measuring rainfall and runoff parameter from two monitoring stations located at the inlet and outlet of the system. Water samples were then collected to obtain pollutant concentration values. The observed flow discharges were validated based on water levels obtained from the seven (7) observed storm events against DRAINS model. The observed dataset was plotted against the DRAINS results, and best-fit equations were obtained. Subsequently, the adjusted flow discharges and observed pollutants constituents were used to compute the Event Mean Concentration (EMC) values and to calculate load estimations by applying different mathematical techniques (regression, average and ratio estimator) as well as different removal efficiency calculations (efficiency ratio, summation of loads and regression) to determine the order of difference in the magnitude of these approaches for estimating load concentrations and determining the removal efficiency of the DDBBO. The specific site conditions were also modelled in a computer software known as MUSIC, and the results from this process were compared against the observed data to determine the level of accuracy model to predict pollutant concentrations and removal efficiency. The results from the sampling process were compared with local and international research findings found in the literature review.

Statistical analysis was also used to find any potential correlation between rainfall parameters, flow discharge and volume and pollutant concentrations as well as between observed constituents.

3.5.1 Establishment of water discharge relationship Equation

Discharge curve rating equation is a basic approach used to predict flow discharges based on water level and flow discharge measurement dataset obtained from the inflows and outflows structures and/or devices installed at the WSUD system (Maghrebi and Ahmadi, 2017).

This rating analysis is a process in which the data from paired discharge-water levels measurements are plotted in a graph and a curve defined by the measurement is drawn. Based on that relationship, it can empirically predict the flow discharge for any water levels at that respective location (Maghrebi and Ahmadi, 2017). For this study, the curve rating equation was used to compare the observed water levels and peak flow discharges against the results obtained from the DRAINS model with the objective of verifying and validating the observed flow discharge at the inlet of the DDBBO system.

The validation process of the observed flow discharges was considered an essential process in this research as these are the supporting information for the calculation of the pollutant loads and the overall assessment of the removal efficiency of the DDBBO system.

The following methods were also adopted to validate the level of prediction of the DRAINS model.

3.5.1.1 Nash-Sutcliffe coefficient (NSC)

The Nash-Sutcliffe model efficiency coefficient (NSC) is a method used to validate the predictive power and accuracy of hydrological discharge models (Lin et al., 2017). The NSC equation is defined as follow:

$$NSC = 1 - \frac{\sum_{i-1}^{n}(X_{obs,i} - X_{Model})^2}{\sum_{i-1}^{n}(X_{obs,i} - X_{obs\_Median})^2}$$

Where,

X_{obs}: Observed values

X_{model}: Modelled values at time *I*

X_{obs}: Mean of the modelled values

The NSC can range from -∞ to 1 and NSC value of 1 corresponds to a perfect match between model predictions and observations. If the NSC has a value of 0 indicates that the model predictions are as accurate as the mean of the observed data, while if the coefficient value is less than zero, this indicates that the observed mean has a better prediction than the model. In summary, the closer the coefficient is to 1, the more accurate the model is (Gupta and Kling, 2011).

3.5.1.2 Root Mean Square Error (RMSE)

The RMSE is an approach used to measure how spread out the predicted values are with respect to the observed data from the fieldwork. These individual differences are known as residuals, and the RMSE serves to aggregate them into a single measure of predictive data to determine whether those are the best fit or not (Li, 2010).

The RMSE of a model prediction is as follow:

$$RMSE = \sqrt{\frac{\sum_{i-1}^{n}(X_{obs,i} - X_{Model,i})^2}{n}}$$

Where,

X_{obs}: observed data

X_{model}: predicted data at time i.

In summary, the lower the RMSE with respect to the range the better the model prediction.

3.5.2 **DRAINS Model Setup**

DRAINS is a software commonly used in Australia for stormwater designers and engineers to model stormwater drainage system (O'Loughlin and Stack, 2017).

DRAINS is based on the ILSAX model, which uses time-area calculations, surface depression loses, and soil infiltration procedures to calculate rainfall excess. The ILSAX model started as the RRL (Road Research Laboratory) Model in 1964, which included only impervious areas analysis, but further development was subsequently undertaken in 1974 & 1981 evolving to ILLUDAS Model. However, it is in 1986 & 1998 when the major developments such as the inclusion of detailed methods for overland flow routing and pit entry were incorporated becoming the ILSAX model (Dayaratne, 2000).

DRAINS simulates the rainfall-runoff processes of urban catchments creating flow hydrographs at each entry point of the pipe, channel and pond to subsequently routing and combining flows through the proposed drainage network system, which are subject to the conveyance capacity of the system and any restriction imposed at each entry point (O'Loughlin and Stack, 2017).

For this study, DRAINS was used to compare the predicted flow results based on defined hydrological parameters against the fieldwork dataset measured through the weir systems. The DRAINS results are included in *Appendix C - MUSIC and DRAINS Information.*

The hydrological model parameters required to be inputted into DRAINS to determine the depth of runoff are described below:

3.5.2.1 Soil type

DRAINS software follows the U.S Soil Conservation Service system adopted in the ILLUDAS model from which ILSAX was developed. There are four soil types involving different infiltration characteristics. For this study research, Type 3 or C was adopted based on the Australian Soil Classification system (ASC) provided

Queensland Government and CSIRO. This refer to soils with slow filtration rates (O'Loughlin and Stack, 2017).

3.5.2.2 Paved and grass area depression storages assumptions

This is a depth of rainfall (mm) that is retained in depressions on a catchment surface and evaporated. It is considered to be the initial loss but DRAINS assumes that this occurs after infiltration, so it is subtracted after continuing infiltration losses. For this study, the following values were used, which are in accordance with the values suggested by DRAINS (O'Loughlin and Stack, 2017).

- Paved Area = 1 mm
- Supplementary Area = 0 mm
- Grassed Area = 2 mm

A snapshot of the ILSAX hydrological parameters is shown in Figure 3.15

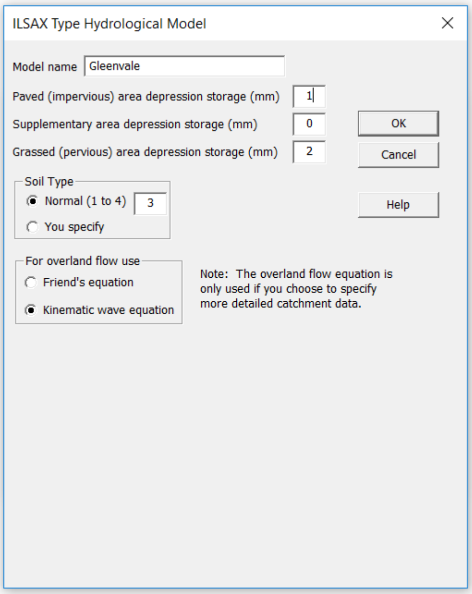


Figure 3.15 - DRAINS hydrological model parameters (O'Loughlin and Stack, 2017)

3.5.2.3 Time of concentration

This is the time required for the stormwater runoff to flow from farthest point of a catchment to its outlet during a storm event following built or natural flow paths. The time of concentration in this study was calculated by using the kerb and channel flow time using Manning's equation described in QUDM (2017), which is shown below:

$$t = 0.0025 \frac{L}{S^{0.5}}$$

Where,

T: Time of gutter flow in minutes

L: Length of gutter flow in metres

S: Slope of the gutter (%)

3.5.3 **Laboratory Water Analysis**

The samples selected from the monitoring process were transported to TRC Laboratory located at the Mt Kynoch Water Treatment Plant on Shuttlewood Court, off the New England Highway. These samples were tested for TSS, TN and TP in accordance with the technique and procedures accredited by the National Association of Testing Authorities (NATA) (APHA et al., 2017).

3.5.3.1 Total Suspended Solids

TSS was analysed using the in-house procedure No QPKYN-009 (APHA2540D). The procedure consists of using a glass fiber filter disc as a filter in a filtering flask. Deionised water is pulled with vacuum through the filter. The fiber filter disc is dried to a constant weight in an oven at 102-105 °C to define the weight of the empty disc. A filtered sample is dried in the same fiber filter disc to a constant weight in an oven at 102-105 °C The weight difference between the empty disc and the disc with the remaining materials shows the Total Non-Filterable Solids. The Volatile Nonfilterable Solids is measured by putting the fiber filter disc in a muffle furnace at 550 °C, which removes all the volatile material. The difference between the disc weight and the disc weight with the remaining materials defines the *Volatile Non-Filterable Solids (*APHA et al., 2017*)*.

3.5.3.2 Nitrogen & Phosphorous

Nitrate, nitrite and total Kjeldahl Nitrogen was analysed by using procedure (APHA 2005) No 4500-NO_3 $^{-1}$I, 4500-N and 4500 NH_3 H respectively. Phosphorous was analysed by using the flow injection analyser (FIA) technique described in the procedure No QP+KYN-101 and 4500 N_{org} d (APHA) described by NATA (APHA et al., 2017).

3.5.4 **Load Estimation Discussion**

Estimation of pollutant load through monitoring is a complex activity that requires accurate measurements of stormwater runoff and pollutant concentrations and careful calculation based on statistical techniques (Eom et al., 2010).

Three crucial factors require careful consideration during the sampling process to obtain reliable load estimation values. These are sample type, sampling frequency and sample distribution in time. For this study, it was adopted a discrete sample type, and the frequency was based on proportional flow approach, in which samples were taken every 1kl of the volume of flow passing through the v-notch weir and circular weir located at the inlet and outlets of the DDBBO, respectively. It was considered that the proportional flow approach was the most suitable approach considering the monitoring constraints and requirements to provide a reliable load estimated.

In this research, it was proposed the implementation of tree technical approaches with the purpose of determining the order of difference in the magnitude of these techniques for estimating load concentrations.

During the water collection process, seven storm events were monitored, but only six were considered for stormwater quality analysis. Three samples at each monitoring station per event were taken for water analysis at TRC laboratory facility. Pollutant load estimations were then developed based on those results using the methods described in the sections below.

3.5.4.1 Numeric Integration

The numeric integration is the most straightforward approach, which consists in calculating the total load by multiplying the obtained pollutant concentration in each sample by its corresponding flow discharge at the time the sample was taken as shown in the equation below (Eom et al., 2010):

$$Load = \sum_{i=1}^{n} C_i . Q_i . t_i$$

Where,

Ci: Pollutant Concentration in the i^{th} sample

Qi: Corresponding flow

Ti: Time interval represented by the i^{th} sample, which is calculated as follows $\frac{1}{2}(t_{i+1} - t_{i-1})$

Once the load estimations for the period in which sample was taken is established, a linear equation is obtained to estimate the concentrations and load estimations for the time during the event on which sample was not taken. The total load is derived by the summation of the calculated and estimated loads per each event. This method assumes a strong relationship between concentrations and flow discharges (Eom et al., 2010).

3.5.4.2 Beale Ratio Estimator

The concept of ratio estimators is a powerful statistical tool for estimating pollutants loads from continuous flow data and intermittent concentration data. This approach assumes that there is a positive linear relationship between concentration and flow discharge. The daily load is calculated as the product of the sampled concentration and mean daily flow, and the mean of these loads over the period of study is also calculated. The mean daily load is then adjusted by multiplying it by a flow ratio, which is derived by dividing the average flow for the period of study by the average flow for the days on which samples were taken. A bias correction factor is included in the calculation to compensate for the effect of correlation between discharge and load (Eom et al., 2010).

This is the most common and robust approach used to estimate load estimation techniques when dealing with a limited dataset due to it maintains a constant ratio between concentration and flow rate (Eom et al., 2010, Donald W Meals, 2013). The equation used in this study is as follows:

$$Load = \frac{K \sum_{i=1}^{n} (Ci\, Qi)}{\sum_{i=1}^{n} (Qi)} . Qr . F$$

$$F = \left[\frac{1 + \frac{1}{N}.\frac{Slq}{l.q}}{1 + \frac{1}{N}.\frac{Sq^2}{q^2}}\right]$$

Where,

K: A conversion factor to account for the period of load (this case daily event) estimation and units (mg to kg if required)

Ci: Sample concentration

Qi: Flow at sample time

Qr: Mean flow for a period of load estimate (derived from a continuous flow record)

N: Number of samples

F: Beale ratio correction factor

L: the mean load calculated from the Ci Qi

q: The mean flow calculated from Qi

$$Sql = \left[\frac{1}{N-1}\right].\left[\sum_{i=1}^{N}[Qi^2.Ci] - N.q.l\right]$$

$$Sq^2 = \left[\frac{1}{N-1}\right].\left[\sum_{i=1}^{N}[Qi^2] - N.q^2\right]$$

3.5.4.3 Regression

This approach consists of developing a regression relationship between concentration and flows based on periods on which samples were taken. The analysis in this study involved the application of simple and multiple regression to determine whether independent variable such as rain depth and rain intensity may affect the pollutant concentration in the stormwater runoff from the specific catchment as well as to identify any trend in this relationship that could be explained scientifically (Eom et al., 2010, Donald W Meals, 2013, Marsh and Waters, 2009).

3.5.5 **Pollutant Removal Efficiency**

For this study, three pollutant removal methods were used to assess the efficiency of the DDBBO and compare the order of difference in the magnitude between them. The methods are explained in the section below (Stormwater Australia, 2014).

3.5.5.1 Efficiency Ratio (ER)

The ER is defined in term of the average event mean concentration (EMC) of pollutants calculated over the duration of the analysed storm(Stormwater Australia, 2014, EPA and ASCE, 2002). The ER was calculated using the following equation:

$$ER = 1 - \frac{Average\ Oulet\ EMC}{Average\ Inlet\ EMC}$$

Single EMC is defined as follows:

$$EMC = \frac{\sum_{i=1}^{n} V_i\, C_i}{V_i}$$

Where,

V: Volume of flow during the period (i)

C: Average concentration associated with a period (i)

n: Total number of measurements taken during the event

The arithmetic average EMC is defined as:

$$Average\ EMC = \frac{\sum_{j=1}^{m} EMC_j}{m}$$

Where,

m: Number of events monitored

3.5.5.2 Summation of Loads (SOL)

The SOL method calculates the efficiency based on ratio between the load inflows and outflows per events as shown in the equation below(Stormwater Australia, 2014, EPA and ASCE, 2002).

$$SOL = 1 - \frac{\sum_{i=1}^{n} C_{inlet}\ V_{inlet}}{\sum_{i=1}^{n} C_{outlet}\ V_{outlet}}$$

Where,

i: Duration of the sample period

n: Number of aliquots

C_{inlet} C_{outlet}: *Inlet and outlet concentrations, respectively*

V_{inlet} V_{outlet}: the Volumetric flow rate of inlet and outlet, respectively

3.5.5.3 Regression of Loads (ROL)

The ROL method defines the efficiency as the slope of a least square linear regression of inlet and outlet loads with the intercept constrained to zero (Stormwater Australia, 2014, EPA and ASCE, 2002). The equation for the ROL efficiency is as follows.

$$ROL = 1 - \frac{Sum\ of\ Outlet\ Loads}{Sum\ of\ Inlet\ Loads}$$

3.5.6 **MUSIC Model Set Up**

MUSIC is a computer software-aid developed to simulate the pollutant runoff quantities and estimate the performance removal efficiency of stormwater improvement measures in the urban catchments. This software enables designers and engineers to make a conceptual evaluation of the appropriateness of the stormwater management measures to achieve the specific stormwater removal objectives required by the legislation (eWater, 2017).

MUSIC calculates the volume runoff produced by a particular rainfall event and applying the urban catchment characteristics and its impervious fraction. It then applies that volume to the pollutant concentration originated per litre of runoff. MUSIC is a simulation tool used by Australian local governments to assess the removal performance efficiency of stormwater treatment strategies to meet specific water quality objectives over the short-term and long-term (eWater, 2017).

In the following sections is outlined the parameters required to set up the MUSIC model to simulate the specific site conditions at Glenvale to predict the treatment performance of DDBBO.

3.5.6.1 Contribution Catchment Properties Node

This node outlines the parameters required for the catchments node that discharge into the DDBBO system (eWater, 2017). These are listed and explained in the sections below:

- Catchment area and land use or surface type.
- Rainfall parameters.
- Pollutant export parameters.

3.5.6.2 Catchment Characteristics & Land Use or Surface Type

MUSIC has five general type of land uses or source nodes, which are urban, rural, forest, user-defined and imported data. An urban node can be lumped into residential, commercial and industrial land uses. These nodes can also be split into nodes representing surfaces types such as roofs, roads and ground level (eWater, 2017).

The total impervious area of a catchment node is generally determined from the analysis of the proposed or existing development layout and/or GIS and aerial images.

Soil properties (soil storage and field capacity) are also required to be defined as part of the cacthment characteristics node when known. MUSIC recommends the soil input properties obtained for BCC as a default parameters (eWater, 2017).

3.5.6.3 Rainfall-runoff parameters

The rainfall-runoff parameters used in the MUSIC modelling are derived through the calibration process using data from the Brisbane City Council's stormwater monitoring program (BCC, 2003). Table 3.3 shows the rainfall-runoff parameters recommended by MUSIC guidelines unless alternative parameters are obtained and supported by an independent peer-reviewed to demonstrate that the proposed figures are scientifically robust than the recommended values and the results require to be submitted to the responsible authority for their approval and final inclusion in the simulation process (eWater, 2017, BCC, 2003).

Table 3.3 - Recommended MUSIC rainfall -runoff parameters extracted from Water by Design (2010b), (eWater, 2017)

PARAMETER	LAND USE			
	URBAN RESIDENTIAL	COMMERCIAL AND INDUSTRIAL	RURAL RESIDENTIAL	FORESTED
Rainfall threshold (mm)	1	1	1	1
Soil storage capacity (mm)	500[10]	18	98	120
Initial storage (% capacity)	10	10	10	10
Field capacity (mm)	200	80	80	80
Infiltration capacity coefficient a	211	243	84	200
Infiltration capacity exponent b	5.0	0.6	3.3	1.0
Initial depth (mm)	50	50	50	50
Daily recharge rate (%)	28	0	100	25
Daily baseflow rate (%)	27	31	22	3
Daily deep seepage rate (%)	0	0	0	0

3.5.6.4 Pollutant export parameters

MUSIC recommends pollutant export parameters for the storm and base flow components based on information provided by Brisbane City Council and research on agricultural land use (Water by Design, 2010b, BCC, 2003). MUSIC recommends using alternative pollutant concentrations to those outlined in

Table 3.4 and

Table 3.5 wherever possible. However, the data needs to be supported by an independent peer-reviewed to demonstrate that the proposed figures are scientifically robust than the recommended values and the results require to be submitted to the responsible authority for their approval and final inclusion in the simulation process (eWater, 2017).

Table 3.4 - Pollutant export parameters for lumped catchment land uses (log10 values) extracted from Water by Design (2010b)

LANDUSE	FLOW TYPE	TSS log^{10} values		TP log^{10} values		TN log^{10} values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

Table 3.5 - Pollutant export parameters for split catchment land uses (log10 values) extracted from (Water by Design, 2010b)

FLOW TYPE	SURFACE TYPE	TSS log10 values		TP log10 values		TN log10 values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
	Urban residential						
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	1.00	0.34	-0.97	0.31	0.20	0.20
	Ground level	1.00	0.34	-0.97	0.31	0.20	0.20
Stormflow parameters	Roof	1.30	0.39	-0.89	0.31	0.26	0.23
	Roads	2.43	0.39	-0.30	0.31	0.26	0.23
	Ground level	2.18	0.39	-0.47	0.31	0.26	0.23
	Industrial						
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.45	-1.11	0.48	0.14	0.20
	Ground level	0.78	0.45	-1.11	0.48	0.14	0.20
Stormflow parameters	Roof	1.30	0.44	-0.89	0.36	0.25	0.32
	Roads	2.43	0.44	-0.30	0.36	0.25	0.32
	Ground level	1.92	0.44	-0.59	0.36	0.25	0.32
	Commercial						
Baseflow parameters	Roof	N/A	N/A	N/A	N/A	N/A	N/A
	Roads	0.78	0.39	-0.60	0.50	0.32	0.30
	Ground level	0.78	0.39	-0.60	0.50	0.32	0.30
Stormflow parameters	Roof	1.30	0.38	-0.89	0.34	0.37	0.34
	Roads	2.43	0.38	-0.30	0.34	0.37	0.34
	Ground level	2.16	0.38	-0.39	0.34	0.37	0.34

MUSIC also recommends using the stochastic option when modelling stormwater runoff and treatment process for residential and industrial development applications. The Stochastic option generates concentrations at each time-step using a model that reproduces the mean and standard deviation of the log values displayed in the text boxes. This has been set as the default option in the model as it tends to produce a more realistic interpretation of pollutant generation from the source nodes (Water by Design, 2010b).

The user can specify serial correlation (autocorrelation) for both baseflow and stormflow data. The R^2 for each should be derived from data in the log domain. The purpose of the stochastic generation option is to provide more realistic temporal variations in concentration; in other words, the concentration predicted by music at time "t" will be related to (correlated with) the concentration at the previous time-step (t-1). This results in more realistic pollutographs over time (Water by Design, 2010b, eWater, 2017).

The default autocorrelation coefficient is set to zero to allow the same model to run by different users to produce the same magnitude of loads. However, users can specify the auto-correlation coefficient if required (say if needing to calibrate against measured concentration data) and should use the values as set out in

Table 3.6. Depending on the time-step and coefficient used, there can be variations in mean annual loads for the same model run on different computers. However, the maximum difference is usually within 10% of the previous run (Water by Design, 2010b, Water by Design, 2015b).

Table 3.6 - Autocorrelation coefficient recommended by MUSIC (eWater, 2017).

Time-step	Autocorrelation Coefficient	
	Baseflow	Stormflow
6 min	0.94	0.95
12 min	0.82	0.93
30 min	0.51	0.84
1 hour	0.41	0.77
3 hour	0.37	0.62
6 hour	0.35	0.50
Day	0.31	0.27

3.5.6.5 Vegetated Swale Parameters

The vegetated swales node is used to model open channel systems which utilise vegetation to aid removal of suspended solids. Vegetated swales assist in reducing peak flows for a range of storm events as well as pollutant removal through infiltration dependent upon the underlying soil conditions. This system can be subject to high hydraulic loading, and its removal efficiency mainly is dependent on the density and height of the vegetation in the channel (Water by Design, 2015b).

3.5.6.6 Inlet Properties

This refers to the amount of water that approaches the swale that will be bypassed or treated. MUSIC indicates that the high flow bypass does not need to be specified as the software calculates the capacity of the swale based on the specified dimensions and vegetation characteristics and all inflows in excess of those figures are considered as a high flow bypass (eWater, 2017).

3.5.6.7 Storage Properties

The storage properties refer to the physical characteristics of the vegetated swale that is used to determine the water depth versus discharge relationship, which defines the hydrologic routing of the stormwater runoff through the swale (eWater, 2017).

- *Length:* This refers to the total length of the vegetated swale. The project site has two swales that discharge into the DDBBO system which are nominated as swale 1 and swale 2 for the simulation model process. Swale1 has a length of 225m, while swale 2 has a length of 55m as shown in the “As Constructed” drawings provided by TRC (RMA, 2011).

- *Bed Slope:* This refers to the longitudinal slope of the swale as a percentage. The project site has an average bed slope of 4.5% based on "As Constructed" drawings provided by TRC (RMA, 2011).

- *Base Width:* This refers to the width of the base of the trapezoidal channel. The base width for the two swales is 1m as shown in Figure 3.16 extracted from the "As Constructed" drawings provided by TRC (RMA, 2011).

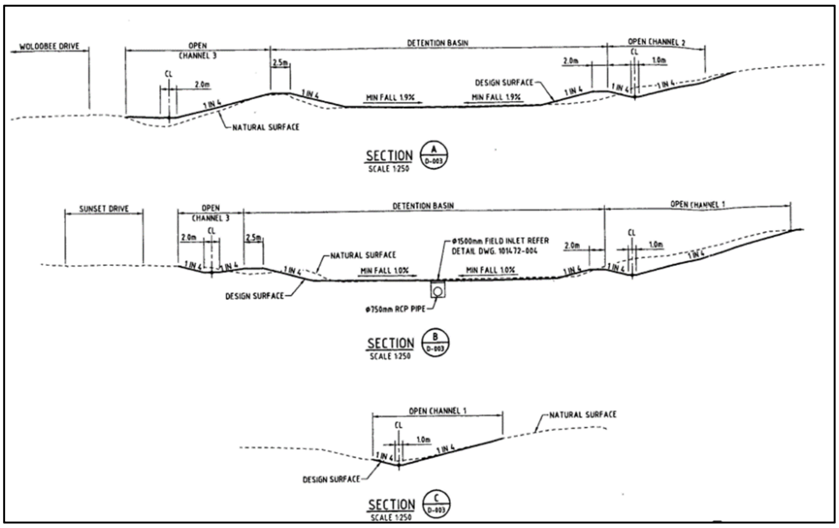


Figure 3.16 - *Cross section of the vegetated swales No 1 & 2 extracted from the "As Constructed" drawings provided by TRC (RMA, 2011)*

- *Top Width:* This defines the width of the top of the trapezoidal/ triangular. The average top width adopted for the two swales is 7.5 m extracted from the "As Constructed" drawings provided by TRC (RMA, 2011).

- *Depth:* This defines the depth of flow to the top of the channel. When the stormwater flow reaches a depth that exceeds this value, flow begins to bypass the vegetated swale, and the swale will treat only a flow rate equal to this flow. All of the stormwater flow in excess of this flow rate will bypass the swale and will not be treated by the swale. Based on the "As Constructed" drawings provided by TRC, it was adopted an average depth of 800mm for both swales. An extract of the cross-section of these swales is shown in Figure 3.16 (RMA, 2011).

- *Vegetation Height*: This refers to the height of the vegetation growing in the swale. The vegetation height is used with a set of empirical relationships to determine the Manning's n roughness of the trapezoidal channel (eWater, 2017). Based on a field investigation was adopted an average height of the vegetation in the swale of 50mm.

- *Exfiltration Rate:* Exfiltration from the vegetated swale into the underlying soil can be modelled by defining the exfiltration rate (mm/hr). Representative exfiltration rates for different soil types are provided in the Table 3.7. The water that seeps from the vegetated swale is lost from the catchment, and cannot re-enter the system downstream. Contaminants in the water that is lost to exfiltration are removed from the vegetated swale, along with the exfiltrated water and are also lost from the catchment. Representative exfiltration rates for different soil types are shown in Table 3.7 (eWater, 2017). For this investigation, it was initially assumed an exfiltration rate of 0 mm/hr.

Table 3.7 - Representative exfiltration rates for different soil types (eWater, 2017)

Soil Type	**Median particle size (mm)**	**Saturated Hydraulic Conductivity**	
		(mm/hr)	(m/s)
Gravel	2	36000	$1x10^{-2}$
Coarse sand	1	3600	$1x10^{-3}$
Sand	0.7	360	$1x10^{-4}$
Sandy loam	0.45	180	$5x10^{-5}$
Sandy clay	0.01	36	$1x10^{-5}$

3.5.6.8 Calculated Swale Properties

The vegetated swale node has additional properties that are calculated automatically (eWater, 2017). These properties are listed below:

- *Manning N: MUSIC* includes an algorithm, which models the storage-discharge relationship by applying Manning's equation. This coefficient is determined based on the vegetation height as well as the slope defined for the vegetated swale (eWater, 2017).

- *Batter Slope:* This refers to the slope of the channel (eWater, 2017).

- *Velocity:* This refers to the speed of the flow travelling down the swale, and this is calculated by applying Manning's formula (eWater, 2017).

- *Hazard:* This refers to velocity – depth (eWater, 2017).

- *Cross-sectional area*: This refers to the cross-sectional area of the swale as shown in Figure 3.17 (eWater, 2017).

- *Swale Capacity:* This refers to the capacity of swale for a given cross-sectional area and vegetation. Inflow in excess of this capacity as treated as a high flow bypass (eWater, 2017).

3.5.6.9 Advanced swale properties

The advanced properties section displays the parameters described for the treatment process in the swale (eWater, 2017).

MUSIC defines the Number of CSTR cell as 10 for swales as most swales are relatively long and thin. However, this number can be changed if a different shape system as the hydraulic efficiency of the system dependent on the shape. Refer to Figure 3.17 for details of the CSTR shapes available in MUSIC (eWater, 2017).

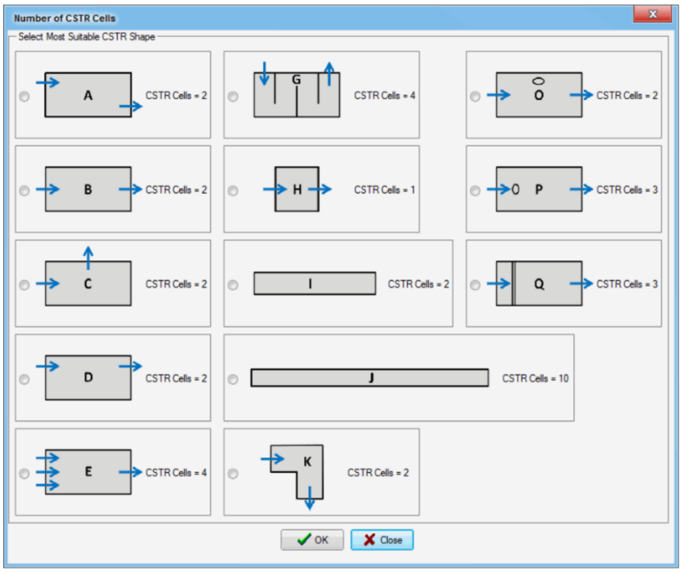


Figure 3.17 - MUSIC most suitable CSTR shapes (eWater, 2017)

K and C values are the rates at which each contaminant is treated, and the background concentration for each contaminant will be different within a vegetated swale, and different values should be used for each contaminant (eWater, 2017).

3.5.6.10 Rainwater Tank Node Parameters

This node is used to simulate the water balance and estimate the pollution reduction through sedimentation process and water reuse strategy within the tank (eWater, 2017).

The rainwater tank parameters required to be entered into the model are listed below:

- *Inlet properties:* This refers to the low and high flow bypass requirements that MUSIC sets as 0 m^3/s and 100 m^3/s, respectively (eWater, 2017).

- *Storage properties*
    - Volume below overflow pipe: MUSIC recommends that this value requires to be equal or greater than five times the maximum daily demand (eWater, 2017).
    - Depth above overflow or freeboard.
    - Surface area.

- *Outlet properties:* MUSIC recommends that overflow diameter should be equal to or greater than 90mm multiply by the square root of the number of tanks within the catchment (eWater, 2017).

- *Reuse parameters:* MUSIC provide guidelines to calculate the outdoor and indoor demands figures to be used in the model in the absence of project specific information (eWater, 2017).
    - Annual demand (KL/day).
    - Daily demand (KL/day).
    - Monthly distribution of annual demand (KL/yr).

MUSIC provides guidance for the calculations of indoor and outdoor water use demands for rainwater tanks in the absence of project specific information and local authority directions. For indoor demands, a residential occupancy rates or per capita internal water demand per person per day approaches are used as described in

Table *3.8* and

Table 3.9, respectively. For outdoor demands, an annual irrigation application between 54mm and 730mm is used for all development application in South East Queensland (SEQ), where the lower rate is applied to a private garden or low importance parkland and the higher rate to the highly managed site without water-wise plants (Water by Design, 2010b, eWater, 2017)

MUSIC also includes an option to apply irrigation only when rainfall is less than the daily evapotranspiration value (PET-rain), and this should be applied when outdoor demands are used (Water by Design, 2010b, eWater, 2017).

Table 3.8 - Residential occupancy rate extracted from Water by Design (2010b), (eWater, 2017)

DWELLING TYPE	SIZE	OCCUPANCY (PEOPLE PER DWELLING)		
		PERMANENT RESIDENTIAL[15,16]	HOLIDAY ACCOMMODATION[17]	
		Average	Peak[18]	Average[19]
Detached dwelling	1 bedroom	1.6	2	0.8
	2 bedroom	1.9	4	1.1
	3 bedroom	2.5	6	1.3
	>3 bedroom	3.4	8	1.9
	Overall mixed	2.8	6.7	1.5
Townhouse	Studio/1 bedroom	1.2	2	0.8
	2 bedroom	1.6	4	1.1
	3 bedroom	2.3	6	1.3
	>3 bedroom	3.3	8	1.9
	Overall mixed	2	5.4	1.2
Unit	Studio/1 bedroom	1.2	2	0.8
	2 bedroom	1.2	2	0.8
	3 bedroom	2.2	6	1.3
	Overall mixed	1.7	4	0.8
Resort	1 bedroom		2	0.8
	2 bedroom		4	1.1
Hotel / motel	Standard room		2	0.8
	Family room		4	1.1

Table 3.9 - Per capita internal water tank demand extracted from [Water by Design (2010b), (eWater, 2017)]

USE	UNIT	PER CAPITA INTERNAL WATER DEMAND (LITRES PER PERSON PER DAY)[22]			
		Standard residential[23]	Some water saving devices[24]	Most water saving devices[25]	Full water saving devices[26]
Permanent residential					
Laundry	Per person	50	43	35	26
Toilet	Per person	38	33	26	21
Kitchen	Per person	15	15	14	13
Bathroom	Per person	82	76	69	63
Total	Per person	185	167	144	123
Holiday accommodation (houses, units, townhouses)[27]					
Laundry	Per person	40	34	28	21
Toilet	Per person	46	40	32	25
Kitchen	Per person	15	15	14	13
Bathroom	Per person	98	91	82	75
Total	Per person	199	180	156	134
Resorts, hotels, motels[28]					
Laundry	Per person	10	9	7	5
Toilet	Per person	46	40	32	25
Kitchen	Per person	15	15	14	13
Bathroom	Per person	123	114	103	94
Total	Per person	194	178	156	137

3.5.6.11 DDBBO Parameters

The MUSIC model does not have a node that can replicate or simulate the performance efficiency of DDBBO system. However, the bioretention basin node can be slightly altered to simulate the physical characteristics of the DDBBO system as shown in the Figure 3.18 (eWater, 2017). A description of these physical parameters and adopted figures based on the specific project site conditions are to be presented in further detail in the following sections.

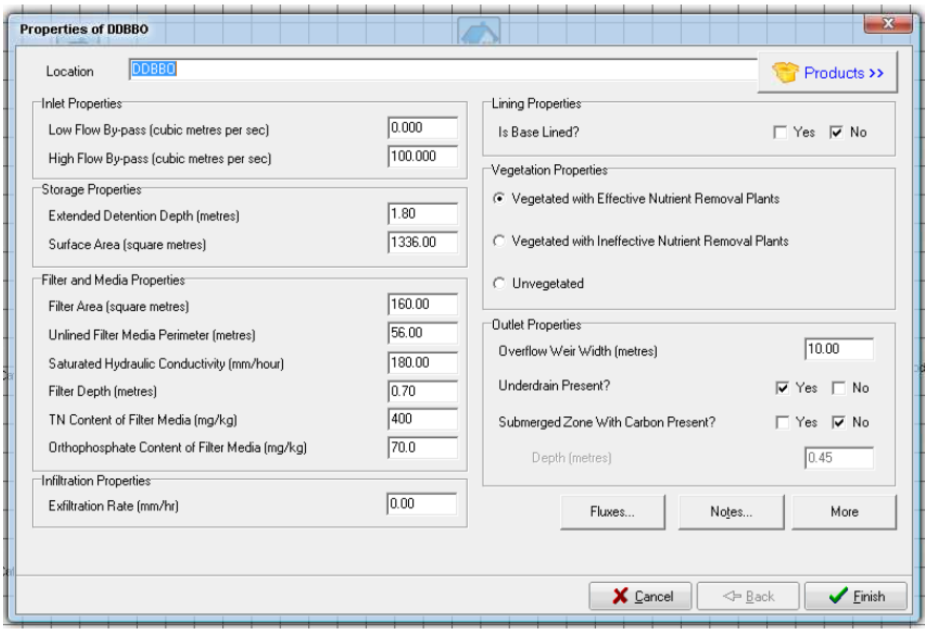


Figure 3.18 - DDBBO node in MUSIC (eWater, 2017)

3.5.6.12 Inlet Properties

This dictates the amount of water that is expected to enter the system and defines whether the basin is prone to either sediment accumulation or scour or whether flows are evenly distributed across the filter media. The physical characteristics of the inlet section define how the flows are hydrologically routed through the DDBBO basin. Low flow bypass (LFB) is the amount of stormwater runoff that approaches the system that will not be treated. All the stormwater flows above the LFB will enter and be treated by DDBBO. High flow bypass (HFB) is the amount of stormwater runoff in excess that will bypass the system and will not be treated. Only flows equal to or less than HFB will be entered and treated by the DDBBO system. For this study values of 0 m^3/s and 100m^3/s were adopted for the LFB and HFB, respectively(Water by Design, 2010b, eWater, 2017).

MUSIC assumes that the LFB and HFB co-occur (Water by Design, 2010b).

3.5.6.13 Storage Properties

This defines the physical characteristics of the surface storage above the filter media of the DDBBO. The surface storage temporarily details water to allow time for the infiltration process through the filter media (Water by Design, 2010b, eWater, 2017).

3.5.6.13.1 *Pond surface area*

This represents the area of the DDBBO system. The hydrological routing calculates the volume of water in storage during a defined storm even by multiplying the depth of water below the overflow weir by the pond surface (Water by Design, 2010b, eWater, 2017).

For this study, it was determined the filter surface from the "Construction" drawings provided by TRC and prepared by RMA (2011). The area of the filter media is 160 m^2.

3.5.6.13.2 *Extended detention depth*

This represents the maximum depth of ponding above the filter media before stormwater flow starts to discharge over the weir or outlet. The extended detention depth is 200 mm. However, to replicate the physical characteristics of the DDBBO structure, it was included an extended detention depth of 1.8m, which is equivalent to the total height of the system as shown in Figure 3.18 (RMA, 2011, RMA, 2010).

3.5.6.14 Filter and Media Properties

3.5.6.14.1 Filter area

This represents the surface area of the filter media. The filter media area usually is smaller than the pond area above it (Water by Design, 2010b). For this study, the filter media area adopted is 160 m^2, which was obtained from the civil construction drawings submitted by RMA (2011).

3.5.6.14.2 Unlined filter media perimeter

This represents the perimeter of the filter media. This input is necessary because MUSIC takes into account the infiltration that will occur through the side of the system (Water by Design, 2010b). The biofilter is 8.0 m wide and 20 m long, which is equivalent to 56 linear meters of unlined filter media (RMA, 2011).

3.5.6.14.3 The depth of the filter media

This represents the depth of the filter media. This typically consists of sand and loam mix that support vegetation and is integral removing of pollutants. Filter media are usually between 500mm and 1,000mm. The DDBBO system installed in Glenvale has a filter media depth of 700 mm, which is the minimum depth recommended for filter media with trees as outlined in the Bioretention Technical Design Guidelines prepared by Water by Design (2014), (eWater, 2017).

3.5.6.14.4 TN content of the filter media (mg/kg)

This represents the nitrogen content presented in the filter media. The CRCWSC Biofiltration guideline recommends that the TN content should be below 1000 mg/kg for optimal treatment performance (Deletic et al., 2015). Unfortunately, the filter media characteristics of the installed biofilter are unknown. Therefore, a conservative value between 400 – 800 mg/kg was adopted with the objective of comparing the differences between the recommended design assumptions and the observed data.

3.5.6.14.5 Orthophosphate Content of the filter media

This represents the orthophosphate content presented in the filter media. The literature indicated that orthophosphate content exceeding 80 mg/kg is likely to leach P from the filter media. Therefore, a value of 60 -80 mg/kg is recommended as this provides an optimal treatment performance as long as the selected plants can establish satisfactorily (Water by Design, 2010b, eWater, 2017, Water by Design, 2015b, Water by Design, 2014, Deletic et al., 2015). For this study a value of 70 mg/kg.

3.5.6.14.6 Vegetation Properties

The vegetation is a critical component of the bioretention system for the pollutant removal efficiency of the system. (Deletic et al., 2015) suggests from recent study researches that particular species of plants can be far more effective at removing pollutants than others. As such, MUSIC recommends that bioretention systems be planted with plants that have been shown to be effective in pollutant removal wherever possible (eWater, 2017). Guidance on plants suitability are provided in the CRCWSC Biofiltration guideline or local and regional researches undertaken for recognised public or private organisations (Water by Design, 2010a, Deletic et al., 2015).

No information was available for this study to confirm the plant selection undertook by the landscape consultant.

3.5.6.14.7 Infiltration Properties

3.5.6.14.7.1 Exfiltration rate

Infiltration into the underlying soil is given by the exfiltration rate (mm/hr). The water that exfiltrates from the infiltration system is lost to the treatment train and does not re-enter the system downstream. MUSIC assumes that the contaminants in the water lost are also removed from the catchment (eWater, 2017). In this study is assumed an exfiltration rate of 0 mm/hr.

3.5.6.14.7.2 Advanced Properties

The advanced properties section displays the hydraulic characteristics for the overflow weir structure as well as the parameters that describe the treatment process in the system including the soil type, porosity and exfiltration rate (eWater, 2017).

- *K and C Value:* This refers to the exponential decay rate constant (K) and the background concentration for TP, TN and TSS. The rate at which the pollutants are treated and the background concentrations are different within a bioretention basin, and therefore different values should be adopted. In this study, the observed EMC was used as a background concentration, and the k values were interpolated based on those values. The values used in the model are shown in Figure 3.19 (eWater, 2017).

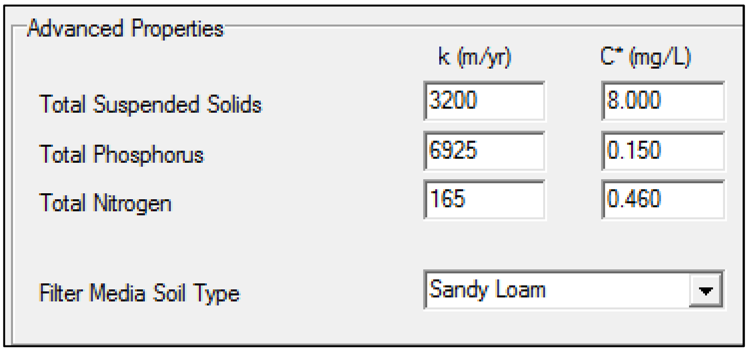


Figure 3.19 – K & C values used in MUSIC to replicate the site conditions (eWater, 2017)

- *Filter Media Soil Type:* This refers to the filter media zone of the bioretention (eWater, 2017). The literature suggests the use of loamy sand, sandy loam and sand (Deletic et al., 2015). In this study, it was assumed a sandy loam as specified in the RMA (2011) report and construction drawings as no additional information was available at the time of this research to confirm supplier material certification when the system was built in 2013.

- *Weir Coefficient:* MUSIC models the overflow weir as a sharp-crested weir and the equation is defined as follow (eWater, 2017):

$$Q = C_w . L . H^{3/2}$$

Where,

Q: Discharge over the weir

CW: Weir coefficient

L: Overflow weir width

H: Height of pond above the extended detention depth

The overflow weir width adopted is 5.7m, which is obtained from the 1500 mm diameter field inlet (RMA, 2011, RMA, 2010).

- *The porosity of the filter media:* This defines the voids ratio of the filter media based on the soil characteristics (eWater, 2017). For this biofilter was specified a say loam which has a typical porosity between 0.35 -0.4 as recommended in the report prepared by RMA (2011). A value of 0.35 was adopted in this study.

- *Porosity of submerged zone:* This defined the voids ratio of the submerged zone. MUSIC provides a tooltip with a guide with the appropriate values to use. However, no submerged zone was specified for the biofilter. Therefore, a value of 0 was adopted for the study.

- Horizontal Flow Coefficient: This defines the exfiltration rate of the wall of the DBBOO system from the unlined perimeters. MUSIC recommends that the default value can only be modified if there is a peer-reviewed published data that supports the modification. There is no current data available to challenge the default values. Therefore, those recommended were adopted in this study

3.5.6.14.7.3 Evapotranspiration Losses

MUSIC has developed a sophisticated ratio between potential evapotranspiration (PET) and the measured ET based on recent field investigations (Winston et al., 2016). This scaling factor takes into account seasonal variation on a monthly basis. The recommended value for the PETS scaling factor is 1.

3.6 Monitoring Sampling Challenges

A monitoring program as it was proposed in this study involves different monitoring challenges, and a list of these challenges encountered are presented below:

- Due to the proposed location of the stations, there was a high likelihood for the equipment to be vandalised. Therefore, it was defined to avoid that to build housing enclosure fitted with TRC and SQU images that together with a research project socialisation for the residents living near the system will help us to reduce or minimise such a risk

- Two new water samplers units from Campbell Scientific were purchased to undertake the monitoring sampling procedure of the DDBBO system. Unfortunately, there were no sensors compatible with the units and a procurement process to purchase the sensors were required, which impacted the commence of the monitoring program as additional training was required to program them into the datalogger, which also impacted the monitoring duration.

- The station at the outlet of the system was placed in a pit in a confined space with hindered the installation process. This also triggered the need to install the pressure transducer on the weir plate and in an upright position to avoid or minimise the turbulence and its effect on the height reading.

- There was also a problem with the power supply required for the water samplers and datalogger for which some samples could not be collected or where collected but not recorded by the datalogger for some of the storm events presented during the study.

- Sample collection and distribution was challenging. Therefore, a protocol collection, transport and storage were included to avoid any issue with gathering and analysing the information.

- Event monitoring in small catchment was challenging undertaking initially and getting the right logging interval to capture the hydrograph was very difficult. Therefore, to address this issue, it was required to undertake short training in the use of the equipment as these were brand new and USQ did not have staffs that were familiar with the sampling units and programming requirements. After that, different programming interactions were required, and finally, a proportional volume approach was adopted.

- As this study was highly dependent on factors such as programming of the sampling units, water testing and use of proprietary software such as MUSIC and DRAINS required the adjustment of the original research programme that resulted in a significant extension of time to complete the program.

- The change of the supervisors during the project was another external factor that impacted the research programme of the study resulting in a more time required to complete the study.

4 Data Analysis and Discussion

4.1 Introduction

The performance of the DDBBO system located at Glenvale in Toowoomba will be evaluated in term of its water quality improvements. In Chapter 2, it was discussed the different sources of pollutants presented within our urban catchment and was also identified the potential benefits that DDBBO system may offer as a WSUD measure in our urban environments.

The objective of this chapter is to evaluate the water quality performance of the DDBBO system. For which, analytical and statistical procedures were applied to validate the dataset and determine the effectiveness of the system for the removal of critical pollutants such as TSS, TN and TP. The accuracy of the MUSIC model to predict pollutant concentrations and removal efficiencies of the DDBBO system was also evaluated, and this is outlined in Section 4.5. The water levels obtained by the sensors through the weir structures installed at the inlet and outlet of the DDBBO system were converted into flow discharges by applying the weir equations. However, it is noted that at the end of the monitoring process, it was determined that the inlet weir was small forcing some of the flows for some of the monitored storm events to overtop it, which might lead to errors in the data for which an additional validation process was implemented in this study. This mainly consisted in simulating the site condition for the inlet into DRAINS model to obtain a curve rating equation to adjust the flow discharges. These adjusted figures were then used to calculate in Excel the storm volume and pollutant loads for each monitored event.

The data obtained from the USQ and TRC laboratories were processed in Excel and converted into event mean concentrations (EMC's) and loads (kg/Ha). Different statistical analysis methods were developed to determine the relationship between flow discharges and pollutant concentrations. Different load estimation techniques were also applied with the objective of determining the order of difference in magnitude between them. All these figures were then compared with previous field research studies undertook throughout Australia and internationally.

As part of this research, it was also proposed to simulate the project site into MUSIC model to compare the simulated results against the observed data and determine the level of accuracy of the model to predict pollutant concentratrions and removal efficiency of the DDBBO system.

4.2 DRAINS

4.2.1 DRAINS Model Parameters

DRAINS model was used to validate the observed flow peak discharges at the inlet as the weir structure used for the inlet was considered to be small based on the storm events and heights recorded in the datalogger. The objective of undertaking this validation process was to increase the level of reliability and confidence in the data used to estimate the pollutant loads and assess the removal efficiency of the DDBBO system.

For the simulation process in DRAINS model, the following parameters were adopted:

Soil Type	Type C or 3
Area Depression Storage	✓ Paved Area = 1 mm ✓ Supplementary Area = 0 mm ✓ Grassed Area = 2 mm

Catchment Areas	The total catchment area was obtained from the information extracted from Online mapping and as constructed plan provided by TRC
Time of Concentration	The length (650m) and slope (2.5%) of gutter was determined by using Toowoomba Regional Council's (TRC) Online Mapping information and as constructed plans. The adopted time of concentration used in the DRAINS model was 15 min

4.2.2 DRAINS model output and its use in the analysis

The DRAINS outputs used for the validation process were the hydrograph and storage volume tables presented in section 4.3, which discusses in more detail the outcomes of this process. The information was exported into EXCEL and then collated and processed with the field data with the objective of comparing the observed flow discharges against the simulated results under the same water level conditions for each monitored stormwater event. The information was then plotted to establish the water discharge relationship between these two values as shown in *Figure 4.8*.

4.3 Establishment of water discharge relationship

The discharge curve rating approach was used in this study to validate the monitored water levels and peak flow discharges by utilising the weir equations described in section 3.3.3 against the prediction figures obtained in DRAINS model. However, it is noted that this approach was used only to validate the inflows as the existing site conditions at the inlet were easily replicated in the model. On the other hand, the outlet conditions are influenced by a combination of variables such as the infiltration rate, bypass and underdrains hydraulic regime, just to mention a few, which made the simulation process difficult to be replicated and further investigation and analysis will be required to undertake this process.

The first step was to plot the hydrographs for the observed data and predicted DRAINS results for each of the monitored storm events and these results are shown from Figure 4.1 to Figure 4.7. As demonstrated on the graphs, the peak flow discharges and its corresponding peak time were consistent between the observed and predicted values, except for the monitored events recorded on 27.02.2018 and 02.04.2015. Therefore, it was defined to exclude these two events from the process of obtaining the water discharge equation as the reason behind the significant mismatch is unknown and are outside of the scope of this work.

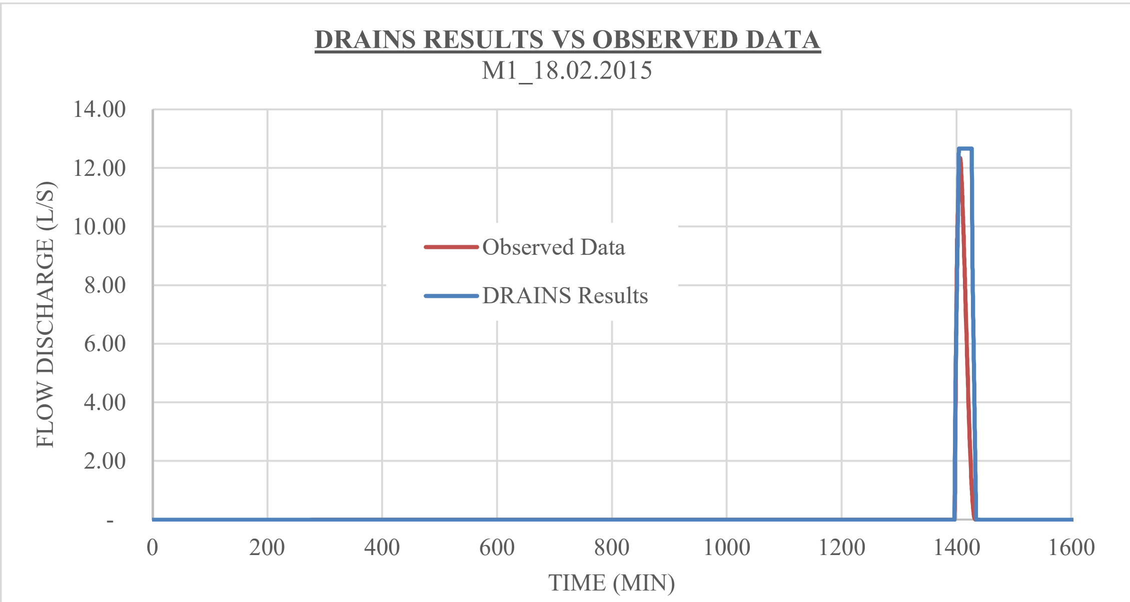


Figure 4.1 - DRAINS results vs observed data M1_18.02.2018

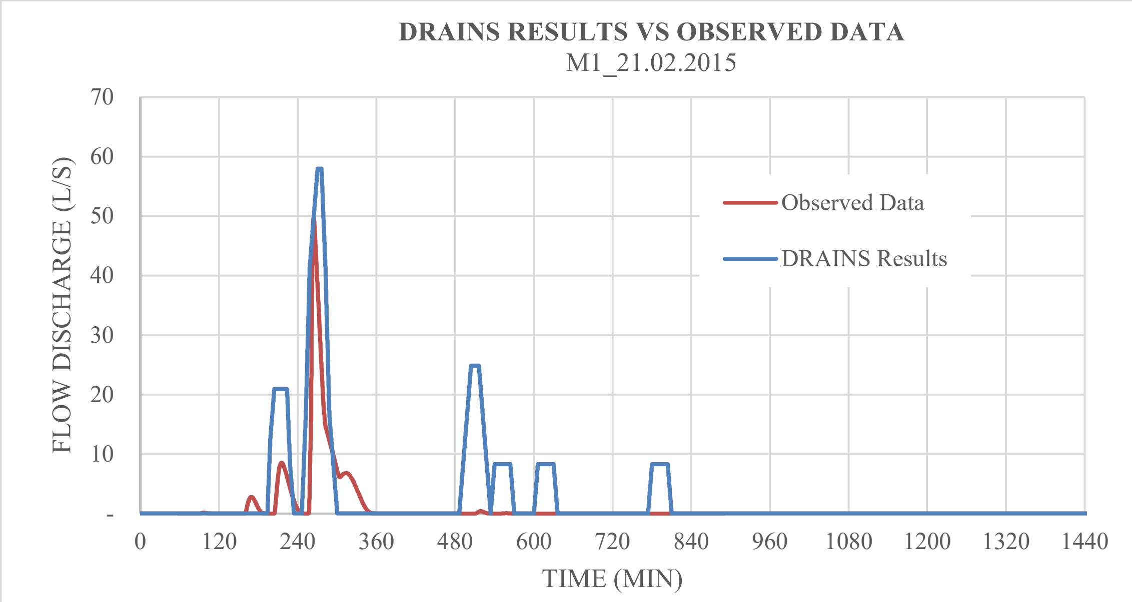


Figure 4.2 - DRAINS results vs observed data M1_21.02.2015

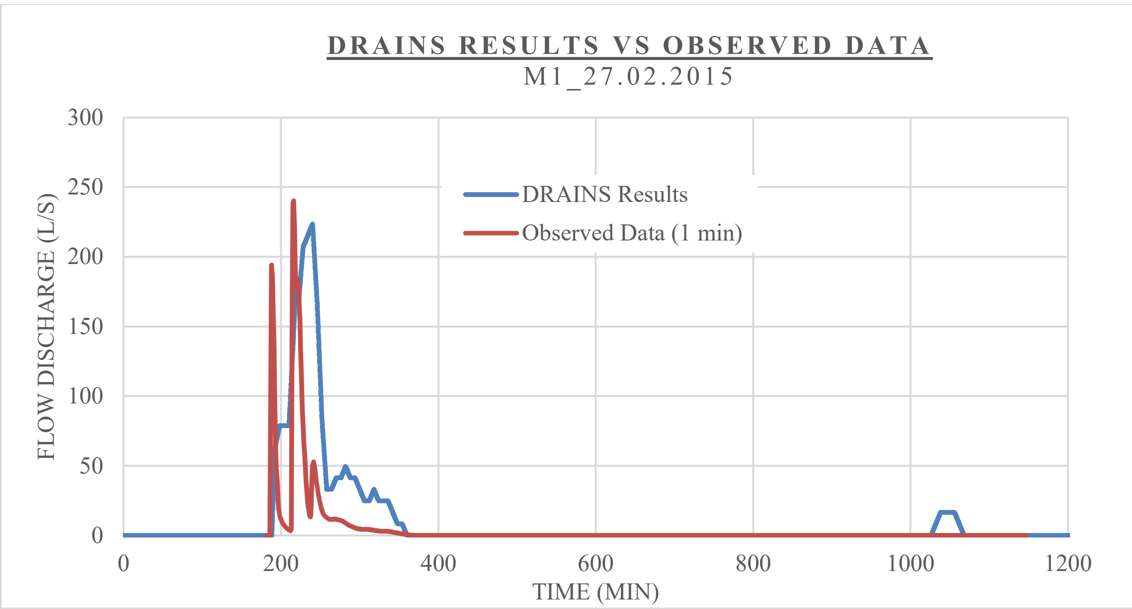


Figure 4.3 - DRAINS results vs observed data M1_27.02.2015

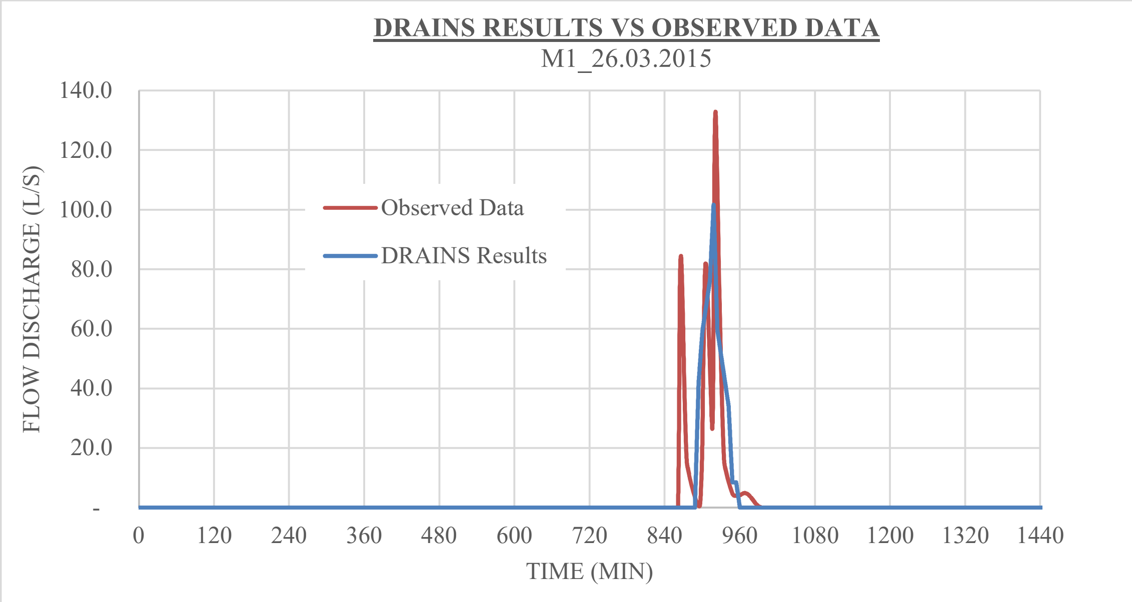


Figure 4.4 - DRAINS results vs observed data M1_26.03.2015

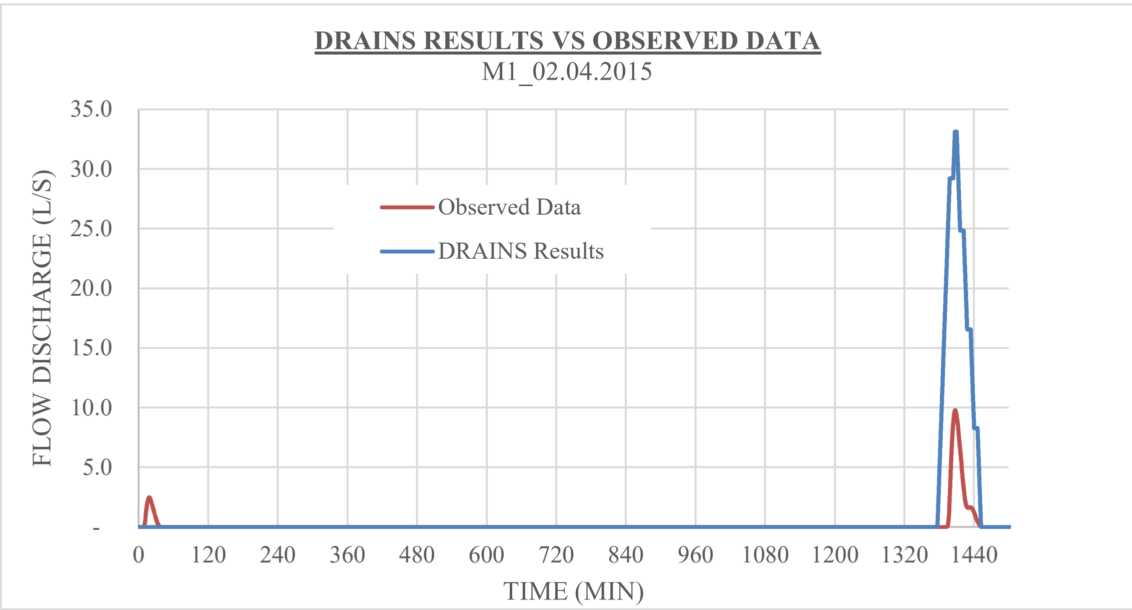


Figure 4.5 - DRAINS results vs observed data M1_02.04.2015

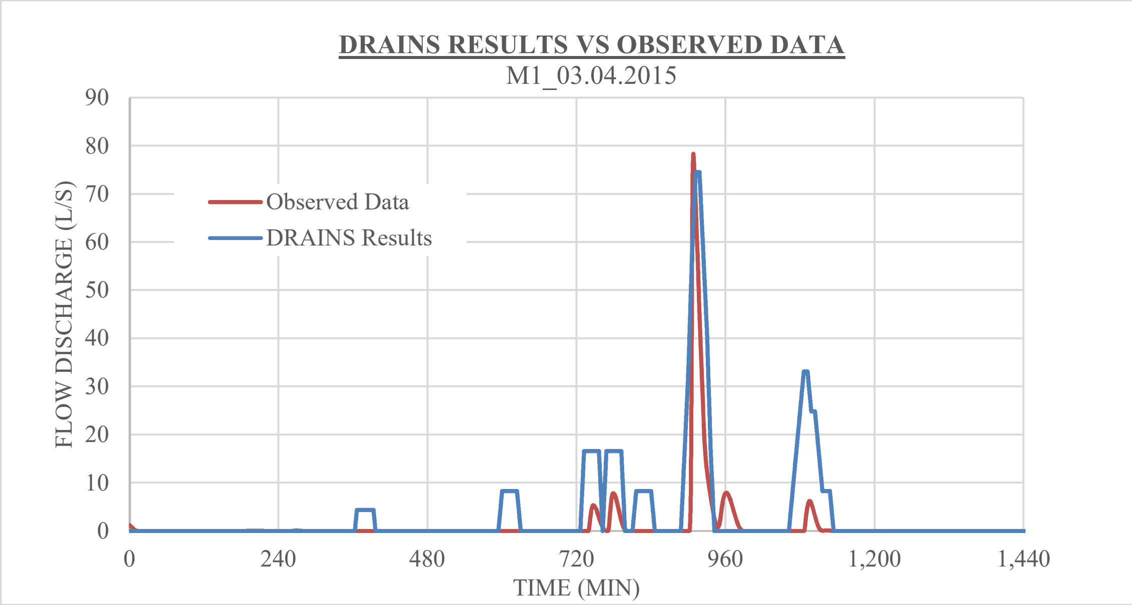


Figure 4.6 - DRAINS results vs observed data M1_03.04.2015

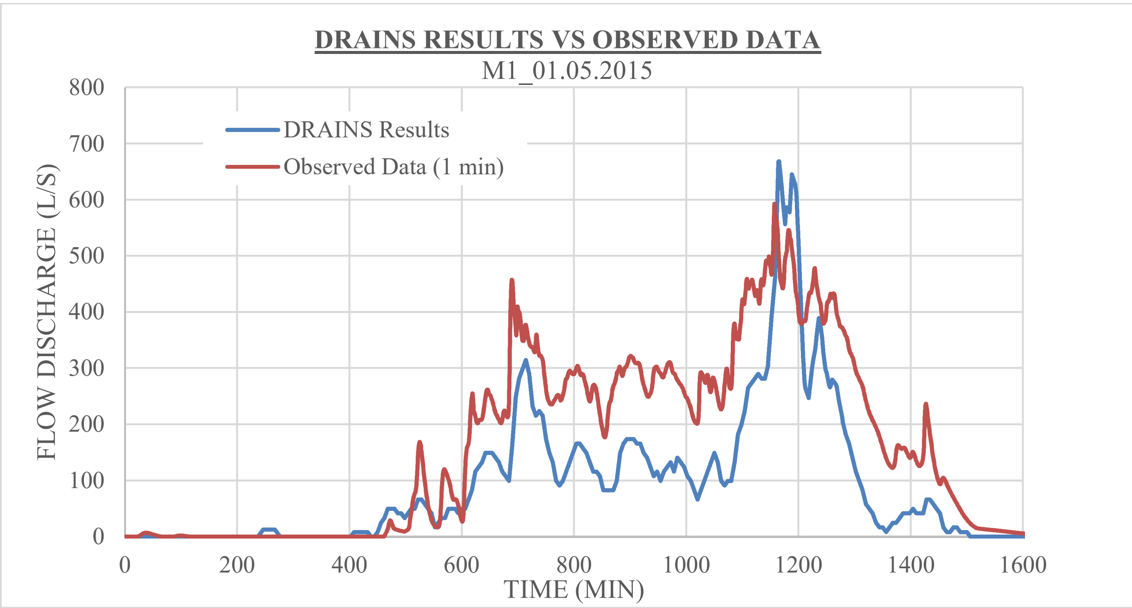


Figure 4.7 - DRAINS results vs observed data M1_01.05.2015

The simulated and observed peak flow rates were plotted as shown in Figure 4.8 to determine, which was the best fit between the exponential and polynomial techniques. The calculations showed R-square values of 0.89and 0.96 for the exponential and polynomial methods, respectively. This means that the equation with the higher R-square value, which is slightly provided by the polynomial equation, is the best fit for the data set (water level vs flow discharge). However, the exponential provide a better fit for the hydrographs once these simulation figures were plotted against the observed dataset. Therefore, the exponential equation was adopted to adjust the obsserved flow discharges. These results were then used to determine the pollutant load estimation and volume as described in section 4.3.

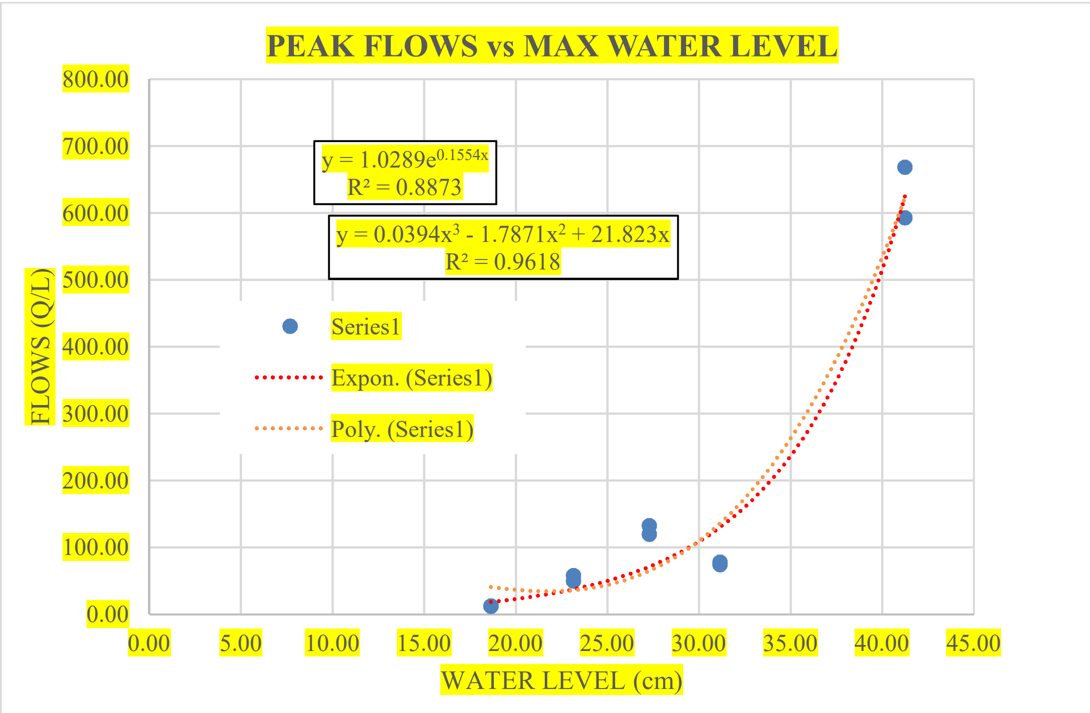


Figure 4.8 - Discharge curve rating equation

Table 4.1 shows the dataset used to obtain the water discharge relationship between the observed data and DRAINS results.

Table 4.1 - Water Levels vs Peak Flows Discharge for the Observed Data and DRAINS Results

Date	Weir Water Level (cm)	Observed Q (L/s) 1 min	DRAINS Peak Flows L/s
18.02.2015	18.64	12.34	12.67
21.02.2015	23.15	49.90	57.98
26.03.2015	27.28	132.89	119.62
03.04.2015	31.15	78.30	74.54
01.05.2015	41.24	592.79	668.51

The NSC and RMSE approaches were also used to validate and measure the accuracy of the DRAINS model to predicts the flow discharges. An average value of 0.9923 for the NSC coefficient was obtained. Individual values for each monitored events were also calculated, and the results are shown in

Table 4.2. As can be seen, all the events used for obtaining the water discharge relationship reported values very close to 1. This indicates that the model can be considered to be an accurate predictor of the observed flow discharge as the majority of the values are very close to 1.

Table 4.2 - NSC results per event

Event Date	NSC
18.02.2015	1.0000
21.02.2015	0.9958
26.03.2015	0.9988
03.04.2015	0.9981
01.05.2015	0.9688

In summary, it was concluded that DRAINS predictions for small and larger flows were relatively accurate in term of the duration and peak flow rate. However, it is noted that in some cases, the model showed a tendency to overestimate or underestimate the peak flow slightly and those values were excluded from the process of obtaining the water discharge relationship. The reasons for what the model does that are very unclear, and this investigation is outside of the scope of works of this study. Therefore, future research is recommended to be undertaken using a range of rainfall intensities to investigate this in more detail and to draw more conclusive arguments of why this happens. Figure 4.9 showed the comparison between the observed and predicted flow discharges for easy visualisation of the results.

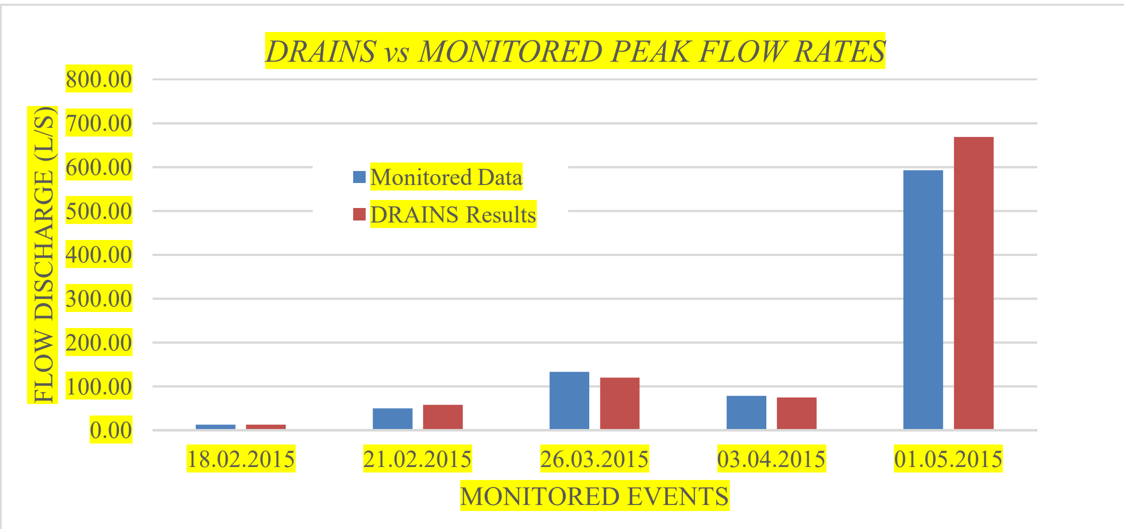


Figure 4.9 - Peak flows discharge for the observed data and DRAINS results

4.4 Stormwater pollutant data

4.4.1 Pollutant Data Collection

For this study six (6) random water samples were collected for each of the seven (7) monitored events and subsequently transported at the TRC NATA accredited laboratory in accordance with the ISO/IEC 17025 for testing of TP, TSS and TN concentrations. The results obtained from the testing and analysis process are in Table 4.3

Table 4.3 - TRC pollutant concentration testing results for TP, TN and TSS

Monitored Date	TP mg/L	TSS mg/L	TN mg/L
18-Feb-15	0.18	2.00	0.03
18-Feb-15	0.24	2.00	0.03
18-Feb-15	0.11	4.00	0.03
18-Feb-15	0.10	10.00	0.50
18-Feb-15	0.10	5.00	0.40
18-Feb-15	0.08	10.00	0.70
21-Feb-15	0.08	2.00	0.30
21-Feb-15	0.13	2.00	0.30
21-Feb-15	0.13	8.00	0.30
21-Feb-15	0.11	7.00	0.30
21-Feb-15	0.09	11.00	0.30
21-Feb-15	0.12	10.00	0.30
27-Feb-15	0.09	2.00	0.40
27-Feb-15	0.12	2.00	0.40
27-Feb-15	0.11	4.00	0.30
27-Feb-15	0.22	3.00	0.30
27-Feb-15	0.16	2.00	0.30
27-Feb-15	0.17	2.00	0.30
26-Mar-15	0.28	71.00	1.50
26-Mar-15	0.26	36.00	1.00
26-Mar-15	0.18	22.00	1.00
26-Mar-15	0.19	22.00	0.90
26-Mar-15	0.19	13.00	0.80
26-Mar-15	0.19	6.00	0.80
02-Apr-15	0.16	18.00	0.30
02-Apr-15	0.15	5.00	0.30
02-Apr-15	0.10	2.00	0.30
02-Apr-15	0.11	2.00	0.80
02-Apr-15	0.11	2.00	0.70
02-Apr-15	0.11	2.00	0.50
03-Apr-15	0.15	2.00	0.30
03-Apr-15	0.15	8.00	0.30
03-Apr-15	0.14	10.00	0.30
03-Apr-15	0.17	13.00	0.30
03-Apr-15	0.11	2.00	1.00
03-Apr-15	0.11	2.00	0.80
01-May-15	0.13	2.00	0.30
01-May-15	0.12	2.00	0.30
01-May-15	0.13	2.00	0.30
01-May-15	0.25	2.00	0.30
01-May-15	0.29	2.00	0.30
01-May-15	0.31	2.00	0.30

Further testing was undertaken at SQU laboratory with the objective to get familiar with some of the pollutant testing techniques and to determine whether a correlation existed between TP, TN and TSS and the additional pollutants such as Nitrate, Phosphate, T Kjeldahl Nitrogen and Turbidity. The results of the testing process are presented in *Table 4.4 - Additional pollutants testing results undertook at USQTable 4.4*.

Table 4.4 - Additional pollutants testing results undertook at USQ

Monitored Date	Nitrate mg/L	Phosphate mg/L	T Kjeldahl Nitrogen mg/L	Turbidity NUT
18-Feb-15	0.09	0.36	0.30	20.45
18-Feb-15	1.20	0.41	0.03	20.10
18-Feb-15	1.10	0.20	0.03	18.45
18-Feb-15	0.90	0.14	0.30	21.95
18-Feb-15	1.30	0.10	0.03	28.30
18-Feb-15	0.60	0.00	0.03	14.00
21-Feb-15	0.60	0.08	0.30	4.55
21-Feb-15	4.20	0.10	0.30	5.21
21-Feb-15	4.10	0.10	0.30	4.15
21-Feb-15	3.90	0.09	0.30	2.59
21-Feb-15	4.20	0.08	0.30	4.28
21-Feb-15	3.70	0.08	0.30	5.63
27-Feb-15	3.60	0.06	0.30	12.00
27-Feb-15	0.25	0.08	0.30	6.10
27-Feb-15	0.18	0.10	0.30	11.95
27-Feb-15	0.14	0.26	0.30	3.86
27-Feb-15	0.79	0.12	0.30	5.79
27-Feb-15	0.70	0.19	0.30	0.00
26-Mar-15	0.47	0.00	0.40	55.55
26-Mar-15	0.60	0.00	0.30	39.25
26-Mar-15	0.40	0.00	0.30	29.85
26-Mar-15	0.50	0.10	0.30	32.40
26-Mar-15	0.50	0.09	0.30	36.40
26-Mar-15	4.40	0.11	0.30	32.00
02-Apr-15	3.70	0.16	0.30	15.85
02-Apr-15	0.40	0.20	0.30	11.60
02-Apr-15	0.40	0.12	0.30	11.85
02-Apr-15	0.30	0.45	0.30	10.85
02-Apr-15	0.70	0.75	0.30	10.05
02-Apr-15	0.80	0.34	0.30	15.85
03-Apr-15	1.00	0.18	0.30	15.75
03-Apr-15	0.03	0.10	0.30	17.85
03-Apr-15	0.02	0.10	0.30	19.35
03-Apr-15	0.03	0.10	0.30	23.30
03-Apr-15	0.03	0.10	0.30	16.05
03-Apr-15	0.03	0.17	0.30	21.10
01-May-15	0.69	0.06	0.30	10.25
01-May-15	0.62	0.05	0.30	12.05
01-May-15	0.60	0.05	0.30	13.70
01-May-15	1.01	0.10	0.30	21.30
01-May-15	1.09	0.11	0.30	15.60
01-May-15	1.20	0.12	0.30	15.80

The statistical analysis of these pollutant concentration results is discussed in detail in section 4.4.3. However, a brief description of the investigated pollutants is shown below:

- ***Total Phosphorous (TP):*** The highest TP concentration obtained for the monitored samples was 0.31 mg/L reported on 01.05.2015, and the lowest value was 0.08 mg/L reported on the 18.02.2015 and 21.02.2015. The mean value for the P concentration was 0.15 mg/L. Based on WQO benchmark values for mixed urban/rural land use set by DEHP (2009), it was found that from the 42 tested samples at the inlet and outlet of the DDBBO system, only 9.5% of the samples exceeded the typical value of 0.25 mg/L, 95% exceeded the lower value of 0.08 mg/L, and no value exceeded the upper limit levels.

- ***Total Nitrogen (TN):*** The maximum TN concentration reported for the monitored samples was 1.50 mg/L on 26.03.2015, and the minimum value was reported on the 18.02.2015. The mean value for the N concentration was 0.46 mg/L. It was found that only 20% of the samples were in exceedance of the lower value of 0.7 mg/L and no values exceeded the typical and upper-level benchmark indicated in the QWQC_2009 for a mixed urban/rural land use.

- ***Total Suspended Solids:*** The highest value of 2 mg/L was found on all the monitored events except for those recorded on 26.03.2015. The mean value of the TSS concentration was 8.05 mg/L. It was found that only 20% of the tested samples were above the lower limit level indicated in the QWQC_2009 and no values were found to be above the typical and upper limit levels.

- ***Phosphate:*** The highest observed phosphate concentration was 0.75 mg/L and was recorded on 02.04.2015. The lowest observed phosphate concentration was 0.05 mg/L and was recorded on 01.05.2015. The mean value for the 42 samples was 0.16 mg/L. Based on the QWQC_2009, it was concluded that 85% of the samples exceeded the lower limits benchmark of 0.08 mg/L. While 15% of the samples exceeded the recommended typical benchmark and no samples exceeded the upper limit benchmark.

- ***Nitrate:*** The nitrate concentrations for the tested samples range from a maximum of 4.4 mg/L to a minimum of 0.02 mg/L with a mean value of 1.2mg/L. The highest nitrate concentration observed on 26.03.2015 while the lowest was observed 03.04.2015.

- ***Turbidity:*** The highest turbidity value was 55.6 N.U.T and was reported on the event recorded on 26.03.2015, while the lowest was 2.6 N.U.T observed in the monitored event recorded on 21.02.2015. The mean value obtained for this variable was 16.90. It was found that the turbidity levels were lower than the recommended water quality levels set by the QWQC_2009.

- ***T-Kjeldahl Nitrogen:*** The concentration range from a maximum of 0.40 mg/L to a minimum of 0.03 mg/L with a mean value of 0.3 mg/L. The highest concentration was recorded on 26.03.2015, and the lowest was recorded 18.02.2015.

4.4.2 **Analysis of Event Mean Concentration (EMC)**

EMC's were calculated at the inlet and outlet of the DDBBO system at Glenvale for each monitored event. The calculation mainly consisted of weighting the pollutant concentrations for TP, TN and TSS obtained from the TRC laboratory testing at each monitoring station against its corresponding runoff volume measured through the weir structures and the height produced by the sensors. The EMC results for TSS, TN and TP are presented in Table 4.5.

Table 4.5 - EMCs results for TSS, TN and TP at Glenvale DDBBO system

Event Date	**TP**		**TN**		**TSS**	
	Inlet (mg/L)	**Outlet (mg/L)**	**Inlet (mg/L)**	**Outlet (mg/L)**	**Inlet (mg/L)**	**Outlet (mg/L)**
18.02.2015	0.16	0.09	0.55	0.03	2.00	7.83
21.02.2015	0.12	0.11	0.30	0.30	5.42	8.97
27.02.2015	0.10	0.17	0.33	0.30	3.14	2.07
26.03.2015	0.20	0.19	1.07	0.83	32.35	13.04
02.04.2015	0.11	0.11	0.25	0.66	6.24	2.00
03.04.2015	0.14	0.11	0.30	0.84	8.77	2.47
AVERAGE	**0.14**		**0.48**		**7.86**	
MEDIAN	**0.12**		**0.31**		**5.83**	

The results in Table 4.5 shows that there was evidence of some treatment effects by DDBBO system with significant variations between the inflow and outflows. For instance, in some cases, some of the monitored events showed higher TP, TN and TSS concentrations for the outflows to those reported for the inflows. Higher TN values of approximately three time the inflow concentrations were reported at the outflows on the monitored events recorded on the 02.04.2015 and 03.04.2015. This might be explained by denitrification processes within the filter, and/or organic decomposition of grass clippings left during maintenance activities. Higher TSS values were also reported on the monitored events recorded on 18.02.2015 and 21.02.2015 that might be attributed to resettling of sediment particle at the top of the biofilter or due to erosion process of the filter media or vegetated swales network connected to the system. A small increase in the concentration of TP was also found on the monitored event recorded on 27.02.2015 that might also be attributed to the inadequate maintenance processes. Unfortunately, the results of this research cannot be considered as conclusive, and further data needs to be gathered to assess the impact that maintenance process may impose upon these systems.

As part of the EMC's analysis, it was prepared Box and Whisker Plots for the TSS, TN and TP concentrations to show the treatment variability described above and identify whether there is an outlier or not.

Figure 4.10 shows that all TP concentrations were below 0.22 mg/L and the median and mean concentrations were below 0.12 mg/L and 0.14 mg/L, respectively. It can also be seen a slight decrease in concentrations between the inflows and outflows figures, but no outlier was found in the data.

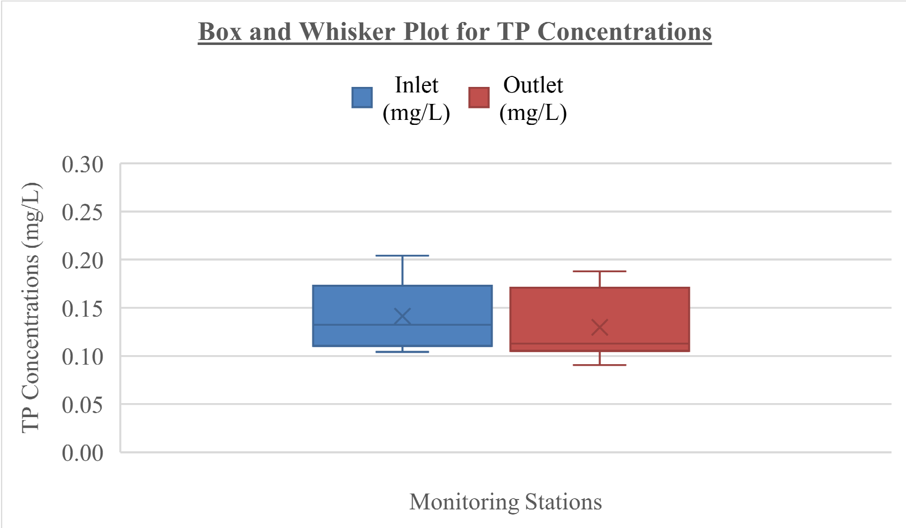


Figure 4.10 - Box and whisker plot for TP concentrations

Figure 4.11 shows that TSS had the highest concentrations variability at the inlet location. The TSS inflows values fluctuated between 32 mg/L and 2 mg/L and the median and mean TSS concentrations were below 5.5 mg/L and 7.5 mg/L, respectively. The figure shows a significant decrease in concentration between the inflows and outflows, but no outliers were found in the data.

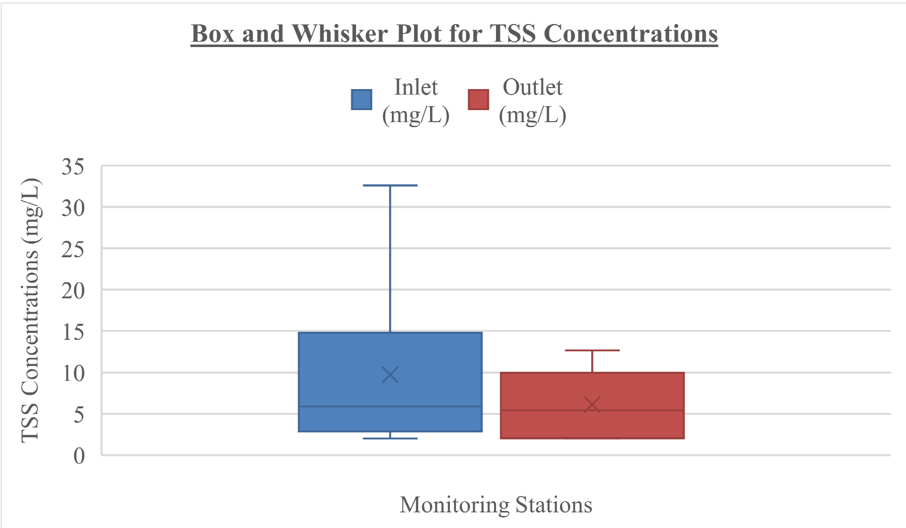


Figure 4.11 – Box and whisker plot for TSS concentrations

Figure 4.12 shows that TN concentrations are higher in the outflows when compared with the inflows. It also shows an approximately 60% increase in median concentration between them. All TN concentrations were below 1.1 mg/L, and no outlier was found for the data.

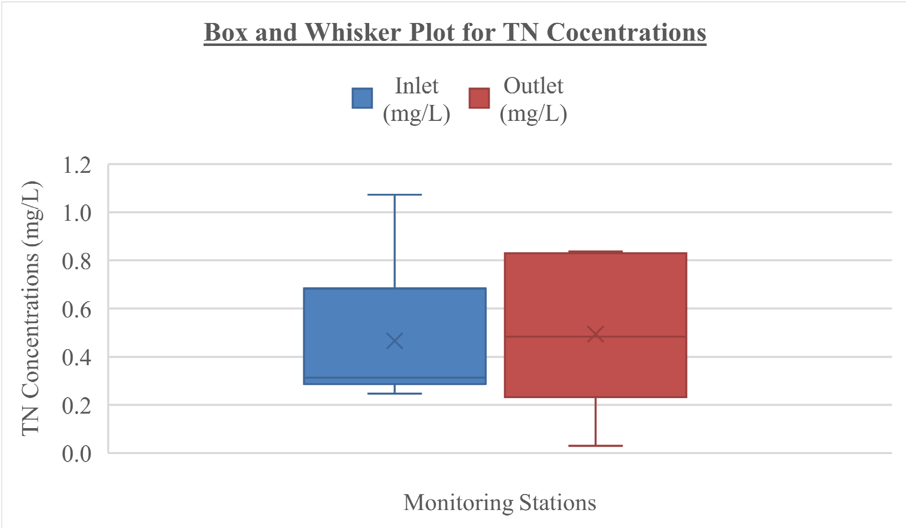


Figure 4.12 - Box and whisker plot for TN concentrations

The calculated average EMC's for the monitored events were compared with local and global results found in the literature review. The results are shown in Figure 4.13, Figure 4.14 and Figure 4.15, respectively.

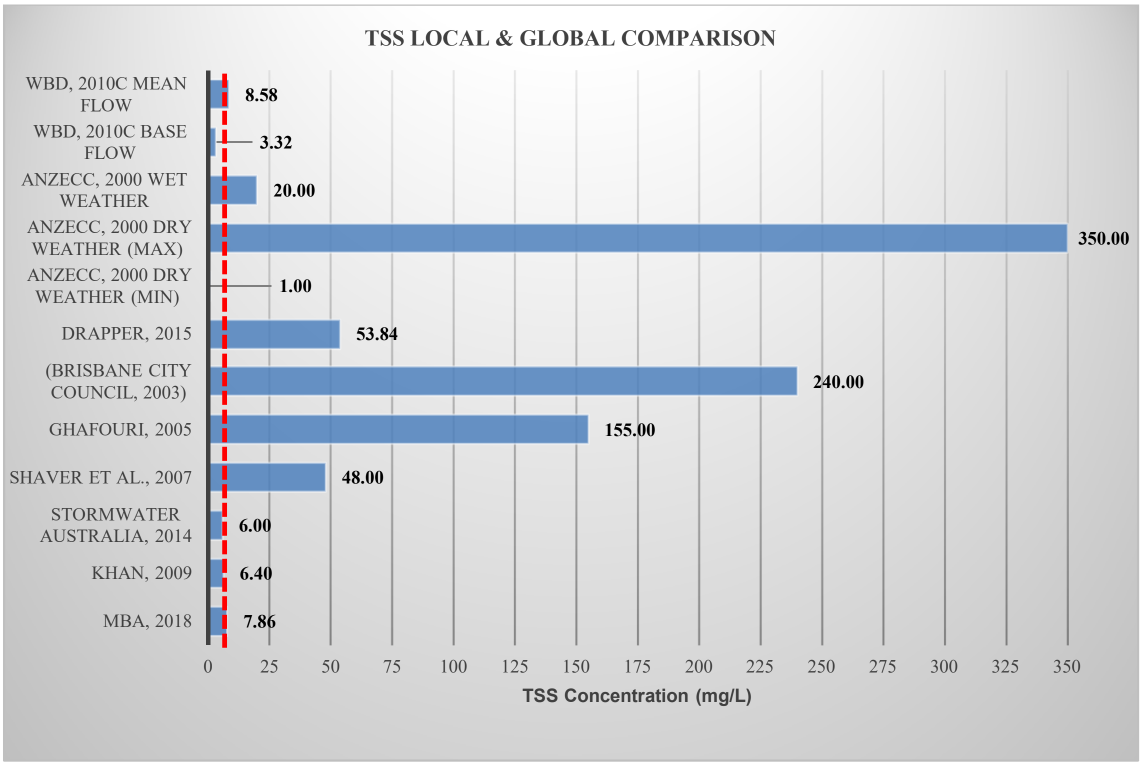


Figure 4.13 – Local and global TSS concentration comparison graph

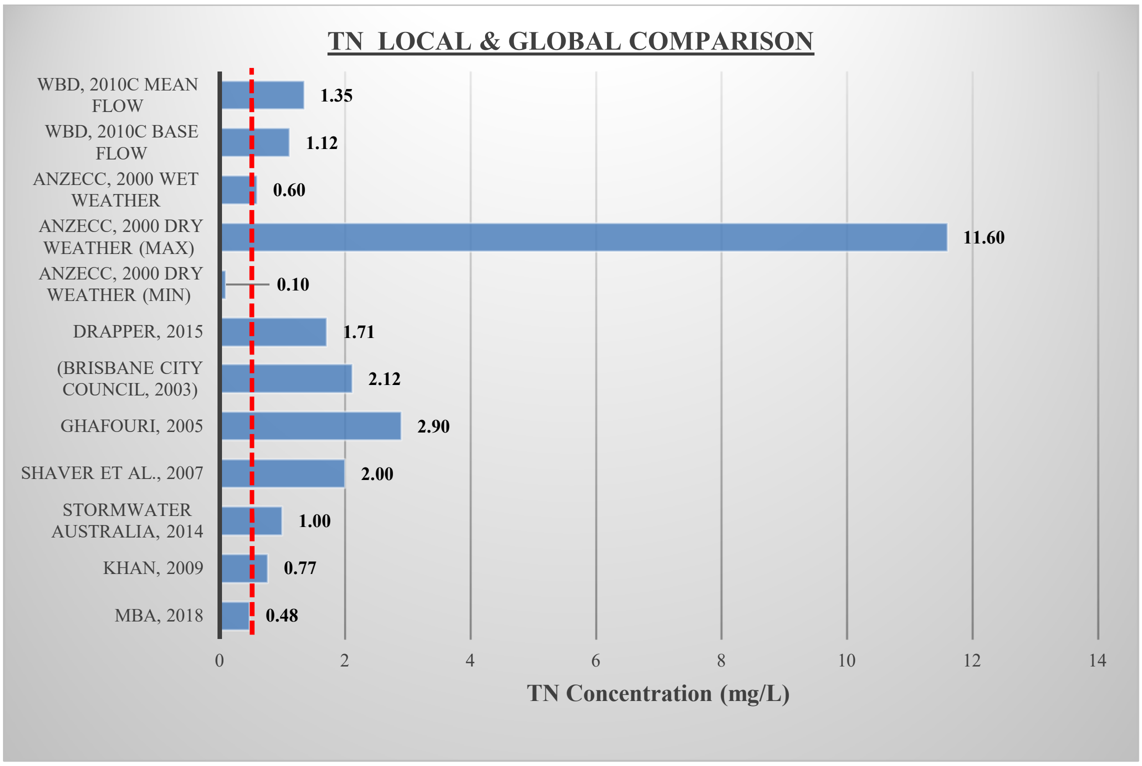


Figure 4.14 – Local and global TN concentration comparison graph

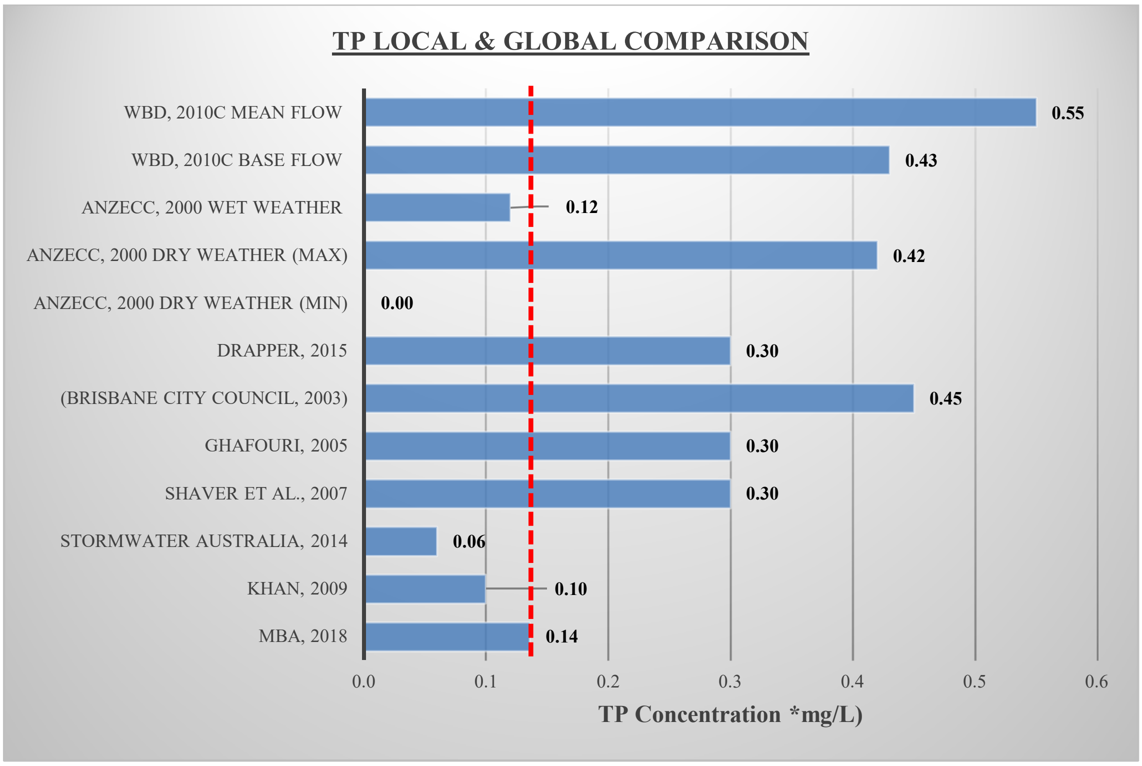


Figure 4.15 - Local and global TP concentration graph

The figures below show that TN, TSS and TP values were lower than those reported locally or internationally in the literature review. However, it is important to note that a stormwater characterisation research project of a residential catchment with similar characteristics to those at Glenvale was undertaken by Khan (2009) in Toowoomba. These results showed TN values were two times higher than those reported at DDBBO site, but similar values were found for TSS and TP.

4.4.3 Statistical Analysis

The mean, standard deviation (SD) and coefficient of variation (CV) were calculated to evaluate the spread of results for the TN, TP and TSS as shown in Table 4.6. The results show very high values of CV for TSS and TN, which indicates that the concentration of these pollutants at the inflow varies significantly between each event.

On the contrary, TP values are relatively low, which indicates not significant variation in pollutant concentrations.

Description	TP (mg/L)		TSS (mg/L)		TN (mg/L)	
	M1	M2	M1	M2	M1	M2
Mean	0.142	0.130	9.650	6.061	0.466	0.492
Median	0.132	0.112	5.825	5.150	0.313	0.478
SD	0.038	0.038	11.370	4.595	0.315	0.331
Coefficient Variation	26.8%	29.3%	117.8%	75.8%	67.6%	67.2%

Table 4.6 - Mean, median, SD and CV values for TP, TSS and TN

Analysis of Variance (ANOVA) test and T-test were also carried out to assess the relationship between the inflow and outflow concentrations for the DDBBO system. The t-Test results show that there are no significant differences found for TN, TP and TSS, but more observations could improve these statistics. The ANOVA test showed that there is the potential for mean variation between groups and based on the P-values, TN results show the most similarity in mean followed by TP and TSS. The test results are presented from .

Table 4.7 to

Table 4.12.

Table 4.7 - T-Test for TP

	Inlet (mg/L)	*Outlet (mg/L)*
Mean	0.141892086	0.130515265
Variance	0.0014492	0.001434507
Observations	6	6
Hypothesized Mean Difference	0	
df	10	
t Stat	0.518944537	
P(T<=t) one-tail	0.307544424	
t Critical one-tail	1.812461123	
P(T<=t) two-tail	0.615088847	
t Critical two-tail	2.228138852	

Table 4.8 – ANOVA test for TP

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.002189	1	0.002189	0.02092	0.88787	4.964603
Within Groups	1.04653	10	0.104653			
Total	1.04872	11				

Table 4.9- T-Test for TSS

	Inlet (mg/L)	*Outlet (mg/L)*
Mean	9.718539536	6.100305873
Variance	131.4428391	20.55431422
Observations	6	6
Hypothesized Mean Difference	0	
df	7	
t Stat	0.718876866	
P(T<=t) one-tail	0.24775373	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.49550746	
t Critical two-tail	2.364624252	

Table 4.10 - ANOVA test for TSS

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	39.27484	1	39.27484	0.516784	0.488674	4.964603
Within Groups	759.9858	10	75.99858			
Total	799.2606	11				

Table 4.11 - T-Test for TN

	Inlet (mg/L)	*Outlet (mg/L)*
Mean	0.466317161	0.493331831
Variance	0.099534295	0.1097718
Observations	6	6
Hypothesized Mean Difference	0	
df	10	
t Stat	-0.144638648	
P(T<=t) one-tail	0.443934869	
t Critical one-tail	1.812461123	
P(T<=t) two-tail	0.887869737	
t Critical two-tail	2.228138852	

Table 4.12 - ANOVA test for TN

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.002189	1	0.002189	0.02092	0.88787	4.964603
Within Groups	1.04653	10	0.104653			
Total	1.04872	11				

Correlation analysis was carried out to find out if a strong relationship exists between rainfall parameters, flow discharge and volume and observed pollutant concentrations. Table 4.13 shows the correlations found for the observed dataset in this study, from which can be concluded that there are strong relationships between TP, TSS, TN, Turbidity and Nitrate. Surprisingly, no significant correlation was found between TP, TN and TSS with rainfall depth, stormwater runoff volume and flow discharges.

Tab*le 4.13 - Correlation analysis of the observed data*

	TP	***TSS***	***TN***	***Vol M 1***	***Rainfall Depth***	***Nitrate TRC***	***Turbidity USQ***	***Mean Sample Flows***
TP	1.00							
TSS	0.90	1.00						
TN	0.82	0.90	1.00					
Vol M 1	-0.18	-0.30	-0.28	1.00				
Rainfall Depth	-0.19	-0.32	-0.30	1.00	1.00			
Nitrate TRC	0.89	0.84	0.86	-0.32	-0.33	1.00		
Turbidity USQ	0.89	0.87	0.94	-0.09	-0.11	0.94	1.00	
Mean Sample Flow	-0.20	-0.33	-0.29	0.99	1.00	-0.31	-0.10	1.00

The strong relationship between TSS and TN, TP and Nitrate were expected as these elements tend to adsorb onto suspended solids, which is essential because removing TSS from the stormwater runoff can help considerably to reduce the concentration and load associated with TSS and improve the ecological health of our urban environment.

One surprising results of this analysis was that did not exist any relationship between rainfall depth or runoff volume and the tested pollutants. In fact, the results showed that pollutant concentrations were inclined to be lower for higher rainfall depth and volume.

4.4.4 **Load estimation analysis**

Numeric Integration approach was defined as the true load for the purpose of the comparative analysis proposed in this study. Only three samples were taken per monitoring station per event as it was unaffordable to undertake laboratory testing for the 336 samples taken for the seven storm event monitored for this research. Therefore, it was defined to divide the time interval per event into three subgroups based on the time those samples were taken, and the total load was derived from the summation of the calculated and estimated loads of these subgroup per monitoring station per event.

For the Beale Ratio, the load was calculated as the product of the concentrations and the flows for which samples were taken. The mean of the loads was then adjusted by multiplying it by the flow ratio that was derived by dividing the average flow for the event for the average flow of the sample taken. Additionally, a bias correction was adopted to compensate for the effect of correlation between flow discharge and load. A sample of the computed calculation for the TP recorded on 18.02.2015 is shown in

. For further detail of the calculations, refer to *Appendix A – Project Research Supporting Information*

Table 4.14 - Example of the "Beale Ratio" calculation for the TP on 18.02.2015

Sample #	Date	Concentration (mg/L)	Volume 2 (Simpson Rule)	Rain_mm_Tot	Q (l/s)
11	18/02/2015_M1	0.18	138.28		2.36
13	18/02/2015_M1	0.24	605.40		8.16
14	18/02/2015_M1	0.11	585.17		8.26
2	18/02/2015_M2	0.10	118.14		3.68
9	18/02/2015_M2	0.10	436.97		7.28
19	18/02/2015_M2	0.08	131.65		2.18
N =		6			
Mean (mg/l) =		0.14		Slq =	145
Mean (L/s) =		5.32	q	Sq^2 =	7199
Load Estimate =		0.72	1	F =	0.17
Total average event (L/s) =		9.76			
Average Flows (L/s) =		5.32			
Beale ratio =		**0.31**			

For the regression, an equation relationship was found by outputting the regression analysis in Excel between the 41 tested samples for TSS, TN and TP and its corresponding flows and volume. A sample of the summary output from Excel for TP is shown in Table 4.15 - *Example of the summary outputs from Excel for TP*

. For further detail of the calculations, refer to *Appendix A – Project Research Supporting Information*

Table 4.15 - Example of the summary outputs from Excel for TP

SUMMARY OUTPUT					
Regression Statistics					
Multiple R	0.087404939				
R Square	0.007639623				
Adjusted R Square	-0.017805514				
Standard Error	0.062348989				
Observations	41				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.001167148	0.001167148	0.300239025	0.586855351
Residual	39	0.151608462	0.003887396		
Total	40	0.15277561			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*
Intercept	0.158603679	0.010757942	14.74293922	1.5522E-17	0.136843688
60.27460074	-1.23222E-06	2.24882E-06	-0.547940713	0.586855351	-5.78089E-06

RESIDUAL OUTPUT

Observation	*Predicted 0.18*	*Residuals*	*Standard Residuals*
1	0.157857694	0.082142306	1.334243717
2	0.157882621	-0.047882621	-0.777761044
3	0.158331683	-0.058331683	-0.947485959
4	0.158065235	-0.058065235	-0.943158019
5	0.158441458	-0.078441458	-1.274130553
6	0.157856537	0.022143463	0.359677944
7	0.157897707	0.082102293	1.333593778
8	0.15712407	-0.04712407	-0.765439846
9	0.158255599	-0.058255599	-0.946250116
10	0.158358572	-0.058358572	-0.947922723
11	0.158360843	-0.078360843	-1.272821133
12	0.13668779	-0.04668779	-0.758353318
13	0.144272281	-0.024272281	-0.394256507
14	0.158111118	-0.048111118	-0.78147255
15	0.15015487	0.06984513	1.134499751
16	0.144974958	0.015025042	0.244052895
17	0.145580205	0.024419795	0.396652588
18	0.157837995	0.122162005	1.984286729
19	0.155704948	0.104295052	1.694072447
20	0.157948706	0.022051294	0.358180838
21	0.158303893	0.031696107	0.514842278
22	0.158274985	0.031725015	0.515311823
23	0.158286254	0.031713746	0.515128791
24	0.158585818	0.001414182	0.022970665
25	0.158209652	-0.008209652	-0.133349998
26	0.158479075	-0.058479075	-0.949880064
27	0.158540794	-0.048540794	-0.788451799
28	0.158504255	-0.048504255	-0.787858299
29	0.158506481	-0.048506481	-0.787894463
30	0.158092731	-0.008092731	-0.131450841
31	0.158516374	-0.008516374	-0.138332115
32	0.141380951	-0.001380951	-0.022430897
33	0.158356637	0.011643363	0.189124034
34	0.158343442	-0.048343442	-0.785246202
35	0.158291692	-0.048291692	-0.784405618
36	0.158603679	-0.028603679	-0.464611732
37	0.158603679	-0.038603679	-0.627042492
38	0.158603679	-0.028603679	-0.464611732
39	0.158603679	0.091396321	1.484557383
40	0.158603679	0.131396321	2.134280421
41	0.158603679	0.151396321	2.45914194

4.4.5 **Load Estimation Results**

Different load estimations techniques were applied with the objective of determining the difference order in magnitude between them. The loads were estimated for TP, TSS and TN based on the six (6) monitored storm events as described in section 3.5.4. The numeric integration approach was defined as the true load for this study, and the results are shown in Figure 4.16,

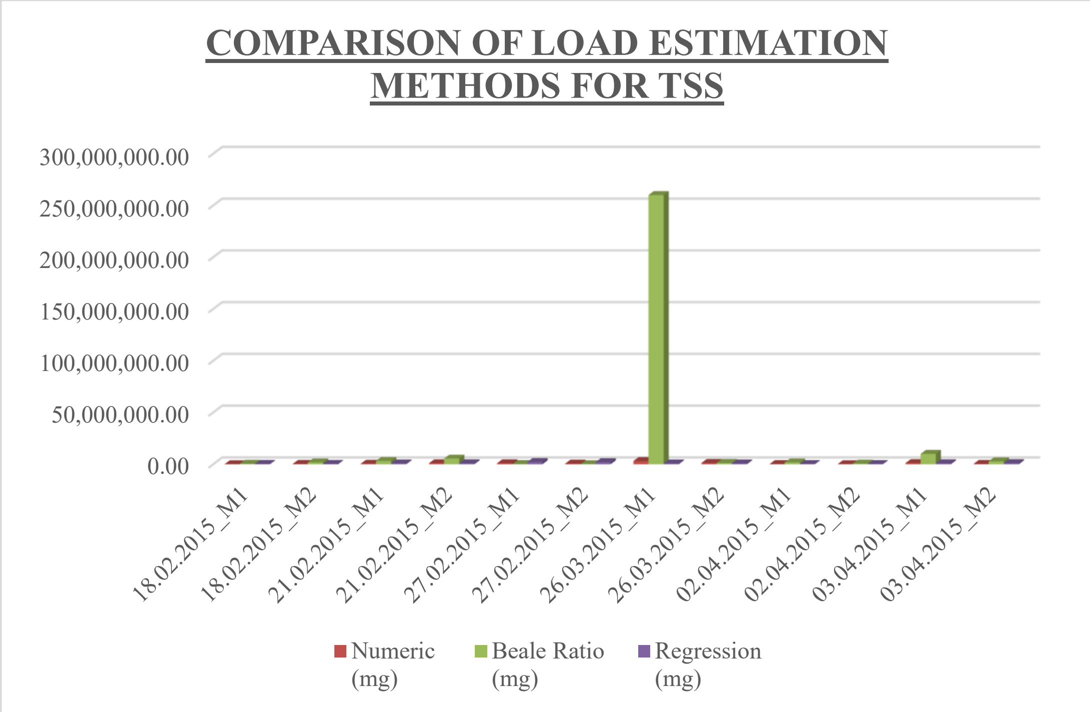


Figure 4.17 and

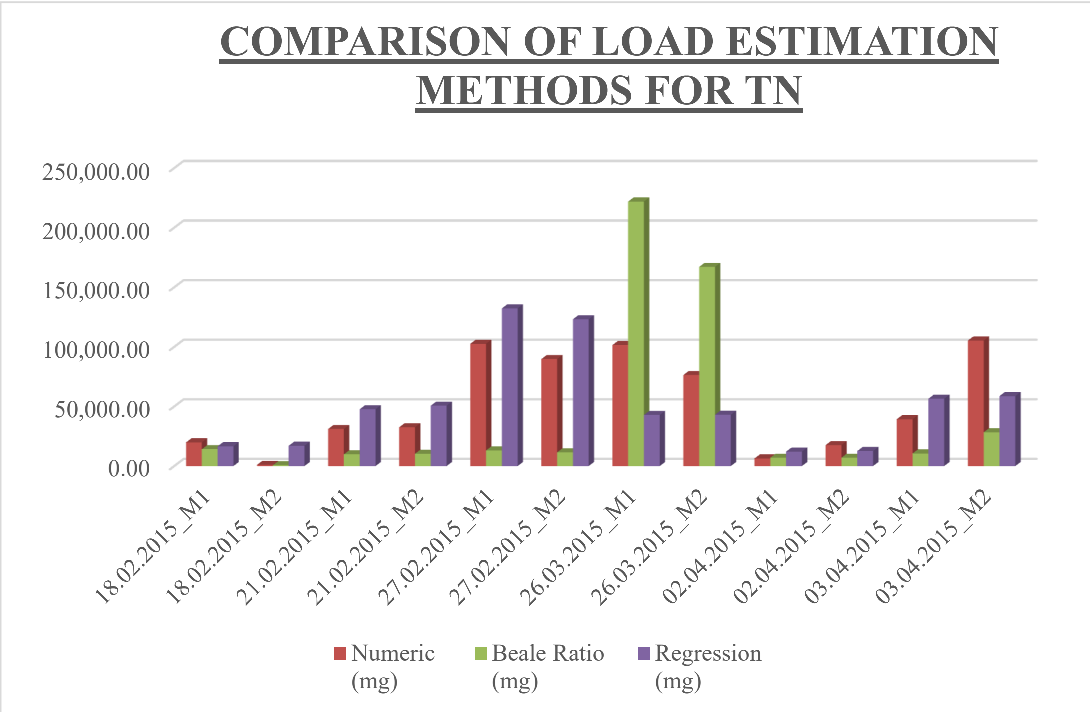


Figure 4.18. These figures showed the TP, TSS and TN load estimations by applying different methods to the monitored event dataset and the results showed that the regression method was the best fit when compared with the selected true load.

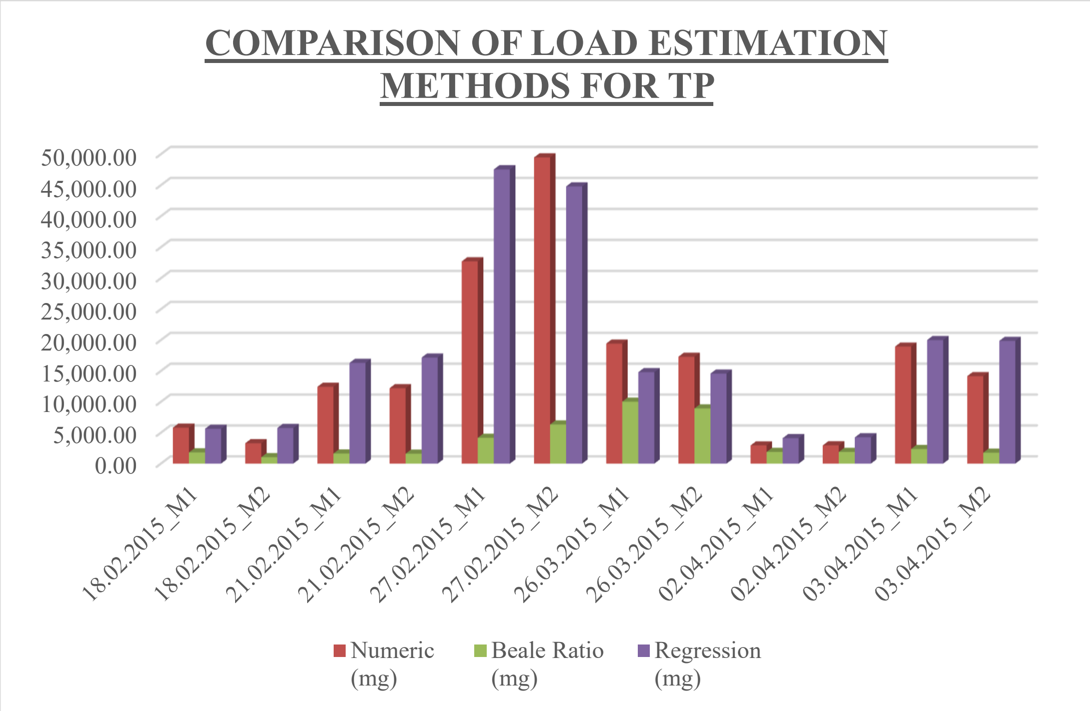


Figure 4.16 - Comparison of load estimation method (TP)

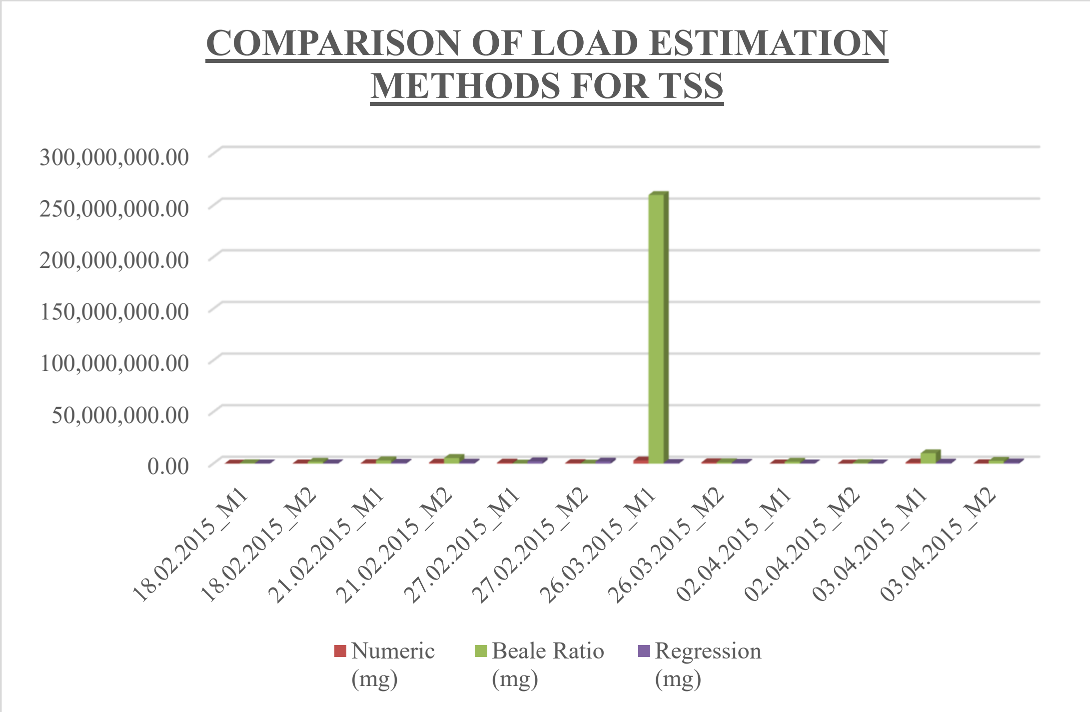


Figure 4.17 - Comparison of load estimation method (TSS)

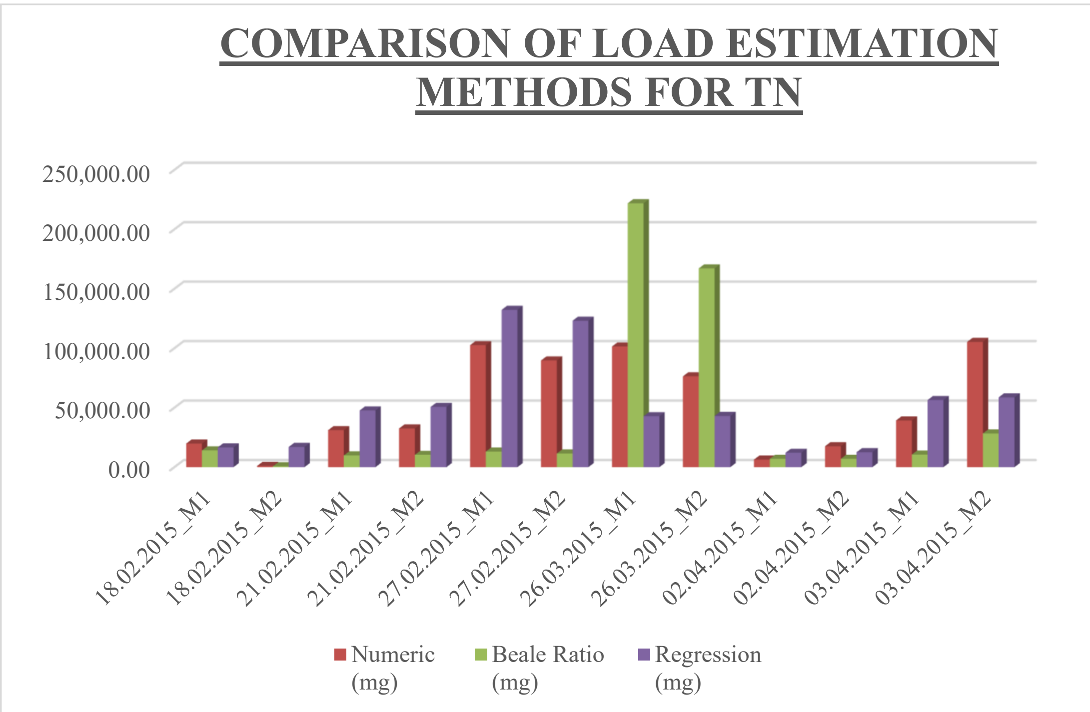


Figure 4.18 - Comparison of load estimation method (TN)

The mean values of the TP, TSS and TP load estimation were also plotted, and the results are shown in Figure 4.19, Figure 4.20 and Figure 4.21.

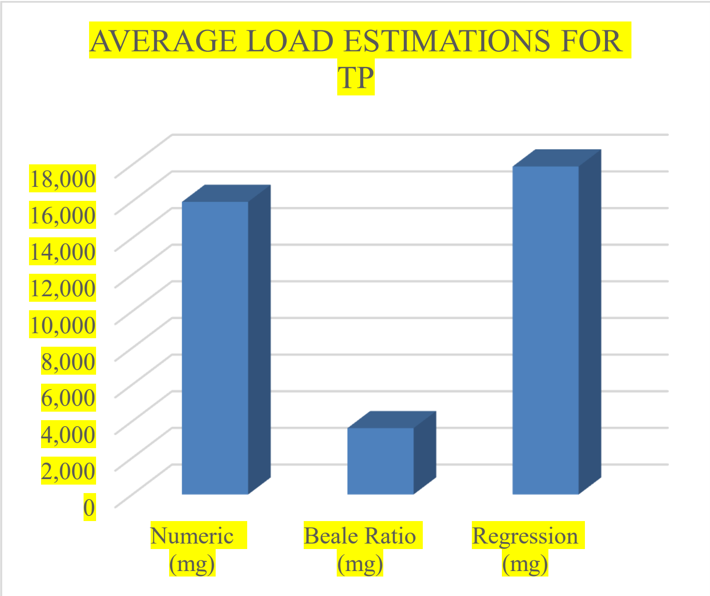


Figure 4.19 - Average load estimation comparison for TP

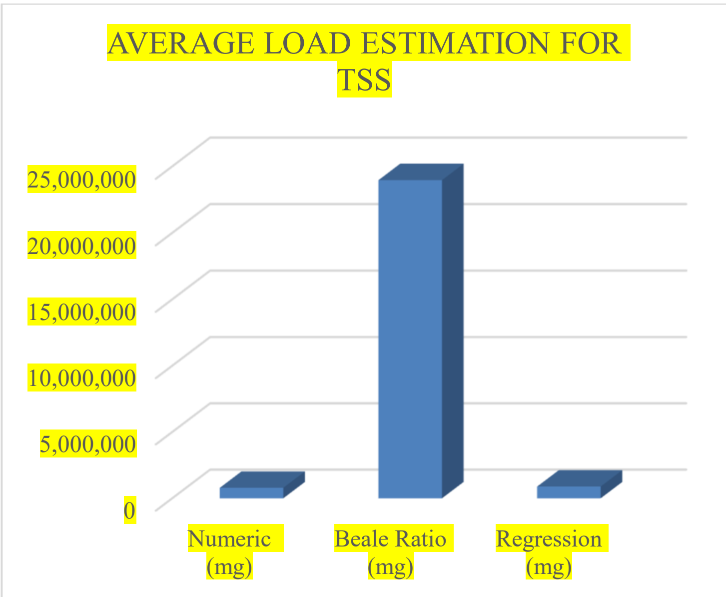


Figure 4.20 - Average load estimation comparison for TSS

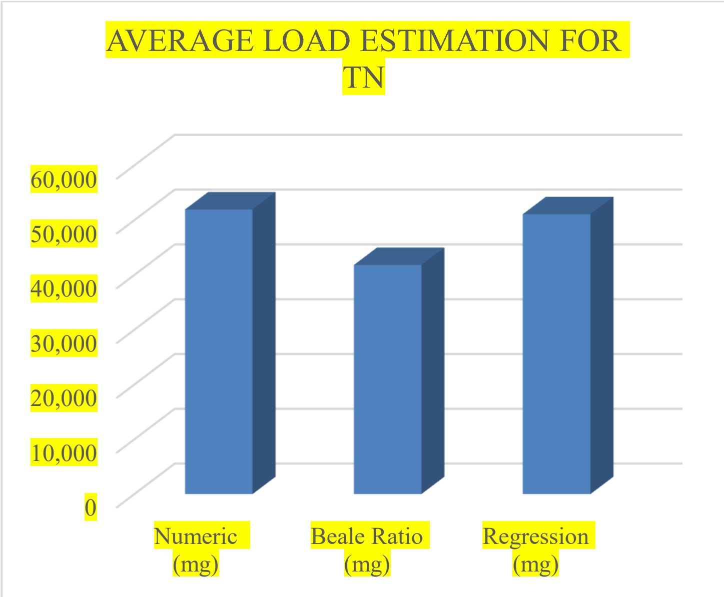


Figure 4.21 - Average load estimation comparison for TN

As can be seen in the graphs above, the different load estimation techniques applied to the same dataset resulted in significant differences in the estimates of the pollutant loads. Surprisingly, the regression approach provided the best-fit for the true load than did the Beale ratio. However, due to the lower data set and significant variability in the load figures, it is recommended to gather more data to strengthen these results and caution should be used in drawing any conclusion from the results

4.4.1 **Pollutant Removal Efficiency**

For this study, three different removal efficiency techniques were analysed as described in section 3.5.5 to determine the order of magnitude between them. Pollutant removal efficiency of TP, TN and TSS based on the analytical laboratory results were calculated, and the results are presented as overall treatment removal efficiency in Table 4.19,

Table *4.17* and Table 4.18.

Table 4.16 - Removal efficiency comparison for TP

Event Date	Rainfall Depth (mm)	Removal Efficiency (Efficiency Ratio_ER) (%)	Removal Efficiency (Summation of Loads SOL) (%)	Removal Efficiency (Regression of Loads ROL) (%)
18.02.2015	1.8	44	43	43
21.02.2015	4.4	6	6	6
27.02.2015	11.2	-60*	-60*	-60*
26.03.2015	3.8	8	8	8
02.04.2015	2.2	3	3	3
03.04.2015	5.4	22	23	23
AVERAGE		17	16	16

**These figures were excluded from the averaging calculation due to non-relationship within the dataset*

Table 4.17 - Removal efficiency comparison for TSS

Event Date	Rainfall Depth (mm)	Removal Efficiency (Efficiency Ratio_ER) (%)	Removal Efficiency (Summation of Loads SOL) (%)	Removal Efficiency (Regression of Loads ROL) (%)
18.02.2015	1.8	-291*	-317*	-317*
21.02.2015	4.4	-66*	-66*	-66*
27.02.2015	11.2	34	34	34
26.03.2015	3.8	60	60	60
02.04.2015	2.2	68	68	68
03.04.2015	5.4	72	72	72
AVERAGE		**58**	**58**	**58**

**These figures were excluded from the averaging calculation due to non-relationship within the dataset*

Table 4.18 - Removal efficiency comparison for TN

Event Date	Rainfall Depth (mm)	Removal Efficiency (Efficiency Ratio_ER) (%)	Removal Efficiency (Summation of Loads SOL) (%)	Removal Efficiency (Regression of Loads ROL) (%)
18.02.2015	1.80	95	95	95
21.02.2015	4.40	0*	0*	0*
27.02.2015	11.20	8	8	8
26.03.2015	3.80	23	23	23
02.04.2015	2.20	-167*	-167*	-167*
03.04.2015	5.40	-180*	-178*	-178*
AVERAGE		**42**	**41**	**41**

**These figures were excluded from the averaging calculation due to non-relationship within the dataset*

Table *4.17*, Table 4.18 and Table 4.19, above show a significant removal efficiency variability for the system, in some cases exhibiting a reduction for TSS, TP and TN and in others displaying an increase in exported pollutant. For instance, removal efficiency for TP showed variability between -60% and 44%, while TSS and TN varied from -317% to 72% and -179% to 95%, respectively.

For this study, it was defined that due to the non-relationship of the negative values within the dataset, these results were excluded from the total averaging calculations. The reason for these figures may be explained due to external factors that may be causing a negative impact for the DDBBO system such as inadequate maintenance activities and procedures as well as resettling of suspended solids from previous rainfall events. The results for the ER, SOL and ROL techniques were very similar when monitored events were analysed independently. Surprisingly, the average TP values reported the lowest removal efficiency with a value of 17%, while the averaging figures for TSS and TN reported removal efficiency significantly by the DDBBO system with values of 58% and 42%, respectively.

As can be seen, the removal efficiency results shown in Table 4.19 indicated that the DDBBO system had a favourable removal efficiency for TSS, TN and TP. However, the results showed in this study are not conclusive, and further research into the influence of inadequate maintenance procedures in nutrient export from DDBBO systems as well as resettling of suspended solids require to be investigated in more detail to understand their relationship and impact in the overall removal efficiency of the system.

The ER, SOL and ROL were also compared with removal targets established by the SPP 07/17 and TRC Planning Scheme. It was found that the observed TSS and TP removal efficiencies were significantly lower than those figures set by the legislation. While, TN was slight under the targeted value as shown in Table 4.19.

Table 4.19 – Average removal efficiency comparison for TN, TP and TSS

Parameters	**Pollutant Removal Efficiency**			**SPP 07/17 (%)**
	ER (%)	**SOL (%)**	**ROL (%)**	
TP	17	16	16	**60**
TSS	58	58	58	**80**
TN	42	41	41	**45**

4.5 Assessment of pollutant removal efficiency in MUSIC Model

The purpose of using the MUSIC in this study was to assess and compare the predicted TSS, TN and TP concentrations and removal efficiency of the DDBBO system, under specific site condition such as those presented at the Glenvale. For a detailed overview of MUSIC model and project set up, refer to section 3.5.6.

The outcomes of the modelling are described in the following sections:

4.5.1 **Modelling scenarios**

Based on the information provided by TRC, two possible treatment train scenarios were identified for the project site. These scenarios are described in sections below:

4.5.1.1 Scenario 1:

This scenario consisted of collecting all the roof water into rainwater tanks (RWTs), which in conjunction with the ground runoff were discharged into the vegetated swales via overland paths and underground drainage to be conveyed to the DDBBO system subsequently.

In order to determine the performance efficiency of the system, the following information was included in the model:

- All the catchments were divided into dwellings roofs and balance areas
- Field observed Rainfall data obtained from datalogger CR800 was exported into the model
- All stormwater runoff from roof areas were discharged into rainwater tanks. The volume assumed for each dwelling was 9KL which is in accordance with the TRC guidelines and requirement at the time these catchments were developed.
- Daily reuse of 190 L/dwelling/day was also included in the model in accordance with the targets outlined in the Queensland Development Code

MP4.2 – “Water saving Targets” and TRC requirements at the time these catchments were developed.

- Catchment 1,2 & 4 discharge directly to the swale
- Catchment 3 discharges directly to the DDBBO system
- The bioretention basin node was used to simulate the DDBBO system as MUSIC does not currently have a node to model the DDBBO system
- Three variables for the filter media, which were unknown at the time of this study, were considered to undertake a sensitivity analysis of the model with the objective of determining their impact in the predicted results. These parameters are as follows:
    - Vegetation properties: effective and ineffective nutrients removal plants were modelled.
    - TN content of filter media (mg/kg).
    - Orthophosphate contend of filter media (mg/kg).

4.5.1.2 Scenario 2

This scenario consisted of discharging the runoff from roof and ground areas via overland and underground stormwater drainage into a vegetated swale network to subsequently be conveyed and treated by the DDBBO system.

In order to determine the performance efficiency of the system, the following information was included in the model:

- All the catchments were divided into dwellings roofs and balance areas

- Field observed Rainfall data obtained from datalogger CR800 was exported into the model
- Catchment 1,2 & 4 discharge directly to the swale
- Catchment 3 discharges directly to the DDBBO system
- The bioretention basin node was used to simulate the DDBBO system as MUSIC does not currently have node to model the DDBBO system
- Three variables for the filter media, which were unknown at the time of this study, were considered to undertake a sensitivity analysis of the model with the objective of determining their impact in the predicted results. These parameters are as follows:
    - Vegetation properties: effective and ineffective nutrients removal plants were modelled.
    - TN content of filter media (mg/kg).
    - Orthophosphate contend of filter media (mg/kg).

4.5.2 **MUSIC Modelling Results & Discussion**

One of the primary objectives of this study was to analyse and compared the field observed data concentration for TSS, TP and TN against MUSIC modelling with the aim to assess its accuracy to predict pollutant concentrations under site-specific conditions. The first step was to compare the log-normally distributed TSS, TN and TP default parameter for the “urban residential” storm flow provided by the model as shown in Figure 4.22 against the data obtained from the monitoring process, which were converted to Log10 values and then graphed against the MUSIC mean and standard deviation as shown in Figure 4.23, Figure 4.24 and Figure 4.25.

LANDUSE	FLOW TYPE	TSS log¹⁰ values		TP log¹⁰ values		TN log¹⁰ values	
		Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Urban residential	Baseflow	1.00	0.34	-0.97	0.31	0.20	0.20
	Stormflow	2.18	0.39	-0.47	0.32	0.26	0.23
Industrial	Baseflow	0.78	0.45	-1.11	0.48	0.14	0.20
	Stormflow	1.92	0.44	-0.59	0.36	0.25	0.32
Commercial	Baseflow	0.78	0.39	-0.60	0.50	0.32	0.30
	Stormflow	2.16	0.38	-0.39	0.34	0.37	0.34
Rural residential	Baseflow	0.53	0.24	-1.54	0.38	-0.52	0.39
	Stormflow	2.26	0.51	-0.56	0.28	0.32	0.30
Forest	Baseflow	0.51	0.28	-1.79	0.28	-0.59	0.22
	Stormflow	1.90	0.20	-1.10	0.22	-0.075	0.24
Agriculture	Baseflow	1.00	0.13	-1.155	0.13	-0.155	0.13
	Stormflow	2.477	0.31	-0.495	0.30	0.29	0.26

Figure 4.22 - Pollutant export parameters for lumped catchment land uses (Log 10 values) extracted from MUSIC modelling guidelines v1.0

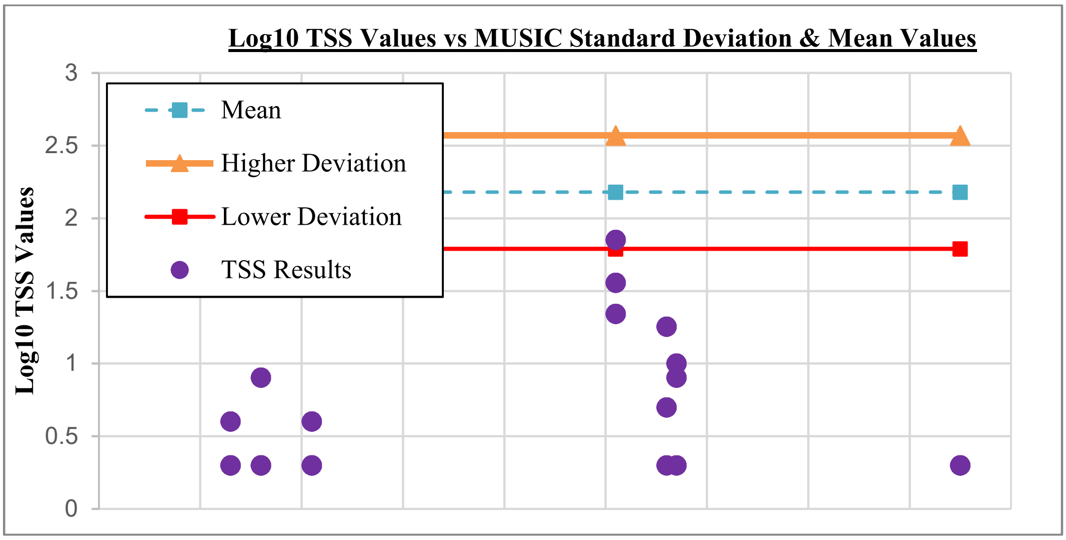


Figure 4.23 - Log10 TSS values vs MUSIC standard deviation and mean values

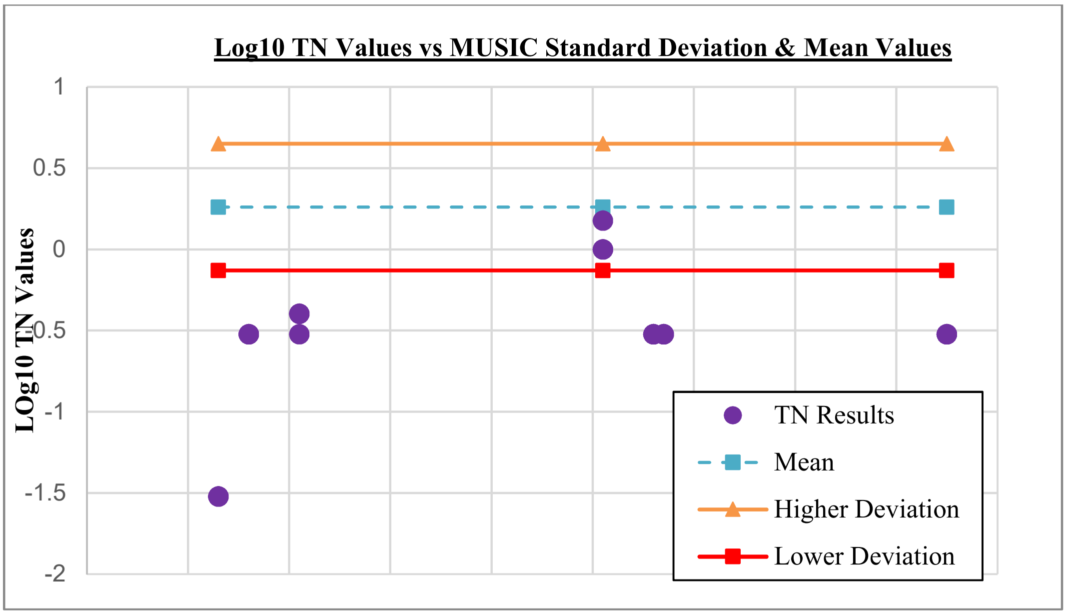


Figure 4.24 - Log10 TN values vs MUSIC standard deviation and mean values

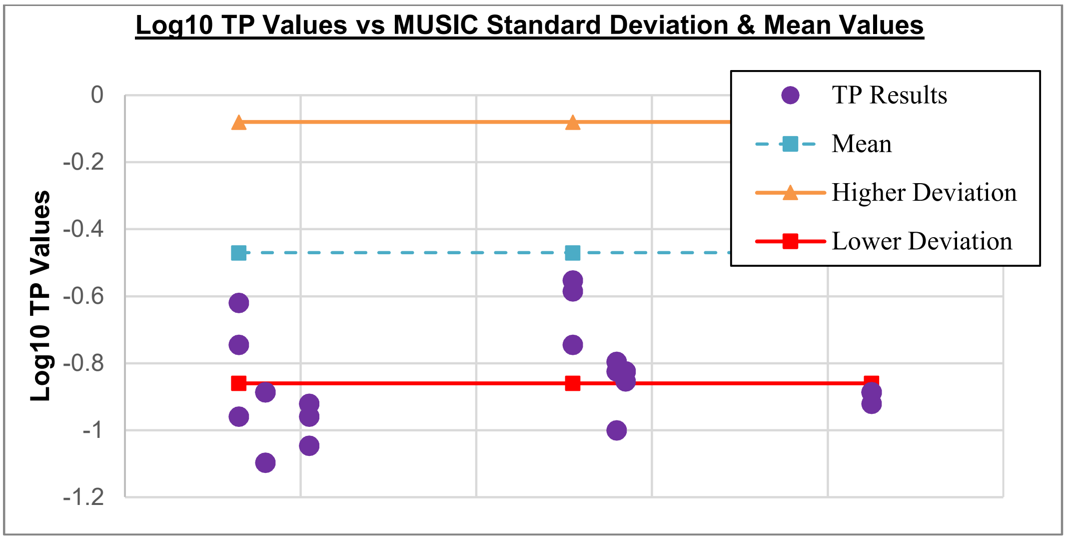


Figure 4.25 - Log10 TP values vs MUSIC standard deviation and mean values

The TSS and TN Observed values compared against MUSIC results showed the inflow concentrations within one and two standard deviations, respectively. All the remaining figures fell well below the lower deviation from the mean recommended by (Water by Design, 2010b).

For the TP results, the figures show that 50% of the inflow tested sample are within the standard deviation range and the remaining 50% figures fell below the lower deviation. These results require to be considered as preliminary at this stage due to the monitored storm events for this study were below protocol requirements. Therefore, it is recommended that future research collect additional samples to strengthen the figure presented herein.

The observed pollutant concentrations at the inlet and outlet of the DDBBO system were subsequently compared against the figures predicted by the MUSIC model, and these results are shown in *Table 4.20* to

Table 4.23. RMSE values were also obtained to validate and measure the accuracy of the MUSIC to predicts pollutant inflows and outflows concentrations. The observed data was compared against two stormwater treatment scenarios defined for the project catchment based on engineering documentation provided by TRC as described in section 4.5.1. These two scenarios were subdivided into two subgroups, which consisted of using an effective and ineffective nutrien removal vegetation . These were then subdivided into a higher, medium and lower TN and Orthophosphate contents to determine the level of sensitivity of the model to those variables and compare it against the results obtained from the monitored process.

Table 4.20 - MUSIC and observed data TSS, TN & TP concentrations comparison for scenario 1 (with RWTs and ineffective nutrient removal vegetation) with its corresponding RMSE values

Description	Date	TSS (Inflow)	TSS (Outflow)	TP (Inflow)	TP (Outflow)	TN (Inflow)	TN (Outflow)
observed	18-Feb	2.00	7.83	0.16	0.09	0.55	0.03
observed	21-Feb	5.42	8.97	0.12	0.11	0.30	0.30
observed	27-Feb	3.14	2.07	0.10	0.17	0.33	0.30
observed	26-Mar	32.35	13.04	0.20	0.19	0.20	0.83
observed	2-Apr	6.24	2.00	0.11	0.11	0.25	0.66
observed	3-Apr	8.77	2.47	0.14	0.11	0.30	0.84
MS1/3	18-Feb	14.00	1.87	0.13	0.46	1.43	0.80
MS1/3	21-Feb	14.15	1.71	0.13	0.46	1.47	0.80
MS1/3	27-Feb	19.27	1.82	0.14	0.46	1.60	0.80
MS1/3	26-Mar	14.13	1.94	0.13	0.47	1.53	0.80
MS1/3	2-Apr	14.00	2.06	0.13	0.47	1.45	0.80
MS1/3	3-Apr	14.09	1.95	0.13	0.47	1.46	0.80
MS1/1	18-Feb	14.00	1.87	0.13	0.38	1.43	0.80
MS1/1	21-Feb	14.15	1.71	0.13	0.38	1.47	0.80
MS1/1	27-Feb	19.27	1.82	0.14	0.38	1.60	0.80
MS1/1	26-Mar	14.13	1.94	0.13	0.38	1.53	0.80
MS1/1	2-Apr	14.00	2.06	0.13	0.38	1.45	0.80
MS1/1	3-Apr	14.09	1.95	0.13	0.38	1.46	0.80
MS1/2	18-Feb	14.00	1.87	0.13	0.42	1.43	0.80
MS1/2	21-Feb	14.15	1.71	0.13	0.42	1.47	0.80
MS1/2	27-Feb	19.27	1.82	0.14	0.42	1.60	0.80
MS1/2	26-Mar	14.13	1.94	0.13	0.42	1.53	0.80
MS1/2	2-Apr	14.00	2.06	0.13	0.42	1.45	0.80
MS1/2	3-Apr	14.09	1.95	0.13	0.42	1.46	0.80

	RMSE					
	TSS Inflows	**TP Inflows**	**TN Inflows**	**TSS Outflows**	**TP Outflows**	**TN Outflows**
Observed / MS1/1	5.29	0.01	1.17	4.17	0.25	0.31
Observed / MS1/2	4.80	0.01	0.04	9.78	0.07	0.14
Observed / MS1/3	2.45	0.00	0.48	0.08	0.17	0.02

**MS1/1 – Scenario1 with RWTs, a biofilter with ineffective plant nutrient removal and a filter media content for TN (400 mg/kg) and Orthophosphate (60 mg/kg).*
**MS1/2 – Scenario1 with RWTs, a biofilter with ineffective plant nutrient removal and a filter media content for TN (600 mg/kg) and Orthophosphate (70mg/kg).*
**MS1/2 – Scenario1 with RWTs, a biofilter with ineffective plant nutrient removal and a filter media content for TN (800 mg/kg) and Orthophosphate (80mg/kg).*

Table 4.21 -MUSIC and observed data TSS, TN & TP concentrations comparison for scenario 1 (with RWTs and effective nutrient removal vegetation) with its corresponding RMSE values

Description	Date	TSS (Inflow)	TSS (Outflow)	TP (Inflow)	TP (Outflow)	TN (Inflow)	TN (Outflow)
observed	18-Feb	2.00	7.83	0.16	0.09	0.55	0.03
observed	21-Feb	5.42	8.97	0.12	0.11	0.30	0.30
observed	27-Feb	3.14	2.07	0.10	0.17	0.33	0.30
observed	26-Mar	32.35	13.04	0.20	0.19	0.20	0.83
observed	2-Apr	6.24	2.00	0.11	0.11	0.25	0.66
observed	3-Apr	8.77	2.47	0.14	0.11	0.30	0.84
MS1/3	18-Feb	14.00	1.87	0.13	0.22	1.43	0.60
MS1/3	21-Feb	14.15	1.71	0.13	0.22	1.47	0.60
MS1/3	27-Feb	19.27	1.82	0.14	0.22	1.60	0.60
MS1/3	26-Mar	14.13	1.94	0.13	0.23	1.53	0.60
MS1/3	2-Apr	14.00	2.06	0.13	0.23	1.45	0.60
MS1/3	3-Apr	14.09	1.95	0.13	0.23	1.46	0.60
MS1/1	18-Feb	14.00	1.87	0.13	0.14	1.43	0.60
MS1/1	21-Feb	14.15	1.71	0.13	0.14	1.47	0.60
MS1/1	27-Feb	19.27	1.82	0.14	0.14	1.60	0.60
MS1/1	26-Mar	14.13	1.94	0.13	0.14	1.53	0.60
MS1/1	2-Apr	14.00	2.06	0.13	0.14	1.45	0.60
MS1/1	3-Apr	14.09	1.95	0.13	0.14	1.46	0.60
MS1/2	18-Feb	14.00	1.87	0.13	0.18	1.43	0.60
MS1/2	21-Feb	14.15	1.71	0.13	0.18	1.47	0.60
MS1/2	27-Feb	19.27	1.82	0.14	0.18	1.60	0.60
MS1/2	26-Mar	14.13	1.94	0.13	0.18	1.53	0.60
MS1/2	2-Apr	14.00	2.06	0.13	0.18	1.45	0.60
MS1/2	3-Apr	14.09	1.95	0.13	0.18	1.46	0.60

	RMSE					
	TSS Inflows	**TP Inflows**	**TN Inflows**	**TSS Outflows**	**TP Outflows**	**TN Outflows**
Observed MS1/1	5.29	0.01	1.17	4.17	0.01	0.11
Observed MS1/2	4.80	0.01	0.04	9.78	0.01	0.09
Observed MS1/3	2.45	0.00	0.48	0.08	0.07	0.06

**MS1/1 – Scenario1 with RWTs, a biofilter with effective plant nutrient removal and a filter media content for TN (400 mg/kg) and Orthophosphate (60 mg/kg).*
**MS1/2 – Scenario1 with RWTs, a biofilter with effective plant nutrient removal and a filter media content for TN (600 mg/kg) and Orthophosphate (70mg/kg).*
**MS1/3 – Scenario1 with RWTs, a biofilter with effective plant nutrient removal and a filter media content for TN (800 mg/kg) and Orthophosphate (80mg/kg).*

Table 4.22 -MUSIC and observed data TSS, TN & TP concentrations comparison for scenario 2 (without RWTs and ineffective vegetation) with its corresponding RMSE values

Description	Date	TSS (Inflow)	TSS (Outflow)	TP (Inflow)	TP (Outflow)	TN (Inflow)	TN (Outflow)
MS2/1	18-Feb	14.04	1.87	0.13	0.38	1.48	0.80
MS2/1	21-Feb	14.77	1.71	0.13	0.38	1.48	0.80
MS2/1	27-Feb	25.12	1.82	0.17	0.38	1.65	0.80
MS2/1	26-Mar	15.12	1.94	0.14	0.38	1.57	0.80
MS2/1	2-Apr	14.08	2.03	0.13	0.38	1.48	0.80
MS2/1	3-Apr	15.03	1.93	0.13	0.38	1.49	0.80
MS2/2	18-Feb	14.04	1.87	0.13	0.42	1.48	0.80
MS2/2	21-Feb	14.77	1.71	0.13	0.42	1.48	0.80
MS2/2	27-Feb	25.12	1.82	0.17	0.42	1.65	0.80
MS2/2	26-Mar	15.12	1.94	0.14	0.42	1.57	0.80
MS2/2	2-Apr	14.08	2.03	0.13	0.42	1.48	0.80
MS2/2	3-Apr	15.03	1.93	0.13	0.42	1.49	0.80
MS2/3	18-Feb	14.04	1.87	0.13	0.46	1.48	0.80
MS2/3	21-Feb	14.77	1.71	0.13	0.46	1.48	0.80
MS2/3	27-Feb	25.12	1.82	0.17	0.46	1.65	0.80
MS2/3	26-Mar	15.12	1.94	0.14	0.47	1.57	0.80
MS2/3	2-Apr	14.08	2.03	0.13	0.47	1.48	0.80
MS2/3	3-Apr	15.03	1.93	0.13	0.47	1.49	0.80
observed	18-Feb	2.00	7.83	0.16	0.09	0.55	0.03
observed	21-Feb	5.42	8.97	0.12	0.11	0.30	0.30
observed	27-Feb	3.14	2.07	0.10	0.17	0.33	0.30
observed	26-Mar	32.35	13.04	0.20	0.19	0.20	0.83
observed	2-Apr	6.24	2.00	0.11	0.11	0.25	0.66
observed	3-Apr	8.77	2.47	0.14	0.11	0.30	0.84

	RMSE					
	TSS Inflows	**TP Inflows**	**TN Inflows**	**TSS Outflows**	**TP Outflows**	**TN Outflows**
Observed MS1/1	6.71	0.00	1.20	4.18	0.25	0.31
Observed MS1/2	5.89	0.00	0.05	10.22	0.07	0.13
Observed MS1/3	2.57	0.00	0.49	0.09	0.17	0.02

**MS2/1 – Scenario2 without RWTs, a biofilter with ineffective plant nutrient removal and a filter media content for TN (400 mg/kg) and Orthophosphate (60 mg/kg).*
**MS2/2 – Scenario2 without RWTs, a biofilter with ineffective plant nutrient removal and a filter media content for TN (600 mg/kg) and Orthophosphate (70mg/kg).*
**MS2/3 – Scenario 2 without RWTs, a biofilter with ineffective plant nutrient removal and a filter media content for TN (800 mg/kg) and Orthophosphate (80mg/kg).*

Table 4.23 -MUSIC and observed data TSS, TN & TP concentrations comparison for scenario 2 (without RWTs and effective vegetation) with its corresponding RMSE values

Description	Date	TSS (Inflow)	TSS (Outflow)	TP (Inflow)	TP (Outflow)	TN (Inflow)	TN (Outflow)
⊟**MS2/1**	18-Feb	14.04	1.87	0.13	0.14	1.48	0.60
MS2/1	21-Feb	14.77	1.71	0.13	0.14	1.48	0.60
MS2/1	27-Feb	25.12	1.82	0.17	0.14	1.65	0.60
MS2/1	26-Mar	15.12	1.94	0.14	0.14	1.57	0.60
MS2/1	2-Apr	14.08	2.03	0.13	0.14	1.48	0.60
MS2/1	3-Apr	15.03	1.93	0.13	0.14	1.49	0.60
⊟**MS2/2**	18-Feb	14.04	1.87	0.13	0.18	1.48	0.60
MS2/2	21-Feb	14.77	1.71	0.13	0.18	1.48	0.60
MS2/2	27-Feb	25.12	1.82	0.17	0.18	1.65	0.60
MS2/2	26-Mar	15.12	1.94	0.14	0.18	1.57	0.60
MS2/2	2-Apr	14.08	2.03	0.13	0.18	1.48	0.60
MS2/2	3-Apr	15.03	1.93	0.13	0.18	1.49	0.60
⊟**MS2/3**	18-Feb	14.04	1.87	0.13	0.22	1.48	0.60
MS2/3	21-Feb	14.77	1.71	0.13	0.22	1.48	0.60
MS2/3	27-Feb	25.12	1.82	0.17	0.22	1.65	0.60
MS2/3	26-Mar	15.12	1.94	0.14	0.23	1.57	0.60
MS2/3	2-Apr	14.08	2.03	0.13	0.23	1.48	0.60
MS2/3	3-Apr	15.03	1.93	0.13	0.23	1.49	0.60
⊟**observed**	18-Feb	2.00	7.83	0.16	0.09	0.55	0.03
observed	21-Feb	5.42	8.97	0.12	0.11	0.30	0.30
observed	27-Feb	3.14	2.07	0.10	0.17	0.33	0.30
observed	26-Mar	32.35	13.04	0.20	0.19	0.20	0.83
observed	2-Apr	6.24	2.00	0.11	0.11	0.25	0.66
observed	3-Apr	8.77	2.47	0.14	0.11	0.30	0.84

<table>
<tr><th rowspan="2"></th><th colspan="6">RMSE</th></tr>
<tr><th>TSS Inflows</th><th>TP Inflows</th><th>TN Inflows</th><th>TSS Outflows</th><th>TP Outflows</th><th>TN Outflows</th></tr>
<tr><td>Observed</td><td rowspan="2">6.71</td><td rowspan="2">0.00</td><td rowspan="2">1.20</td><td rowspan="2">4.18</td><td rowspan="2">0.01</td><td rowspan="2">0.11</td></tr>
<tr><td>MS1/1</td></tr>
<tr><td>Observed</td><td rowspan="2">5.89</td><td rowspan="2">0.00</td><td rowspan="2">0.05</td><td rowspan="2">10.22</td><td rowspan="2">0.01</td><td rowspan="2">0.08</td></tr>
<tr><td>MS1/2</td></tr>
<tr><td>Observed</td><td rowspan="2">2.57</td><td rowspan="2">0.00</td><td rowspan="2">0.49</td><td rowspan="2">0.09</td><td rowspan="2">0.07</td><td rowspan="2">0.06</td></tr>
<tr><td>MS1/3</td></tr>
</table>

**MS2/1 – Scenario2 without RWTs, a biofilter with effective plant nutrient removal and a filter media content for TN (400 mg/kg) and Orthophosphate (60 mg/kg).*
**MS2/2 – Scenario2 without RWTs, a biofilter with effective plant nutrient removal and a filter media content for TN (600 mg/kg) and Orthophosphate (70mg/kg).*
**MS2/3 – Scenario 2 without RWTs, a biofilter with effective plant nutrient removal and a filter media content for TN (800 mg/kg) and Orthophosphate (80mg/kg).*

The observed and predicted results showed in the tables below were plotted as bar graphs for easy visualisation, comparison and identification of the variability of the dataset. These graphs are shown in the Figure *4.26*, to *Figure 4.37*.

Figure 4.26 to *Figure 4.29* showed that the observed TN inflows concentrations were significantly lower than those predicted by the model for scenarios 1 and 2. While the observed outflows concentrations were in some cases significantly lower such as those reported on 18.02.2015, 21.02.2015 and 27.02.201, in other cases these figures were slightly higher as shown in the figures recorded on 26.03.2015, 02.04.2015 and 03.04.2015. For instance, for the event recorded on the 18.02.2015, the predicted TN outflows concentration for scenarios 1 and 2, where an effective and ineffective nutrient removal vegetation were adopted, were 0.60 and 0.8, respectively. These figures were between 20-27 times higher than the observed TN concentrations. Even though these figures demonstrate that the MUSIC model overestimates the values, the results are consisting of a previous research study undertaken by (Dotto et al., 2011b). The study suggested that TN concentrations predicted by MUSIC model are typically higher for smaller events. However, the model tent to compensate for this in the significant events. Therefore, given the storms events sampled for this study, it is not surprising to find TN inflow concentrations lower than those given by the MUSIC model. Unfortunately, the results in this study are not conclusive to draw a clear explanation of the causes. Therefore, this study suggests that the hydraulic behaviour of the DDBBO system may be a contributing factor that may influence the observed results that may not be included or considered by the model. Therefore, it is recommended that further testing be undertaken in order to investigate this in more detail

The graphs also show that the use of effective vegetation for nutrient removal can represents, regardless of the TN and Orthophosphate contents in the filter media, a 33% reduction in the overall outflow concentration when compared with ineffective nutrient removal plants.

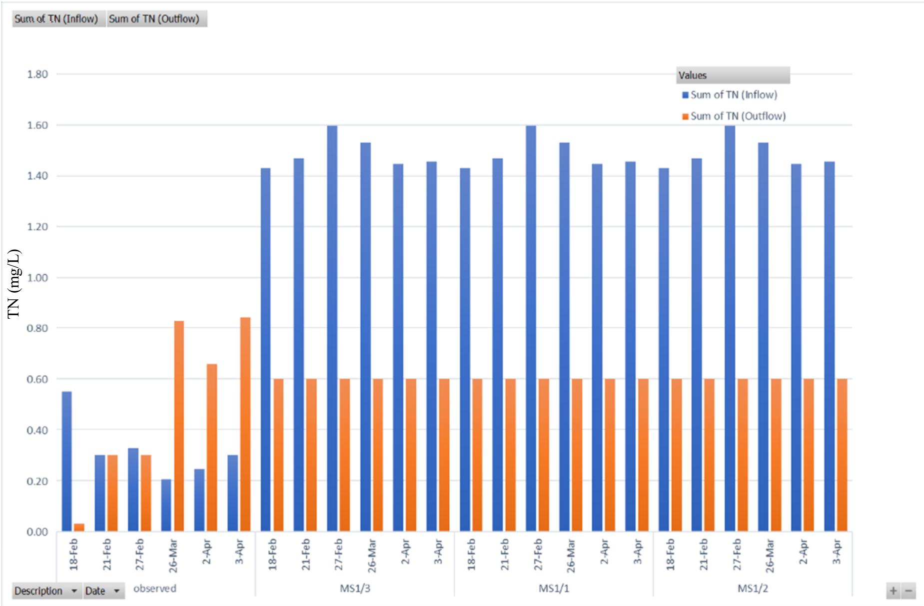


Figure 4.26 - Observed and MUSIC results comparison for TN inflow and outflow concentrations for scenario 1 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and RWTs)

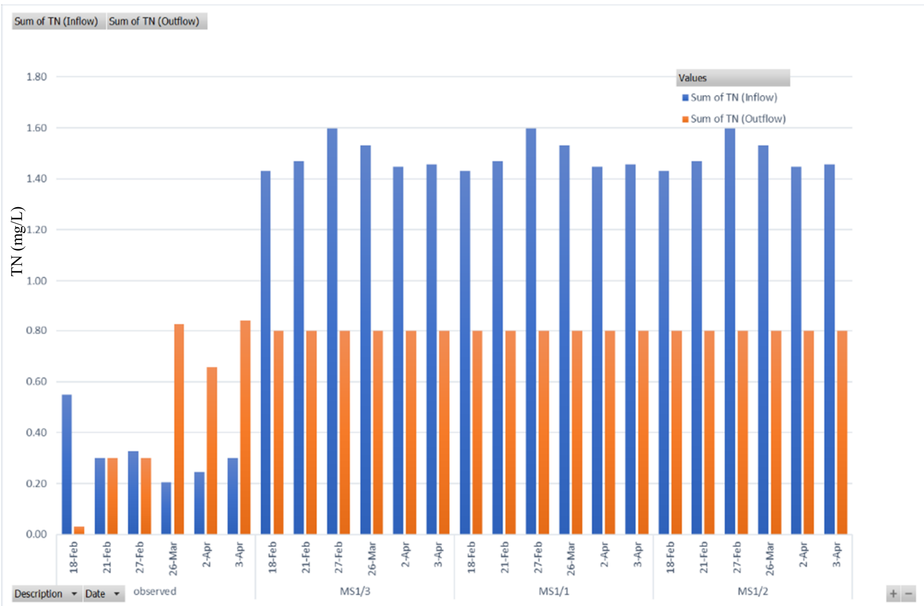


Figure 4.27 - Observed and MUSIC results comparison for TN inflow and outflow concentrations (mg/L) for scenario 1 (ineffective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and RWTs)

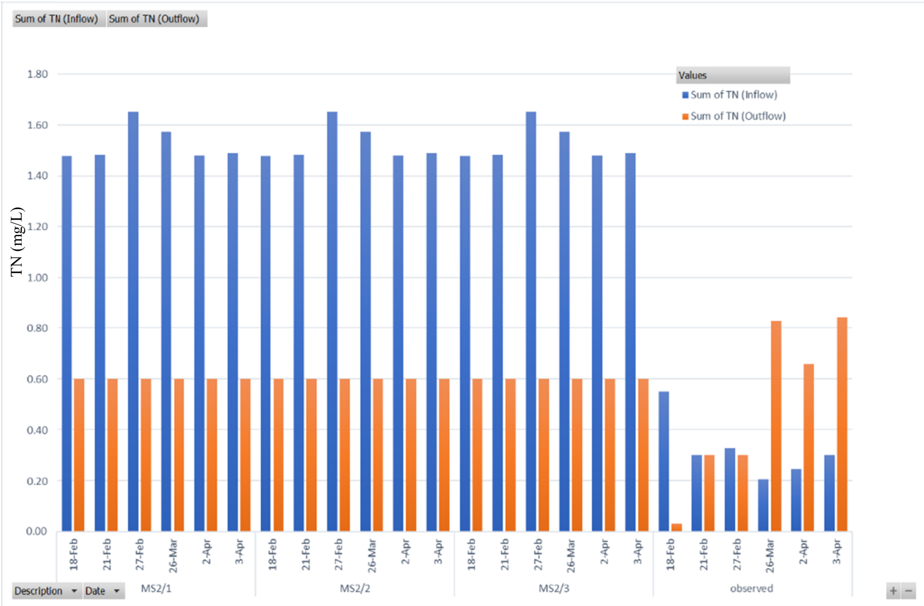


Figure 4.28 - Observed and MUSIC results comparison for TN inflow and outflow concentrations (mg/L) for scenario 2 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and without RWTs)

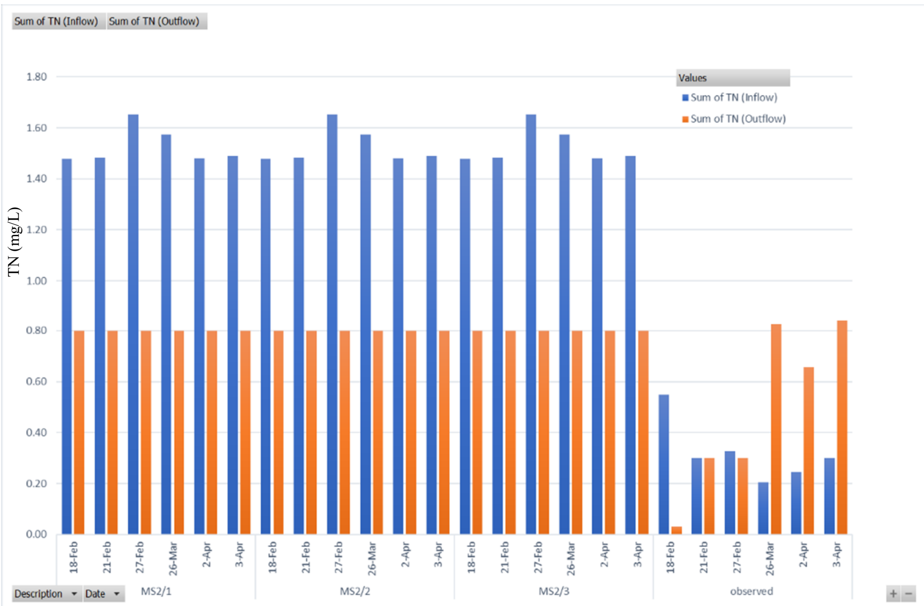


Figure 4.29 - Observed and MUSIC results comparison for TN inflow and outflow concentrations (mg/L) for scenario 2 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and without RWTs)

Figure 4.30, *Figure 4.31*, *Figure 4.32*, *Figure 4.33* showed there is a consistent pattern between the observed TP inflow concentration and the predicted figures for scenario 1 and 2. On the other hand, the observed TP outflow concentrations do not have a consistent pattern with results. For instance, when the observed outflows are compared against scenarios 1 and 2 where an effective nutrient removal plants and lower and median range values for the TN and Orthophosphate contents were adopted for the simulation process, the results showed that some observed data figures were significantly below than the predicted values such as those recorded on 18.02.2018, 21.02.2015, 02.04.02015 and 03.04.201, but in other case were slightly higher than the predicted figures as shown in the event recorded on 27.02.2015 and 26.03.2015. As with the TN, the results from this study are not conclusive and additional samples should be taken in future research to investigate this

The graphs also showed that the use of effective nutrient removal plants represent a 100% reduction in the overall outflow concentration when compared with ineffective plant species. It can also be concluded from these graphs that scenarios 1 and 2 with effective nutrient removal plants and lower range values for TN and Orthophosphate contents of the filter media represent the most consistent pattern when compared with the observed data. Therefore, it suggested the additional investigation be undertaken to determine nutrient removal effectiveness of the plants installed at Glenvale as well as the specific filter media characteristics with the objective of strengthen the results provided in this study.

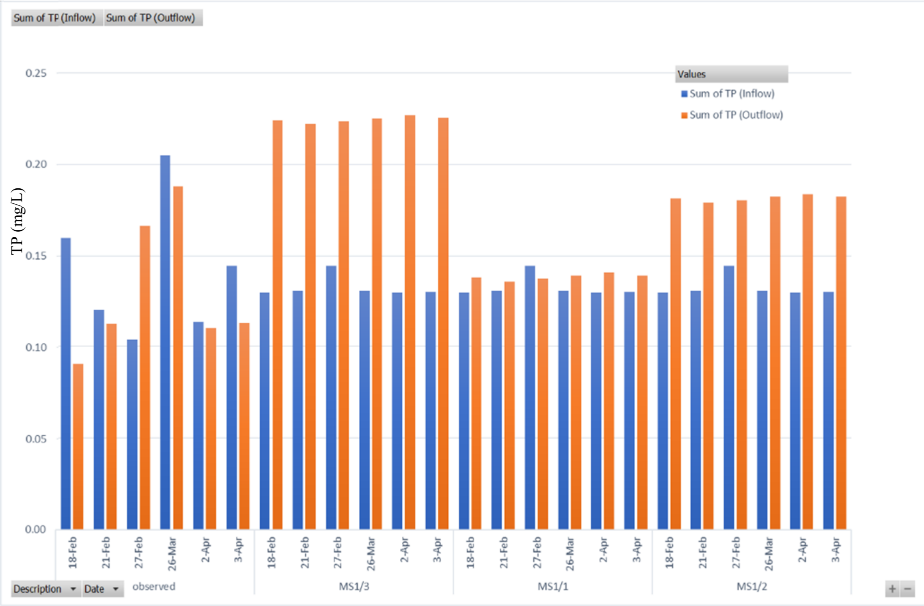


Figure 4.30 - Observed and MUSIC results comparison for TP inflow and outflow concentrations (mg/L) for scenario 1 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and with RWTs)

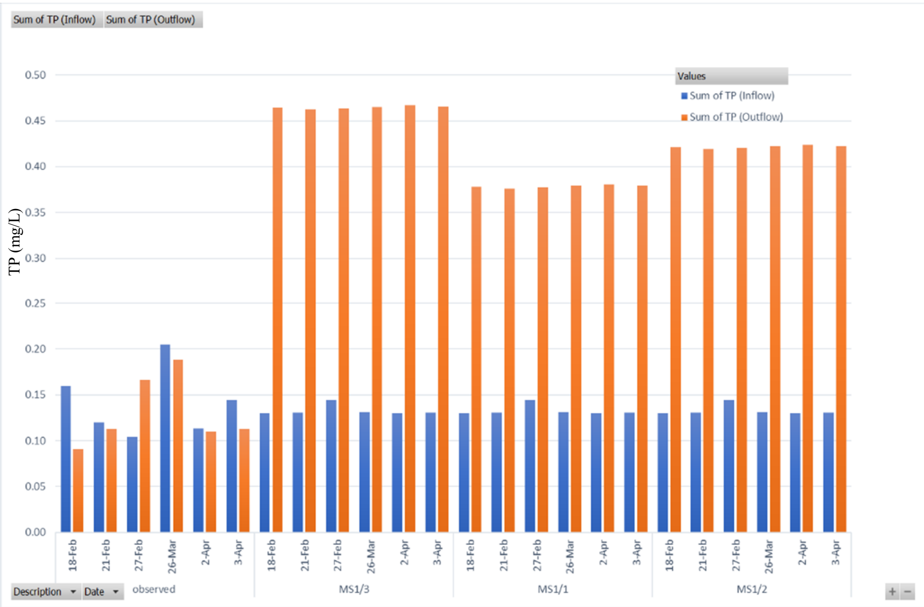


Figure 4.31 Observed and MUSIC results comparison for TP inflow and outflow concentrations (mg/L) for scenario 1 (ineffective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and with RWTs)

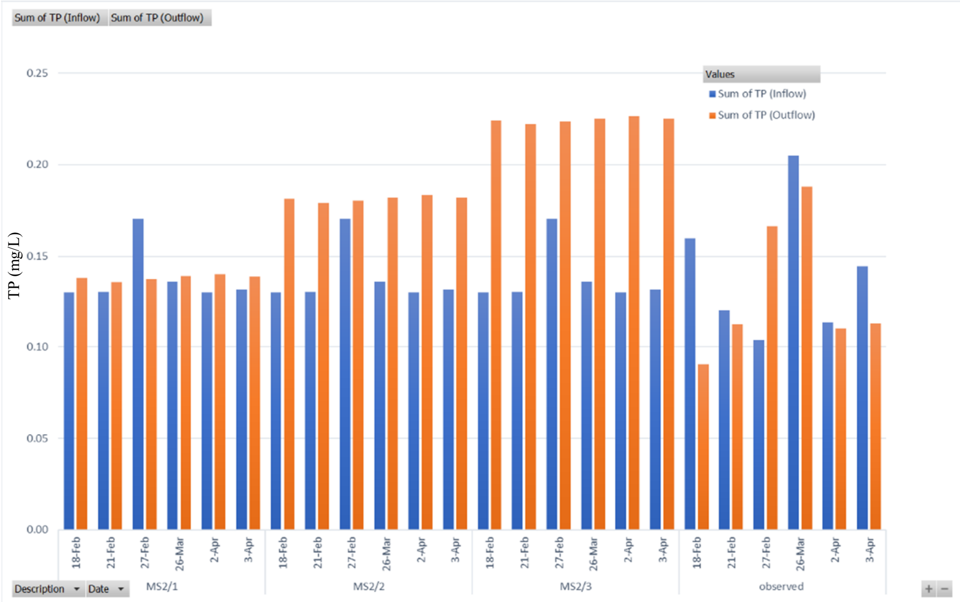


Figure 4.32 - Observed and MUSIC results comparison for TP inflow and outflow concentrations (mg/L) for scenario 2 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and without RWTs)

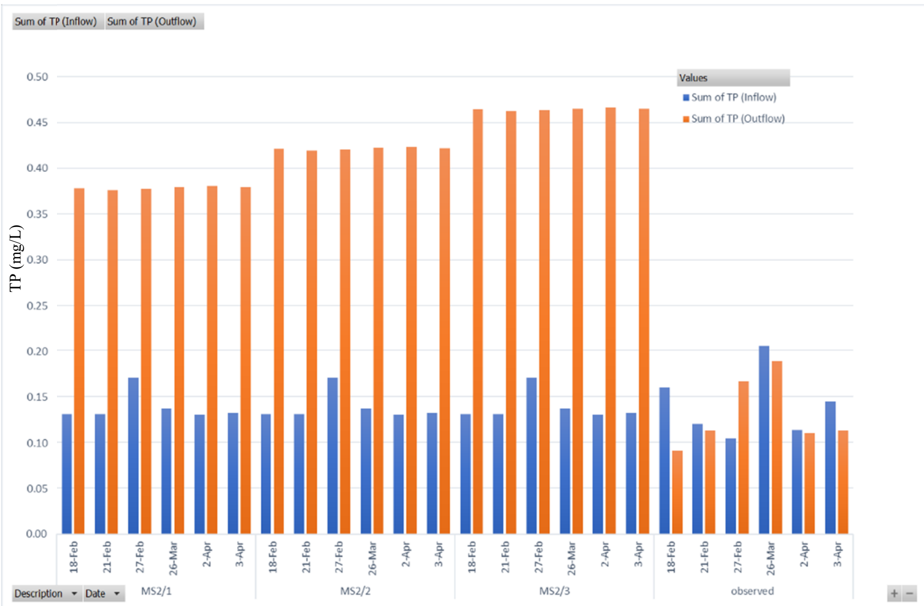


Figure 4.33 - Observed and MUSIC results comparison for TSS inflow and outflow concentrations (mg/L) for scenario 2 (ineffective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and without RWTs)

Figure 4.34, to *Figure 4.37* showed that the observed TSS inflow concentrations vary significantly when compared to the MUSIC predicted values. There is not a consistent pattern between these results. As can be seen in the graphs, the observed TSS inflow concentrations were below than its corresponding predicted values except for the storm event recorded on 26.03.2015, where the observed value was approximately 2 times higher than its predicted MUSIC value. Unfortunately, the data included in this research are inconclusive, and further samples will be required to draw a more definitive explanation about what may be the causes for this.

The figures also showed the observed TSS outflow concentration against the predicted MUSIC results. As can be seen on the graphs, there is significant variability in the results showing observed TSS outflow concentrations to be between 4 and 5 times higher than its corresponding predicted value for the storm events recorded on 18.02.2015, 21.02.2015 and 26.03.2015. The results of this study are not conclusive. However, it is suggested that the hydraulic behaviour of the DDBBO system can be a contributing factor and further samples should be taken in future research to draw more definitive conclusions.

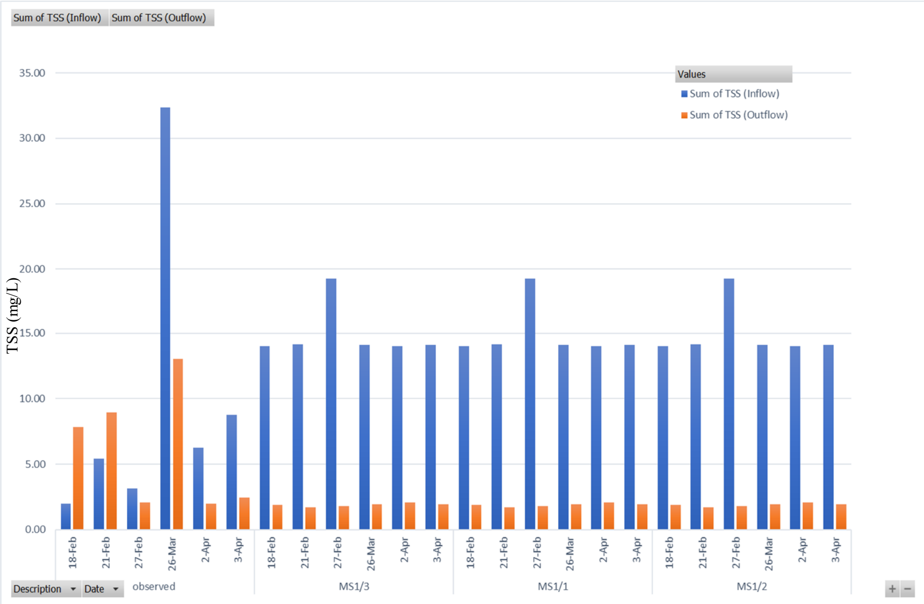


Figure 4.34 - Observed and MUSIC results comparison for TSS inflow and outflow concentrations (mg/L) for scenario 1 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and wit RWTs)

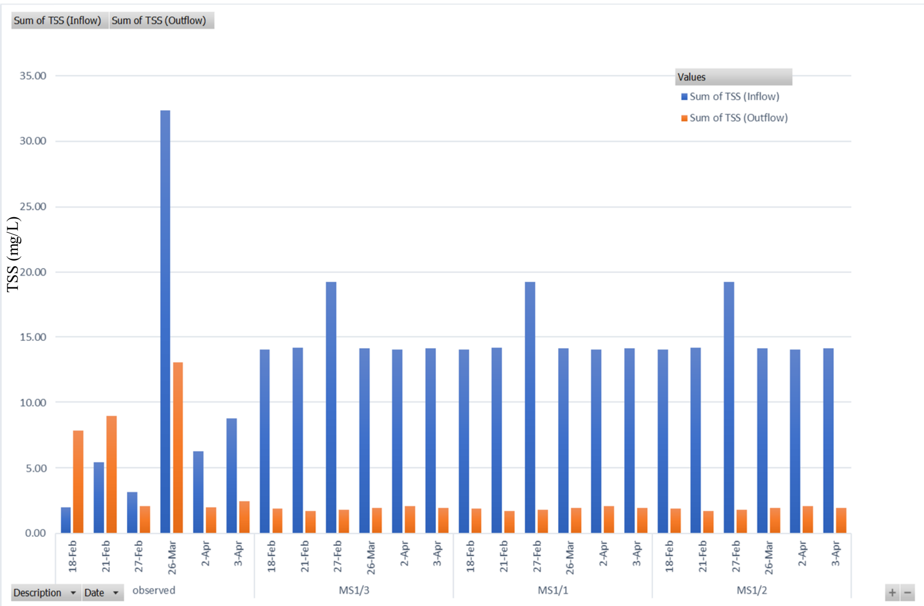


Figure 4.35 - Observed and MUSIC results comparison for TSS inflow and outflow concentrations (mg/L) for scenario 1 with (ineffective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and with RWTs)

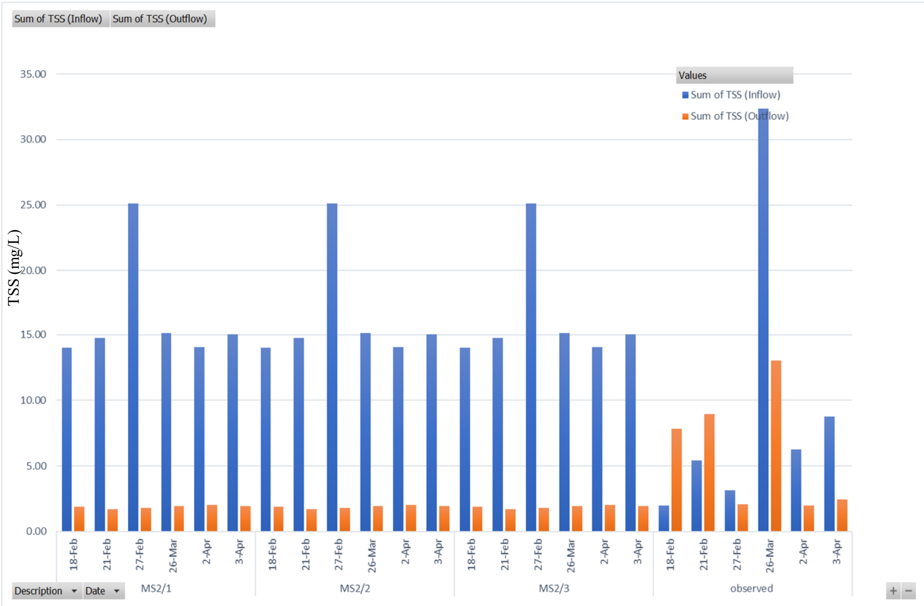


Figure 4.36 - Observed and MUSIC results comparison for TP inflow and outflow concentrations (mg/L) for scenario 2 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and without RWTs)

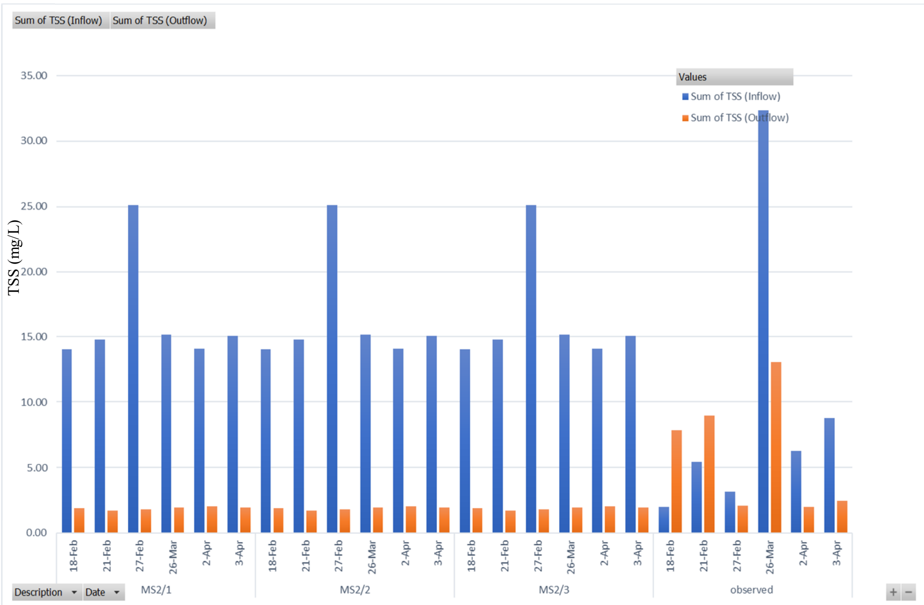


Figure 4.37 - Observed and MUSIC results comparison for TSS inflow and outflow concentrations (mg/L) for scenario 2 (effective vegetation for nutrient removal, different values for TN and Orthophosphate filter media contents and without RWTs)

The results presented in Table 4.24 to Table 4.27 showed that the field-observed data were below the removal targets defined by DILGP (2017). However, TN removal was just slightly under the removal target by approximately 3%, while TSS and TP were approximately 22% and 43%, respectively.

It can also be concluded from the Table 4.24 to Table 4.27 that higher TN and orthophosphate contents in the filter media can have significant implication in the overall removal efficiency of TP and TN for the system while TSS maintains invariable. For instance, the predicted MUSIC figures showed that scenario 1 and 2, where ineffective nutrients removal plants and lower TN and Orthophosphate filter media content were adopted, demonstrated to be the most consistent values for TP and TN removal when compared with the observed data. On the other hand, TSS removal was significantly lower for all the cases modelled in this study. The lower removal of the TSS and TP may be attributed to factor such as the undersized biofilter system when compared with the contributing catchment discharging into it and also due to denitrification process presented at the top of the biofilter due to grass clipping as a result of maintenance activities or leaching process within the filter media. The lower removal in TSS may also be attributed due to the hydraulic behaviour of DDBBO system through the bypass flow mechanism as well as sediment accumulation due to erosion process within the system or vegetated swale network.

It is also noted that the literature review shows that MUSIC predictions for TSS removal in biorientation basins have been very consistent and accurate as described in the research study undertook by Imteaz et al. (2013), but this was not the case for this study. Unfortunately, the number of sample events analysed in this study fell well below the minimum protocol requirements. Therefore, it is recommended that more sample be collected to investigate in more detail the range of factors described in this section and how they may influence the overall removal efficiency of the DDBBO system and how this can be accounted for in the MUSIC model.

Parameters	Pollutant Removal Efficiency			MUSIC Modelling (scenario 1) *Vegetated with ineffective Nutrient Removal Plants*			SPP 07/17
	ER	SOL	ROL	TN cont 400mg/kg Ortho P cont 60mg/kg	TN cont 600 mg/kg Ortho P cont 70mg/kg	TN cont 800mg/kg Ortho P cont 80mg/kg	
TP	17	16	16	21.3	14.3	7.3	**60**
TSS	58	58	58	90.9	90.9	90.9	**80**
TN	42	41	41	39.7	39.7	39.5	**45**

Table 4.24 – Comparison of the observed pollutant removal efficiency values for scenario 1 with RWTs and ineffective vegetation for nutrient removal and different values for TN and Orthophosphate filter media content against MUSIC and SPP 07/17

Parameters	Pollutant Removal Efficiency			MUSIC Modelling (scenario 1) *Vegetated with effective Nutrient Removal Plants*			SPP 07/17
	ER	SOL	ROL	TN cont 400mg/kg Ortho P cont 60mg/kg	TN cont 600 mg/kg Ortho P cont 70mg/kg	TN cont 800mg/kg Ortho P cont 80mg/kg	
TP	17	16	16	60.6	53.6	46.5	**60**
TSS	58	58	58	90.9	90.9	90.9	**80**
TN	42	41	41	46.9	46.9	46.9	**45**

Table 4.25 – Comparison of the observed pollutant removal efficiency values for scenario 1 with RWTs and effective vegetation for nutrient removal and different values for TN and Orthophosphate filter media content against MUSIC and SPP 07/17

Parameters	Pollutant Removal Efficiency			MUSIC Modelling (scenario 2) *Vegetated with ineffective Nutrient Removal Plants*			SPP 07/17
	ER	SOL	ROL	TN cont 400mg/kg Ortho P cont 60mg/kg	TN cont 600 mg/kg Ortho P cont 70mg/kg	TN cont 800mg/kg Ortho P cont 80mg/kg	
TP	17	16	16	21.1	13.9	6.8	**60**
TSS	58	58	58	90.1	90.1	90.1	**80**
TN	42	41	41	38.6	38.3	37.9	**45**

Table 4.26 – Comparison of the observed pollutant removal efficiency values for scenario 2 without RWTs and effective vegetation for nutrient removal and different values for TN and Orthophosphate filter media content against MUSIC and SPP 07/17

Parameters	Pollutant Removal Efficiency			MUSIC Modelling (scenario 2) *Vegetated with effective Nutrient Removal Plants*			SPP 07/17
	ER	SOL	ROL	TN cont 400mg/kg Ortho P cont 60mg/kg	TN cont 600 mg/kg Ortho P cont 70mg/kg	TN cont 800mg/kg Ortho P cont 80mg/kg	
TP	17	16	16	61.1	53.9	46.8	**60**
TSS	58	58	58	90.1	90.1	90.1	**80**
TN	42	41	41	46.2	46.2	46.2	**45**

Table 4.27 – Comparison of the observed pollutant removal efficiency values for scenario 2 without RWTs and effective vegetation for nutrient removal and different values for TN and Orthophosphate filter media content against MUSIC and SPP 07/17

5 Conclusions and recommendations

5.1 Summary

This study research investigated the water quality performance of a DDBBO for the removal of key pollutants such as TSS, TP and TN as established by the legislation. The study also assessed the accuracy of the MUSIC model to predict pollutant concentrations and removal efficiency of the DDBBO under a site-specific condition such as those described at Glenvale.

The conclusions and recommendations drawn from this study are described in this chapter to guide further research in similar WSUD system.

5.2 Conclusions

This study describes a fieldwork monitoring program implemented to obtain the inflow and outflow pollutant concentrations from a DDBBO system located at Glenvale in Toowoomba with the objective to assess its effectiveness for the removal of TSS, TP and TN under real storm events and compare the results against MUSIC model predictions and the findings from the literature. A total of 36 samples were tested between December 2014 through May 2015, for which seven storm events were considered, but only six met all the validity requirements to be included for comparison and analysis of qualifying samples. However, it is important to note that the number of sampled events and the monitoring program duration selected for this study fell below the minimum protocol (SQIDEP) requirements for stormwater quality treatment devices.

Three different load estimation techniques were applied to the event-based samples with the objective of determining the order of difference in magnitude between them. The results showed that there was a significant difference in the pollutant load estimates indicating the regression approach provided the best-fit when compared against the true load.

The event-based samples were also used to calculate the removal efficiency of the DDBBO by applying the efficiency ratio (ER), a summary of loads (SOL) and regression of loads (ROL) techniques. The ER, SOL and ROL techniques demonstrated that the DDBBO system could facilitate removal for TN, TSS and TP with percentage values of 42%, 58% and 17%, respectively. The removal figures for TSS and TP were significantly lower than the minimum values specified by Queensland Government policies, while TN just fell slightly below by approximately 3%. This study suggests P exported from the system might be attributed to denitrification process generated on the basin due to grass clipping left during the maintenance activities or TSS accumulation at the top of the biofilter after a rainfall event.

The figures obtained in this study were benchmarked against local and global figures reported in the literature review and MUSIC model. The results showed that the DDBBO at Glenvale reported lower values for TSS, TN and TP than those found locally or internationally. However, a research project of a residential catchment in Toowoomba with similar characteristics to those presented at Glenvale showed TN values were two times higher than those reported at Glenvale, but similar values were found for TSS and TP.

MUSIC Model was used to compare the order of difference in magnitude between the predicted and observed pollutants concentrations. For instance, it was found that observed TSS and TN inflow concentrations were considerably lower than the lower deviation level set by the model. However, it was found that 50% of the observed TP inflow concentrations were within the upper and lower levels and the remaining 50% fell below the lower deviation level.

In relation to the MUSIC predicted values, it was found that observed TN inflow concentrations were significantly lower in some cases but in others were slightly higher than those predicted by the model. The cause of this is unknown, and no definitive explanation can be drawn from the results of this study.

For the TP concentration, the observed and predicted inflow concentrations showed a consistent pattern for most of the samples taken. However, the observed TP outflow concentrations were significantly lower or slightly higher than those reported by the MUSIC model, where effective nutrient removal plants and lower to median values of TN and Orthophosphate were adopted. As with the TN, the cause of such variability is unknown, and no conclusive explanation can be drawn from the results showed in this study. The observed and simulated TSS inflow and outflows concentrations results showed that there are a significant variability and no consistent pattern between the dataset. Unfortunately, the reason for this is unknown at this stage, and no definite conclusion can be drawn from this study.

In summary, this study demonstrated that the pollutant removal efficiency obtained from the monitoring program were significantly lower for TSS but similar figures were reported for TP and TN when compared with those obtained from the MUSIC simulation process, in which ineffective removal nutrients plants and lower TN and Orthophosphate contents were adopted. TSS removal was approximately 40% lower for all the scenarios modelled in MUSIC. While, TP and TN reported approximately similar removal value of 17% and 42%, respectively.

This study concluded that the DDBBO system could be effective at removing pollutant loads at Glenvale and valuable information was gained during this research that could be used in future research projects that assess the DDBBO or similar structure in urban settings.

5.3 Limitations

The limitations of this study were as follow:

- The total number of samples tested and the duration of the collection process, which fell below the minimum protocol (SQIDEP) requirements for stormwater quality treatment devices. The protocol requires at least 15 samples to be collected in a period not less than a year but due to funding, time constraints, sampler units programming and sampling difficulties; it was not possible to meet such requirements, and only 36 samples were tested in a period of five months. Therefore, the results of this study should be used as preliminary and further and more detailed research need to undertake to strengthen information presented this study.

- Besides the efforts and procedures put in place to minimise the loss of data during the monitoring process, the event sampled dated the 01.05.2015 was not recorded for the datalogger and sensor unit installed for the monitoring station 2 (outlet) due to a system malfunction. Therefore, it was decided that this event will be included in the establishment of the water discharge equation. However, the event will be disregarded for the assessment of the pollutant load concentration and removal efficiency of the DDBBO system.

- The pollutants modelled in MUSIC were in daily time step instead of traditional yearly loads. Therefore, it was expected to find a low level of accuracy in the predicted figures. Therefore, further testing in future research may be able to demonstrate if the MUSIC model can be relatively accurate to predict inflow and outflow concentrations under real storm and catchment characteristics.

- The lack of information with regard to the filter media characteristic that were installed and the effectiveness of the vegetation under specific Toowoomba weather conditions was the major restriction encountered during the MUSIC simulation process.

5.4 Recommendations for future research

Assessment of WSUD performance such as the DDBBO system is hugely challenging to monitor due to the highly unpredictable and random nature of the rainfall event, especially without the incorporation of automatic water samplers. Unfortunately, the acquisition of automatic equipment such as this, as well as the associated cost of the collection and sample testing processes, make continual monitoring and testing process very expensive. However, understating the operation of the DDBBO systems can lead to more cost-effective management strategies of these systems, and more consistent improved water quality discharges in the long term, which represents a great benefit not just for the catchment and receiving waterways, but also for the human health and wellbeing. Therefore, it is recommended that future research of this system includes a monitoring process with a duration not less than a year and that the collection process for a specific storm event to be extended beyond the peak hours to gain a better understanding about the effectiveness of these systems and its behaviours. This will add an extra cost to the project research, but it can provide a better understanding of the system as it will capture a wide range of flow conditions and pollutant characteristics, which help to determine how this may influence the overall performance of the system

Future research should also investigate the influence that major flows might have when discharged into the system, and the influence that these flows have in resuspension of sediments and filter media erosion as the preliminary results for this study showed in some cases higher TP and TN concentrations at the outflows than those recorded in the inflows.

The understating gained in this research is limited to the monitored structure. It was evident that DDBBO failed in meeting WQO, which suggested that still exists a significant lack of understating of its and maintenance requirements, which this research suggested it may be a contributing factor for the overall performance of the system. Hence, the maintenance frequency requirements for sediment removal or the inclusion of preventing erosion and sediment control measures to ensure that hydraulic and treatment performance are maintained, and there are not compromised in the long term. In addition, to the impact that mowing procedures such as grass clippings in this system may impact water quality performance should also be investigated in more detail in future research as this study show higher TSS, TN and TP concentrations at the outflow for some storm events than those recorded in the inflows.

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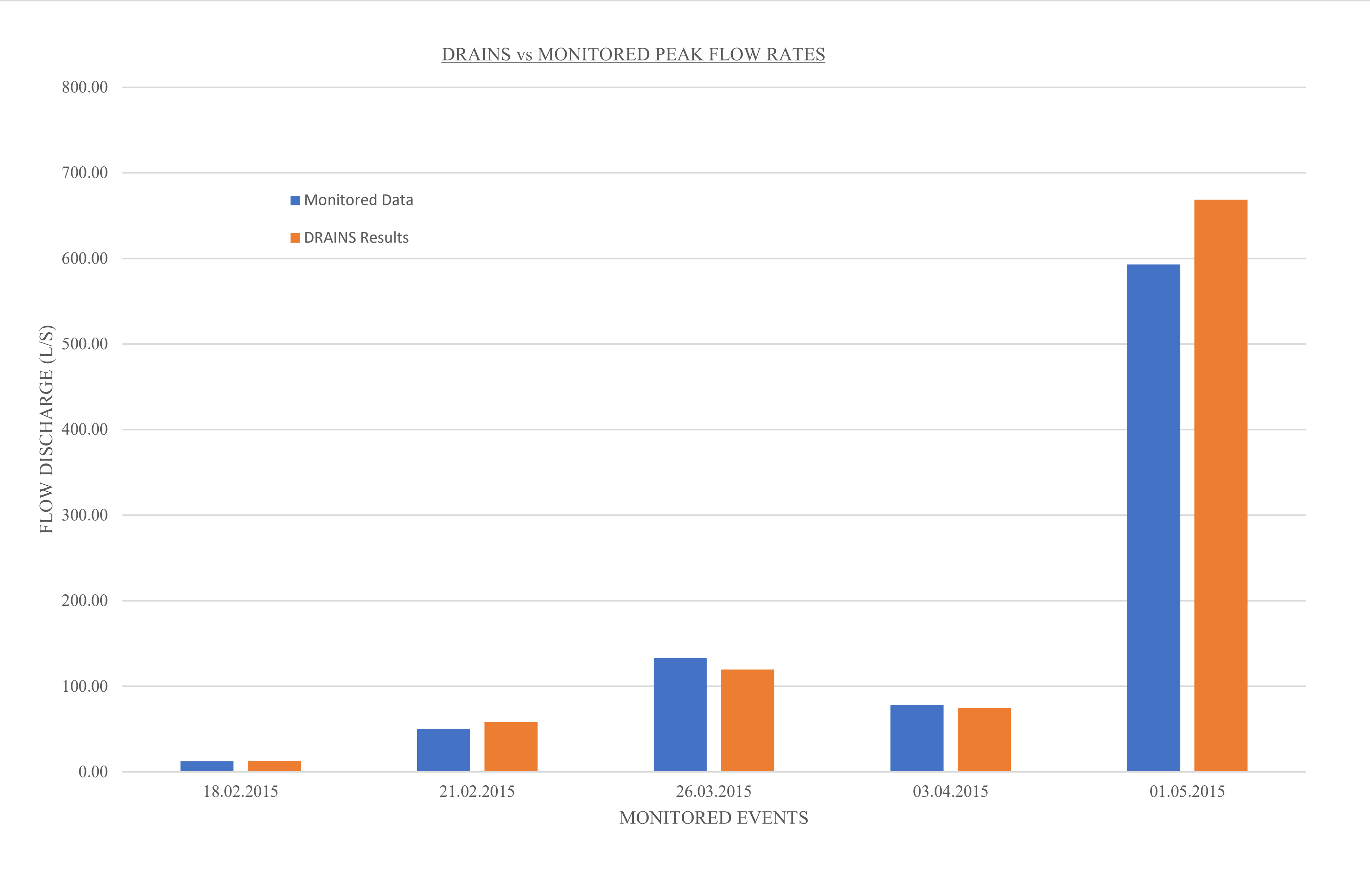
Appendix A – Project Research Supporting Information

Date	Weir Water Level (cm)	Observed Q (L/s) 1 min	DRAINS Peak Flows L/s	Weir Water Level (cm)	Observed Q (L/s) 6 min		Percent Bias	RMSE		$(Obs\text{-}Pred)^2$	$(Obs\text{-}Obs_{mean})^2$	Nash schutcliffe model efficiency	Nash schutcliffe model efficiency
18.02.2015	18.64	12.34	12.67	18.34	11.86	0.33	2.6%	0.3	54.25	0.11	26145.53	1.000	0.93
21.02.2015	23.15	49.90	57.98	22.74	43.55	8.08	16.2%	8.1		65.23	15409.83	0.996	
26.03.2015	27.28	132.89	119.62	26.71	119.62	-13.27	-10.0%	13.3		176.01	1692.98	0.896	
03.04.2015	31.15	78.30	74.54	30.56	218.80	-3.76	-4.8%	3.8		14.15	9164.86	0.998	
01.05.2015	41.24	592.79	668.51	40.18	549.97	75.72	12.8%	75.7		5733.80	175355.88	0.967	


DRAINS vs MONITORED PEAK FLOW RATES
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
FLOW DISCHARGE (L/S)
Monitored Data
DRAINS Results
18.02.2015
21.02.2015
26.03.2015
03.04.2015
01.05.2015
MONITORED EVENTS

Date Event 01.05.2015	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	11,285,236.88	1,449,311.84	119,046.53	1,561,130.04	0.13	NA	NA	NA
Phosphorous_M2	-	-	-		-			
Total Suspended Solids_M1	11,285,236.88	22,570,473.75	29,014,392.22	44,960,597.50	2.00	NA	NA	NA
Total Suspended Solids_M2	-	-	-		-			
Total Nitrogen_M1	11,285,236.88	3,385,571.06	652,893.29	3,805,249.95	0.30	NA	NA	NA
Total Nitrogen_M2	-	-	-		-			
Nitrate TRC_M1	11,285,236.88	3,951,779.21	324,599.28	9,853,258.68	0.35	NA	NA	NA
Nitrate TRC_M2	-	-	-		-			
Nitrate USQ_M1	11,285,236.88	7,192,930.92	590,827.60	- 2,398,857.08	0.47	NA	NA	NA
Nitrate USQ_M2	-	-	-		-			
Phosphate USQ_M1	11,285,236.88	602,411.99	49,482.14	1,211,854.44	0.05	NA	NA	NA
Phosphate USQ_M2	-	-	-		-			
T Kjeldahl Nitrogen TRC_M1	11,285,236.88	3,385,571.06	278,090.93	3,450,289.22	0.30	NA	NA	NA
T Kjeldahl Nitrogen TRC_M2	-	-	-		-			
Turbidity USQ_M1	11,285,236.88	138,271,975.49	11,357,664.94	47,542,755.53	12.25	NA	NA	NA
Turbidity USQ_M2	-	-	-		-			

Date Event 02.04.2015	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	26,042.98	2,943.51	1,886.18	4,114.60	0.113	3%	0%	0%
Phosphorous_M2	26,814.10	2,949.55	1,890.05	4,251.20	0.110			
Total Suspended Solids_M1	26,042.98	163,298.95	1,773,388.20	223,412.70	6.270	68%	67%	67%
Total Suspended Solids_M2	26,814.10	53,628.19	582,389.57	233,480.71	2.000			
Total Nitrogen_M1	26,042.98	6,368.11	7,019.93	12,122.62	0.245	-168%	-176%	-176%
Total Nitrogen_M2	26,814.10	17,584.70	7,019.93	12,577.98	0.656			
Nitrate TRC_M1	26,042.98	3,986.41	3,345.86	35,971.06	0.153	-322%	-334%	-334%
Nitrate TRC_M2	26,814.10	17,307.98	14,526.87	37,417.99	0.645			
Nitrate USQ_M1	26,042.98	75,562.33	755,925.57	22,641.18	2.901	-31%	-35%	-35%
Nitrate USQ_M2	26,814.10	102,298.11	102,298.11	24,124.67	3.815			
Phosphate USQ_M1	26,042.98	3,587.47	3,081.07	4,065.58	0.138	-325%	-338%	-338%
Phosphate USQ_M2	26,814.10	15,698.50	13,482.56	4,222.57	0.585			
T Kjeldahl Nitrogen TRC_M1	26,042.98	6,368.11	6,462.90	7,108.06	0.245	-23%	-26%	-26%
T Kjeldahl Nitrogen TRC_M2	26,814.10	8,044.23	8,163.97	7,293.88	0.300			
Turbidity USQ_M1	26,042.98	272,263.87	7,636,182.75	425,409.51	10.454	-14%	-17%	-17%
Turbidity USQ_M2	26,814.10	318,421.29	8,930,759.37	447,115.52	11.875			

Date Event 21.02.2015	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	103,728.75	12,425.93	1,623.87	16,298.94	0.120	6%	2%	2%
Phosphorous_M2	108,561.61	12,206.45	1,595.19	17,170.46	0.112			
Total Suspended Solids_M1	103,728.75	560,057.04	3,159,725.33	868,944.28	5.399	-66%	-74%	-74%
Total Suspended Solids_M2	108,561.61	973,342.35	5,491,395.13	935,636.91	8.966			
Total Nitrogen_M1	103,728.75	31,118.63	9,884.89	47,700.47	0.300	0%	-5%	-5%
Total Nitrogen_M2	108,561.61	32,568.48	10,345.44	50,654.69	0.300			
Nitrate TRC_M1	103,728.75	12,259.05	1,583.92	140,960.31	0.118	39%	36%	36%
Nitrate TRC_M2	108,561.61	7,826.87	1,011.27	150,426.06	0.072			
Nitrate USQ_M1	103,728.75	4,100.06	191.86	85,256.77	0.040	39%	36%	36%
Nitrate USQ_M2	108,561.61	2,632.66	123.19	95,400.35	0.024			
Phosphate USQ_M1	103,728.75	9,766.41	1,012.76	15,971.42	0.094	11%	7%	7%
Phosphate USQ_M2	108,561.61	9,104.44	944.12	16,993.48	0.084			
T Kjeldahl Nitrogen TRC_M1	103,728.75	31,118.63	9,884.89	28,460.52	0.300	0%	-5%	-5%
T Kjeldahl Nitrogen TRC_M2	108,561.61	32,568.48	10,345.44	29,599.45	0.300			
Turbidity USQ_M1	103,728.75	463,933.13	2,165,167.61	1,639,245.25	4.473	4%	0%	0%
Turbidity USQ_M2	108,561.61	465,284.63	2,171,475.06	1,784,763.64	4.286			

	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	35,735.66	5,819.76	1,812.40	5,640.06	0.163	44%	43%	43%
Phosphorous_M2	36,349.00	3,288.92	1,024.24	5,756.08	0.090			
Total Suspended Solids_M1	35,735.66	71,471.31	452,894.56	305,180.17	2.000	-290%	-297%	-297%
Total Suspended Solids_M2	36,349.00	283,536.23	1,796,693.10	314,910.36	7.800			
Total Nitrogen_M1	35,735.66	19,853.41	14,124.76	16,595.82	0.556	95%	95%	95%
Total Nitrogen_M2	36,349.00	1,090.47	775.82	17,006.10	0.030			
Nitrate TRC_M1	35,735.66	28,588.53	62,782.14	49,205.91	0.800	-194%	-199%	-199%
Nitrate TRC_M2	36,349.00	85,374.83	187,488.32	50,547.24	2.349			
Nitrate USQ_M1	35,735.66	34,360.06	41,859.13	30,742.28	0.962	85%	85%	85%
Nitrate USQ_M2	36,349.00	5,150.08	6,274.08	32,327.77	0.142			
Phosphate USQ_M1	35,735.66	11,227.26	5,281.79	5,564.04	0.314	75%	74%	74%
Phosphate USQ_M2	36,349.00	2,905.26	1,366.76	5,707.18	0.080			
T Kjeldahl Nitrogen TRC_M1	35,735.66	6,707.06	953.64	9,763.41	0.188	72%	71%	71%
T Kjeldahl Nitrogen TRC_M2	36,349.00	1,916.48	272.49	9,898.91	0.053			
Turbidity USQ_M1	35,735.66	5,819.76	1,812.40	231,297.34	0.163	44%	43%	43%
Turbidity USQ_M2	36,349.00	3,288.92	1,024.24	-5,580.11	0.090			

Date Event 26.03.2015	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	94,985.70	19,428.96	10,026.19	14,795.42	0.205	8%	11%	11%
Phosphorous_M2	92,083.28	17,294.49	8,924.71	14,574.53	0.188			
Total Suspended Solids_M1	94,985.70	3,064,112.24	260,061,567.71	765,385.49	32.259	57%	59%	59%
Total Suspended Solids_M2	92,083.28	1,266,704.75	1,266,704.75	796,034.88	13.756			
Total Nitrogen_M1	94,985.70	101,491.03	221,933.14	42,833.34	1.068	22%	25%	25%
Total Nitrogen_M2	92,083.28	76,435.45	167,143.44	43,033.40	0.830			
Nitrate TRC_M1	94,985.70	369,688.82	2,976,625.40	125,726.33	3.892	2%	5%	5%
Nitrate TRC_M2	92,083.28	351,411.71	2,829,463.53	127,860.43	3.816			
Nitrate USQ_M1	94,985.70	21,604.14	11,192.11	70,931.45	0.227	10%	12%	12%
Nitrate USQ_M2	92,083.28	18,931.85	9,807.71	81,488.73	0.206			
Phosphate USQ_M1	94,985.70	13,553.68	3,477.32	14,303.71	0.143	32%	34%	34%
Phosphate USQ_M2	92,083.28	8,889.64	2,280.72	14,439.70	0.097			
T Kjeldahl Nitrogen TRC_M1	94,985.70	29,580.81	18,872.31	26,278.07	0.311	4%	7%	7%
T Kjeldahl Nitrogen TRC_M2	92,083.28	27,624.98	17,624.51	25,089.36	0.300			
Turbidity USQ_M1	94,985.70	3,332,241.53	277,563,214.94	1,421,089.40	35.082	7%	9%	9%
Turbidity USQ_M2	92,083.28	3,016,427.84	251,257,119.54	1,520,233.15	32.758			

Date Event 27.02.2015	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	314,771.92	32,712.50	4,183.41	47,549.35	0.104	-59%	-51%	-51%
Phosphorous_M2	299,138.00	49,465.01	6,325.78	44,795.15	0.165			
Total Suspended Solids_M1	314,771.92	990,430.22	126,660.20	2,190,266.59	3.147	35%	38%	38%
Total Suspended Solids_M2	299,138.00	614,437.78	78,576.77	1,989,737.70	2.054			
Total Nitrogen_M1	314,771.92	102,591.76	13,119.85	132,279.59	0.326	8%	13%	13%
Total Nitrogen_M2	299,138.00	89,741.40	11,476.49	123,147.79	0.300			
Nitrate TRC_M1	314,771.92	302,734.14	38,714.86	378,364.45	0.962	34%	37%	37%
Nitrate TRC_M2	299,138.00	190,796.05	24,399.77	349,426.25	0.638			
Nitrate USQ_M1	314,771.92	27,282.03	3,488.94	153,550.42	0.087	-2%	3%	3%
Nitrate USQ_M2	299,138.00	26,395.63	3,375.58	124,319.95	0.088			
Phosphate USQ_M1	314,771.92	27,085.89	3,463.85	43,730.08	0.086	-68%	-59%	-59%
Phosphate USQ_M2	299,138.00	43,167.39	5,520.42	40,585.17	0.144			
T Kjeldahl Nitrogen TRC_M1	314,771.92	91,267.96	11,671.71	85,760.52	0.290	-3%	2%	2%
T Kjeldahl Nitrogen TRC_M2	299,138.00	89,741.40	11,476.49	85,760.52	0.300			
Turbidity USQ_M1	314,771.92	3,343,490.20	427,578.97	3,796,111.59	10.622	58%	60%	60%
Turbidity USQ_M2	299,138.00	1,332,999.50	170,469.34	3,365,517.39	4.456			

Date Event 03.04.2015	Volume (L)	Numeric (mg)	Beale Ratio (mg)	Regression (mg)	Event Mean Concentration (EMC)	Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
Phosphorous_M1	130,976.93	18,940.30	2,363.62	20,002.96	0.145	22%	25%	25%
Phosphorous_M2	125,457.78	14,159.39	1,766.99	19,871.41	0.113			
Total Suspended Solids_M1	130,976.93	1,143,254.92	10,036,670.24	962,234.19	8.729	71%	72%	72%
Total Suspended Solids_M2	125,457.78	316,737.93	2,780,652.05	1,087,939.03	2.525			
Total Nitrogen_M1	130,976.93	39,293.08	10,575.15	56,461.92	0.300	-180%	-168%	-168%
Total Nitrogen_M2	125,457.78	105,311.94	28,343.14	58,725.03	0.839			
Nitrate TRC_M1	130,976.93	60,980.19	28,028.34	163,062.59	0.466	-709%	-675%	-675%
Nitrate TRC_M2	125,457.78	472,827.22	217,325.69	174,576.90	3.769			
Nitrate USQ_M1	130,976.93	3,451.87	68.86	75,869.55	0.026	-6%	-1%	-1%
Nitrate USQ_M2	125,457.78	3,503.06	69.88	111,821.79	0.028			
Phosphate USQ_M1	130,976.93	13,680.98	1,221.33	18,735.53	0.104	-39%	-33%	-33%
Phosphate USQ_M2	125,457.78	18,201.30	1,624.87	19,709.16	0.145			
T Kjeldahl Nitrogen TRC_M1	130,976.93	39,293.08	10,476.51	36,900.22	0.300	0%	4%	4%
T Kjeldahl Nitrogen TRC_M2	125,457.78	37,637.34	10,035.05	34,158.50	0.300			
Turbidity USQ_M1	130,976.93	2,427,841.59	41,593,452.29	1,713,756.78	18.536	-6%	-1%	-1%
Turbidity USQ_M2	125,457.78	2,459,898.32	42,142,643.70	2,080,169.45	19.607			

REGRESSION TP

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.087404939
R Square	0.007639623
Adjusted R Square	-0.017805514
Standard Error	0.062348989
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.001167148	0.001167148	0.300239025	0.586855351
Residual	39	0.151608462	0.003887396		
Total	40	0.15277561			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.158603679	0.010757942	14.74293922	1.5522E-17	0.136843688	0.18036367	0.136843688	0.18036367
60.27460074	-1.23222E-06	2.24882E-06	-0.547940713	0.586855351	-5.78089E-06	3.31645E-06	-5.78089E-06	3.31645E-06

RESIDUAL OUTPUT

Observation	*Predicted 0.18*	*Residuals*	*Standard Residuals*
1	0.157857694	0.082142306	1.334243717
2	0.157882621	-0.047882621	-0.777761044
3	0.158331683	-0.058331683	-0.947485959
4	0.158065235	-0.058065235	-0.943158019
5	0.158441458	-0.078441458	-1.274130553
6	0.157856537	0.022143463	0.359677944
7	0.157897707	0.082102293	1.333593778
8	0.15712407	-0.04712407	-0.765439846
9	0.158255599	-0.058255599	-0.946250116
10	0.158358572	-0.058358572	-0.947922723
11	0.158360843	-0.078360843	-1.272821133
12	0.13668779	-0.04668779	-0.758353318
13	0.144272281	-0.024272281	-0.394256507
14	0.158111118	-0.048111118	-0.78147255
15	0.15015487	0.06984513	1.134499751
16	0.144974958	0.015025042	0.244052895
17	0.145580205	0.024419795	0.396652588
18	0.157837995	0.122162005	1.984286729
19	0.155704948	0.104295052	1.694072447
20	0.157948706	0.022051294	0.358180838
21	0.158303893	0.031696107	0.514842278
22	0.158274985	0.031725015	0.515311823
23	0.158286254	0.031713746	0.515128791
24	0.158585818	0.001414182	0.022970665
25	0.158209652	-0.008209652	-0.133349998
26	0.158479075	-0.058479075	-0.949880064
27	0.158540794	-0.048540794	-0.788451799
28	0.158504255	-0.048504255	-0.787858299
29	0.158506481	-0.048506481	-0.787894463
30	0.158092731	-0.008092731	-0.131450841
31	0.158516374	-0.008516374	-0.138332115
32	0.141380951	-0.001380951	-0.022430897
33	0.158356637	0.011643363	0.189124034
34	0.158343442	-0.048343442	-0.785246202
35	0.158291692	-0.048291692	-0.784405618
36	0.158603679	-0.028603679	-0.464611732
37	0.158603679	-0.038603679	-0.627042492
38	0.158603679	-0.028603679	-0.464611732
39	0.158603679	0.091396321	1.484557383
40	0.158603679	0.131396321	2.134280421
41	0.158603679	0.151396321	2.45914194

REGRESSION TN

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.114406364
R Square	0.013088816
Adjusted R Square	-0.012216599
Standard Error	0.311064094
Observations	41

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.050047993	0.050047993	0.517233805	0.476311604
Residual	39	3.773673958	0.096760871		
Total	40	3.823721951			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.469472814	0.053465576	8.780842701	8.88379E-11	0.361328479	0.57761715	0.361328479	0.57761715
1761.290195	-8.04168E-06	1.11816E-05	-0.719189686	0.476311604	-3.06586E-05	1.45752E-05	-3.06586E-05	1.45752E-05

RESIDUAL OUTPUT

Observation	Predicted 0.5	Residuals	Standard Residuals
1	0.469472814	0.030527186	0.099388143
2	0.469472814	0.030527186	0.099388143
3	0.469027345	-0.439027345	-1.429352613
4	0.467888812	-0.437888812	-1.42564586
5	0.467764544	-0.437764544	-1.425241277
6	0.46459684	-0.16459684	-0.535882164
7	0.464865521	-0.164865521	-0.536756915
8	0.459816631	-0.159816631	-0.520319115
9	0.467201183	-0.167201183	-0.544361188
10	0.467873206	-0.167873206	-0.546549111
11	0.467888028	-0.167888028	-0.546597367
12	0.326445971	0.073554029	0.239471743
13	0.375943659	0.024056341	0.078320848
14	0.466258279	-0.166258279	-0.541291352
15	0.414334441	-0.114334441	-0.372241577
16	0.380529449	-0.080529449	-0.262181798
17	0.384479392	-0.084479392	-0.275041729
18	0.464475828	1.035524172	3.371382664
19	0.450555201	0.549444799	1.788841555
20	0.46519835	0.53480165	1.741167478
21	0.467516357	0.432483643	1.408048112
22	0.467327703	0.332672297	1.083089749
23	0.467401241	0.332598759	1.082850327
24	0.46935625	-0.16935625	-0.551377497
25	0.466901325	-0.166901325	-0.543384934
26	0.468659629	-0.168659629	-0.549109491
27	0.469062414	0.330937586	1.077442007
28	0.468823956	0.231176044	0.752645788
29	0.468838486	0.031161514	0.101453341
30	0.466138279	-0.166138279	-0.540900664
31	0.468903048	-0.168903048	-0.549901996
32	0.357074345	-0.057074345	-0.185818413
33	0.467860574	-0.167860574	-0.546507985
34	0.467774463	0.532225537	1.73278036
35	0.467436732	0.332563268	1.08273478
36	0.469472814	-0.169472814	-0.551756998
37	0.469472814	-0.169472814	-0.551756998
38	0.469472814	-0.169472814	-0.551756998
39	0.469472814	-0.169472814	-0.551756998
40	0.469472814	-0.169472814	-0.551756998
41	0.469472814	-0.169472814	-0.551756998

REGRESSION NITRATE

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.097599988
R Square	0.009525758
Adjusted R Square	-0.015871018
Standard Error	1.446682553
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.78499599	0.78499599	0.375077446	0.543804193
Residual	39	81.62272596	2.092890409		
Total	40	82.40772195			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.397011647	0.248655238	5.618267525	1.75521E-06	0.894058955	1.899964338	0.894058955	1.899964338
1761.290195	-3.18484E-05	5.20028E-05	-0.612435667	0.543804193	-0.000137034	7.33373E-05	-0.000137034	7.33373E-05

RESIDUAL OUTPUT

Observation	*Predicted 0.8*	*Residuals*	*Standard Residuals*
1	1.397011647	-0.597011647	-0.417933565
2	1.397011647	-0.597011647	-0.417933565
3	1.395247405	0.704752595	0.493356815
4	1.390738343	0.409261657	0.286500581
5	1.39024619	1.50975381	1.056891932
6	1.37770078	-1.21770078	-0.852442379
7	1.378764866	-1.178764866	-0.825185582
8	1.358769182	-1.288769182	-0.902193285
9	1.388015048	-1.338015048	-0.936667488
10	1.390676537	-1.320676537	-0.924529793
11	1.390735238	-1.300735238	-0.910570034
12	0.830566397	0.369433603	0.258619247
13	1.026597642	0.073402358	0.051384775
14	1.384280761	-0.484280761	-0.339017147
15	1.178640961	0.121359039	0.084956493
16	1.044759263	-0.444759263	-0.311350416
17	1.060402665	-0.460402665	-0.322301463
18	1.377221521	2.822778479	1.976065091
19	1.3220901	2.7779099	1.944655175
20	1.380083007	2.519916993	1.764049159
21	1.389263269	2.810736731	1.967635354
22	1.38851612	2.31148388	1.618137107
23	1.388807364	2.211192636	1.547928968
24	1.396550005	-1.146550005	-0.802633808
25	1.386827489	-1.206827489	-0.844830612
26	1.393791099	-1.253791099	-0.877707138
27	1.39538629	-0.60538629	-0.423796172
28	1.3944419	-0.6944419	-0.48613889
29	1.394499445	-0.924499445	-0.647188964
30	1.38380551	-0.78380551	-0.548697221
31	1.394755138	-0.994755138	-0.69637094
32	0.951867384	-0.451867384	-0.316326403
33	1.390626509	-0.890626509	-0.623476467
34	1.390285476	3.009714524	2.106928279
35	1.388947921	2.311052079	1.617834828
36	1.397011647	-0.997011647	-0.697950592
37	1.397011647	-0.997011647	-0.697950592
38	1.397011647	-1.097011647	-0.767954848
39	1.397011647	-0.697011647	-0.487937822
40	1.397011647	-0.597011647	-0.417933565
41	1.397011647	-0.397011647	-0.277925052

REGRESSION NITRATE

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.097599988
R Square	0.009525758
Adjusted R Square	-0.015871018
Standard Error	1.446682553
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.78499599	0.78499599	0.375077446	0.543804193
Residual	39	81.62272596	2.092890409		
Total	40	82.40772195			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.397011647	0.248655238	5.618267525	1.75521E-06	0.894058955	1.899964338	0.894058955	1.899964338
1761.290195	-3.18484E-05	5.20028E-05	-0.612435667	0.543804193	-0.000137034	7.33373E-05	-0.000137034	7.33373E-05

RESIDUAL OUTPUT

Observation	*Predicted 0.8*	*Residuals*	*Standard Residuals*
1	1.397011647	-0.597011647	-0.417933565
2	1.397011647	-0.597011647	-0.417933565
3	1.395247405	0.704752595	0.493356815
4	1.390738343	0.409261657	0.286500581
5	1.39024619	1.50975381	1.056891932
6	1.37770078	-1.21770078	-0.852442379
7	1.378764866	-1.178764866	-0.825185582
8	1.358769182	-1.288769182	-0.902193285
9	1.388015048	-1.338015048	-0.936667488
10	1.390676537	-1.320676537	-0.924529793
11	1.390735238	-1.300735238	-0.910570034
12	0.830566397	0.369433603	0.258619247
13	1.026597642	0.073402358	0.051384775
14	1.384280761	-0.484280761	-0.339017147
15	1.178640961	0.121359039	0.084956493
16	1.044759263	-0.444759263	-0.311350416
17	1.060402665	-0.460402665	-0.322301463
18	1.377221521	2.822778479	1.976065091
19	1.3220901	2.7779099	1.944655175
20	1.380083007	2.519916993	1.764049159
21	1.389263269	2.810736731	1.967635354
22	1.38851612	2.31148388	1.618137107
23	1.388807364	2.211192636	1.547928968
24	1.396550005	-1.146550005	-0.802633808
25	1.386827489	-1.206827489	-0.844830612
26	1.393791099	-1.253791099	-0.877707138
27	1.39538629	-0.60538629	-0.423796172
28	1.3944419	-0.6944419	-0.48613889
29	1.394499445	-0.924499445	-0.647188964
30	1.38380551	-0.78380551	-0.548697221
31	1.394755138	-0.994755138	-0.69637094
32	0.951867384	-0.451867384	-0.316326403
33	1.390626509	-0.890626509	-0.623476467
34	1.390285476	3.009714524	2.106928279
35	1.388947921	2.311052079	1.617834828
36	1.397011647	-0.997011647	-0.697950592
37	1.397011647	-0.997011647	-0.697950592
38	1.397011647	-1.097011647	-0.767954848
39	1.397011647	-0.697011647	-0.487937822
40	1.397011647	-0.597011647	-0.417933565
41	1.397011647	-0.397011647	-0.277925052

REGRESSION TURBIDITY

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.288590288
R Square	0.083284354
Adjusted R Square	0.059778825
Standard Error	11.19142982
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	443.7767	443.7767	3.543181	0.067267
Residual	39	4884.676	125.2481		
Total	40	5328.453			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Jpper 95.0%*
Intercept	16.71166998	1.931014	8.654351	1.3E-10	12.80583	20.61751	12.80583	20.61751
60.27460074	-0.000759815	0.000404	-1.88233	0.067267	-0.00158	5.67E-05	-0.00158	5.67E-05

RESIDUAL OUTPUT

Observation	*Predicted 20.45*	*Residuals*	*dard Residuals*
1	16.2516788	3.848321	0.348244
2	16.26704921	2.182951	0.19754
3	16.54395116	5.406049	0.489206
4	16.37965317	11.92035	1.078701
5	16.61164053	-2.61164	-0.23633
6	16.25096574	-11.706	-1.0593
7	16.27635192	-11.0714	-1.00187
8	15.79930981	-11.6493	-1.05417
9	16.49703585	-13.912	-1.25893
10	16.56053167	-12.2805	-1.11129
11	16.56193211	-10.9369	-0.98971
12	3.197842295	1.347158	0.121908
13	7.874609328	-2.66961	-0.24158
14	16.40794601	-12.2579	-1.10925
15	11.50194526	-8.91695	-0.80692
16	8.307895704	-4.0279	-0.36449
17	8.681104303	-3.0561	-0.27655
18	16.23953194	39.31047	3.557299
19	14.92424768	24.32575	2.201296
20	16.30779913	13.5422	1.225466
21	16.52681498	15.87319	1.436403
22	16.50899005	19.89101	1.799985
23	16.51593832	15.48406	1.40119
24	16.70065647	-0.85066	-0.07698
25	16.46870395	-4.8687	-0.44058
26	16.63483655	-4.78484	-0.43299
27	16.67289343	-5.82289	-0.52693
28	16.65036288	-6.60536	-0.59774
29	16.65173575	-0.80174	-0.07255
30	16.39660784	-0.54661	-0.04946
31	16.65783589	-5.05784	-0.4577
32	6.091750635	5.758249	0.521078
33	16.55933814	-5.70934	-0.51665
34	16.55120202	-6.5062	-0.58876
35	16.51929163	-0.66929	-0.06057
36	16.71166998	-6.46167	-0.58473
37	16.71166998	-4.66167	-0.42185
38	16.71166998	-3.01167	-0.27253
39	16.71166998	4.58833	0.415209
40	16.71166998	-1.11167	-0.1006
41	16.71166998	-0.91167	-0.0825

REGRESSION PHOSPHATE

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.102506132
R Square	0.010507507
Adjusted R Square	-0.014864095
Standard Error	0.131580568
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.007170267	0.007170267	0.414144405	0.523639878
Residual	39	0.675224385	0.017313446		
Total	40	0.682394651			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.157624692	0.022703432	6.942769234	2.56828E-08	0.111702665	0.203546719	0.111702665	0.203546719
60.27460074	-3.05417E-06	4.74589E-06	-0.643540523	0.523639878	-1.26536E-05	6.54529E-06	-1.26536E-05	6.54529E-06

RESIDUAL OUTPUT

Observation	*Predicted 0.362378451438002*	*Residuals*	*Standard Residuals*
1	0.155775701	0.254224299	1.956694373
2	0.155837484	0.044162516	0.339906717
3	0.156950525	-0.017302653	-0.133173752
4	0.156290109	-0.055413526	-0.426502637
5	0.157222611	-0.107222611	-0.82526289
6	0.155772834	-0.072332408	-0.556722609
7	0.155874877	-0.054347339	-0.41829649
8	0.153957348	-0.058928323	-0.453555059
9	0.156761944	-0.070651421	-0.543784516
10	0.157017173	-0.080547498	-0.619951898
11	0.157022802	-0.073064709	-0.562358932
12	0.103304191	-0.039404191	-0.303283202
13	0.122103035	-0.043303035	-0.333291523
14	0.156403836	-0.056403836	-0.434124781
15	0.13668356	0.126867268	0.976462396
16	0.123844683	-0.002350334	-0.018089873
17	0.125344841	0.067655159	0.520723116
18	0.155726875	-0.005726875	-0.044078177
19	0.150439927	-0.030439927	-0.23428773
20	0.156001283	-0.006001283	-0.046190223
21	0.156881644	-0.061081644	-0.470128584
22	0.156809995	-0.071409995	-0.549623052
23	0.156837924	-0.050037924	-0.385128114
24	0.157580422	0.000419578	0.003229378
25	0.15664806	0.04735194	0.364454833
26	0.157315851	-0.033315851	-0.25642292
27	0.157468825	0.287531175	2.213048217
28	0.15737826	0.59662174	4.59203311
29	0.157383779	0.179616221	1.382456554
30	0.156358261	0.021482545	0.165345228
31	0.157408299	-0.056397177	-0.43407353
32	0.114936614	-0.01584739	-0.121972997
33	0.157012375	-0.058492001	-0.450196813
34	0.156979671	-0.059618248	-0.458865222
35	0.156851403	0.01545591	0.118959877
36	0.157624692	-0.100624692	-0.774480523
37	0.157624692	-0.104624692	-0.805267421
38	0.157624692	-0.106624692	-0.82066087
39	0.157624692	-0.062624692	-0.482004996
40	0.157624692	-0.052624692	-0.405037751
41	0.157624692	-0.034624692	-0.266496712

REGRESSION TSS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.10225191
R Square	0.010455453
Adjusted R Square	-0.014917484
Standard Error	12.48068728
Observations	41

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	64.18730211	64.18730211	0.412071064	0.524675603
Residual	39	6074.934649	155.7675551		
Total	40	6139.121951			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	8.721420527	2.145175703	4.065597291	0.000224968	4.382393111	13.06044794	4.382393111	13.06044794
1761.290195	-0.000287991	0.000448634	-0.641927616	0.524675603	-0.001195438	0.000619457	-0.001195438	0.000619457

RESIDUAL OUTPUT

Observation	*Predicted 2*	*Residuals*	*Standard Residuals*
1	8.721420527	-6.721420527	-0.545406436
2	8.721420527	-6.721420527	-0.545406436
3	8.705467291	1.294532709	0.105044234
4	8.664693877	-3.664693877	-0.297369822
5	8.660243559	1.339756441	0.108713892
6	8.546801078	-6.546801078	-0.531237025
7	8.556423132	-6.556423132	-0.532017802
8	8.375611187	-0.375611187	-0.030478789
9	8.640068351	-1.640068351	-0.133082558
10	8.664134995	2.335865005	0.189542642
11	8.664665798	1.335334202	0.108355052
12	3.599311944	-1.599311944	-0.129775398
13	5.371933967	-3.371933967	-0.27361396
14	8.606300877	-4.606300877	-0.373776069
15	6.746793033	-3.746793033	-0.304031719
16	5.536161299	-3.536161299	-0.286940108
17	5.677617518	-3.677617518	-0.298418505
18	8.542467357	62.45753264	5.068086447
19	8.043938817	27.95606118	2.268481139
20	8.56834248	13.43165752	1.089905389
21	8.651355451	13.34864455	1.083169342
22	8.644599316	4.355400684	0.353416894
23	8.647232902	-2.647232902	-0.214808441
24	8.717246107	9.282753893	0.7532446
25	8.629329788	-3.629329788	-0.29450022
26	8.692298567	-6.692298567	-0.543043349
27	8.70672316	-6.70672316	-0.544213825
28	8.698183467	-6.698183467	-0.543520876
29	8.698703825	-6.698703825	-0.5435631
30	8.6020034	-6.6020034	-0.535716391
31	8.701015942	-0.701015942	-0.056883601
32	4.696181986	5.303818014	0.430375762
33	8.663682614	4.336317386	0.351868389
34	8.660598801	-6.660598801	-0.540471086
35	8.648503896	-6.648503896	-0.539489651
36	8.721420527	-6.721420527	-0.545406436
37	8.721420527	-6.721420527	-0.545406436
38	8.721420527	-6.721420527	-0.545406436
39	8.721420527	-6.721420527	-0.545406436
40	8.721420527	-6.721420527	-0.545406436
41	8.721420527	-6.721420527	-0.545406436

TOTAL NITROGEN (TN)

	Rainfall Depth (mm)	Volume_ M1 (L)	Volume_ M2 (L)	Numeric (True Load)				Beale Ratio		Regression		Event Mean Concentration (EMC)		Removal Efficiency (Efficiency Ratio_ER)	Removal Efficiency (Summation of Loads SOL)	Removal Efficiency (Regression of Loads ROL)
				Inlet (mg)	Outlet (mg)	Load in (mg/ha)	Load out (mg/ha)	Inlet (mg)	Outlet (mg)	Inlet (mg)	Outlet (mg)	Inlet (mg/L)	Outlet (mg/L)			
18.02.2015	1.80	35,735.66	36,349.00	19,853.41	1,090.47	8.15E-04	4.48E-05	14,124.76	775.82	16,595.82	17,006.10	0.56	0.03	95%	95%	95%
21.02.2015	4.40	103,728.75	108,561.61	31,118.63	32,568.48	1.28E-03	1.34E-03	9,884.89	10,345.44	47,700.47	50,654.69	0.30	0.30	0%	-5%	-5%
27.02.2015	11.20	314,771.92	299,138.00	102,591.76	89,741.40	4.21E-03	3.68E-03	13,119.85	11,476.49	132,279.59	123,147.79	0.33	0.30	8%	13%	13%
26.03.2015	3.80	94,985.70	92,083.28	101,491.03	76,435.45	4.17E-03	3.14E-03	221,933.14	167,143.44	42,833.34	43,033.40	1.07	0.83	22%	25%	25%
02.04.2015	2.20	26,042.98	26,814.10	6,368.11	17,584.70	2.61E-04	7.22E-04	7,019.93	7,019.93	12,122.62	12,577.98	0.24	0.66	-168%	-176%	-176%
03.04.2015	5.40	130,976.93	125,457.78	39,293.08	105,311.94	1.61E-03	4.32E-03	10,575.15	28,343.14	56,461.92	58,725.03	0.30	0.84	-180%	-168%	-168%
AVERAGE				**50,119.33**	**53,788.74**	**2.06E-03**	**2.21E-03**	**46,109.62**	**37,517.38**	**51,332.29**	**50,857.50**	**0.47**	**0.49**			

TOTAL PHOSPHOROUS (TP)																	
Event Date	**Rainfall Depth (mm)**	**Volume_ M1 (L)**	**Volume_ M2 (L)**	**Numeric (True Load)**				**Beale Ratio**		**Regression**		**Event Mean Concentration (EMC)**		**Removal Efficiency (Efficiency Ratio_ER)**	**Removal Efficiency (Summation of Loads SOL)**	**Removal Efficiency (Regression of Loads ROL)**
				Inlet (mg)	**Outlet (mg)**	**Load in (mg/ha)**	**Load out (mg/ha)**	**Inlet (mg)**	**Outlet (mg)**	**Inlet (mg)**	**Outlet (mg)**	**Inlet (mg/L)**	**Outlet (mg/L)**			
18.02.2015	1.8	35,735.66	36,349.00	5,819.76	3,288.92	2.39E-04	1.35E-04	1,812.40	1,024.24	5,640.06	5,756.08	0.163	0.090	44%	43%	43%
21.02.2015	4.4	103,728.75	108,561.61	12,425.93	12,206.45	5.10E-04	5.01E-04	1,623.87	1,595.19	16,298.94	17,170.46	0.120	0.112	6%	2%	2%
27.02.2015	11.2	314,771.92	299,138.00	32,712.50	49,465.01	1.34E-03	2.03E-03	4,183.41	6,325.78	47,549.35	44,795.15	0.104	0.165	-59%	-51%	-51%
26.03.2015	3.8	94,985.70	92,083.28	19,428.96	17,294.49	7.98E-04	7.10E-04	10,026.19	8,924.71	14,795.42	14,574.53	0.205	0.188	8%	11%	11%
02.04.2015	2.2	26,042.98	26,814.10	2,943.51	2,949.55	1.21E-04	1.21E-04	1,886.18	1,890.05	4,114.60	4,251.20	0.113	0.110	3%	-0.2%	-0.2%
03.04.2015	5.4	130,976.93	125,457.78	18,940.30	14,159.39	7.78E-04	5.81E-04	2,363.62	1,766.99	20,002.96	19,871.41	0.145	0.113	22%	25%	25%
AVERAGE				**92,270.95**	**99,363.82**	**6.31E-04**	**6.80E-04**	**3,649.28**	**3,587.83**	**18,066.89**	**17,736.47**	**0.14**	**0.13**			

TOTAL SUSPENDED SOLIDS (TSS)																
	Rainfall Depth (mm)	**Volume_ M1 (L)**	**Volume_ M2 (L)**	**Numeric (True Load)**				**Beale Ratio**		**Regression**		**Event Mean Concentration (EMC)**		**Removal Efficiency (Efficiency Ratio_ER)**	**Removal Efficiency (Summation of Loads SOL)**	**Removal Efficiency (Regression of Loads ROL)**
				Inlet (mg)	**Outlet (mg)**	**Load in (mg/ha)**	**Load out (mg/ha)**	**Inlet (mg)**	**Outlet (mg)**	**Inlet (mg)**	**Outlet (mg)**	**Inlet (mg/L)**	**Outlet (mg/L)**			
18.02.2015	1.8	35,735.66	36,349.00	71,471.31	283,536.23	2.93E-03	1.16E-02	452,894.56	1,796,693.10	305,180.17	314,910.36	2.000	7.800	-290%	-297%	-297%
21.02.2015	4.4	103,728.75	108,561.61	560,057.04	973,342.35	2.30E-02	4.00E-02	3,159,725.33	5,491,395.13	868,944.28	935,636.91	5.399	8.966	-66%	-74%	-74%
27.02.2015	11.2	314,771.92	299,138.00	990,430.22	614,437.78	4.07E-02	2.52E-02	126,660.20	78,576.77	2,190,266.59	1,989,737.70	3.147	2.054	35%	38%	38%
26.03.2015	3.8	94,985.70	92,083.28	3,064,112.24	1,266,704.75	1.26E-01	5.20E-02	260,061,567.71	1,266,704.75	765,385.49	796,034.88	32.259	13.756	57%	59%	59%
02.04.2015	2.2	26,042.98	26,814.10	163,298.95	53,628.19	6.70E-03	2.20E-03	1,773,388.20	582,389.57	223,412.70	233,480.71	6.270	2.000	68%	67%	67%
03.04.2015	5.4	130,976.93	125,457.78	1,143,254.92	316,737.93	4.69E-02	1.30E-02	10,036,670.24	2,780,652.05	962,234.19	1,087,939.03	8.729	2.525	71%	72%	72%
AVERAGE				**998,770.78**	**584,731.21**	**4.10E-02**	**2.40E-02**	**45,935,151.04**	**1,999,401.90**	**885,903.90**	**892,956.60**	**9.63**	**6.18**	**58%**	**59%**	**59%**

Appendix B – TRC Water Sample Results

Issued: 16/06/15
BATCH NO: 15/2027
RECEIVED: 10/06/15
APPROVED: 16/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 18.02.15
PO Box 3021
REPORT NO: 100615-2027-1
Toowoomba QLD 4350
ATTENTION: Scott Moffett

METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M1 - S11 15/2027/1 18/02/2015 Not Stated	M1 - S13 15/2027/2 18/02/2015 Not Stated	M1 - S 14 15/2027/3 18/02/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	<2	<2	4
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.8	0.4	0.4
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.18	0.09	0.09
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.18	0.24	0.11
METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M2 - S1 15/2027/4 18/02/2015 Not Stated	M2 - S 9 15/2027/5 18/02/2015 Not Stated	M2 - S 19 15/2027/6 18/02/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	10	5	10
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	2.1	1.8	2.9
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.47	0.41	0.65
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	0.5	0.4	0.7
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.10	0.10	0.08

Comments
Issued: 16/06/15
BATCH NO: 15/2027
RECEIVED: 10/06/15
APPROVED: 16/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 18.02.15
PO Box 3021
REPORT NO: 100615-2027-1
Toowoomba QLD 4350
ATTENTION: Scott Moffett
J.L. MILLS
Principal Scientist Laboratory Services

Issued: 18/06/15
BATCH NO: 15/2028
RECEIVED: 10/06/15
APPROVED: 18/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 21.02.15
PO Box 3021 **REPORT NO:** 100615-:
Toowoomba QLD 4350
ATTENTION: Scott Moffett

METHOD	Client Reference: / Laboratory Reference: / Sample Date: / Sample Time: / ANALYSIS	UNITS	LOR	M1 - S4 / 15/2028/1 / 21/02/2015 / Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.7
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.16
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.08

METHOD	Client Reference: / Laboratory Reference: / Sample Date: / Sample Time: / ANALYSIS	UNITS	LOR	M2 - S9 / 15/2028/4 / 21/02/2015 / Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	7
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.2
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.05
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.11

Comments
Issued: 18/06/15
BATCH NO: 15/2028
RECEIVED: 10/06/15
APPROVED: 18/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 21.02.15
PO Box 3021 **REPORT NO:** 100615-:
Toowoomba QLD 4350
ATTENTION: Scott Moffett
J.L. MILLS
Principal Scientist Laboratory Services

Issued: 18/06/15
BATCH NO: 15/2029
RECEIVED: 10/06/15
APPROVED: 18/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 27.02.15
PO Box 3021 **REPORT NO:** 100615-2
Toowoomba QLD 4350
ATTENTION: Scott Moffett

METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M1 - S4 15/2029/1 26/02/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	0.3
QP-KYN-058	Nitrate	mg/L NO_3	0.1	1.2
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	0.09
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.27
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	0.4
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.09
METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M2 - S1 15/2029/4 26/02/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	3
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	1.3
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.29
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.22

Comments
Issued: 18/06/15
BATCH NO: 15/2029
RECEIVED: 10/06/15
APPROVED: 18/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 26.02.15
PO Box 3021 **REPORT NO:** 100615-2
Toowoomba QLD 4350
ATTENTION: Scott Moffett
J.L. MILLS
Principal Scientist Laboratory Services

Issued: 22/06/15
BATCH NO: 15/2030
RECEIVED: 10/06/15
APPROVED: 22/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 26.03.15
PO Box 3021 **REPORT NO:** 100615-:
Toowoomba QLD 4350
ATTENTION: Scott Moffett

METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M1 - S6 15/2030/1 28/03/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	36
QP-KYN-058	Nitrite	mg/L NO_2	0.1	0.2
QP-KYN-058	Nitrate	mg/L NO_3	0.1	4.1
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	0.06
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.93
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	1.0
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.26
METHOD	**Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS**	**UNITS**	**LOR**	**M2 - S9 15/2030/4 28/03/2015 Not Stated**
QP-KYN-009	Suspended Solids	mg/L	2	22
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	4.2
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.95
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	0.9
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.19

Comments
Issued: 22/06/15
BATCH NO: 15/2030
RECEIVED: 10/06/15
APPROVED: 22/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 28.03.15
PO Box 3021 **REPORT NO:** 100615-:
Toowoomba QLD 4350
ATTENTION: Scott Moffett
J.L. MILLS
Principal Scientist Laboratory Services

Issued: 18/06/15

BATCH NO: 15/2031

RECEIVED: 10/06/15

APPROVED: 18/06/15

CLIENT:

TRC - Transport and Drainage

ORDER NO: 02.04.15

PO Box 3021 **REPORT NO:** 100615-2031-1

Toowoomba QLD 4350

ATTENTION: Scott Moffett

METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M1 - S1 15/2031/1 02/04/2015 Not Stated	M1 - S8 15/2031/2 02/04/2015 Not Stated	M1 - S10 15/2031/3 02/04/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	18	5	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	1.1	0.8	0.6
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.25	0.18	0.14
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	0.3	<0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.16	0.15	0.10

METHOD	Client Reference: Laboratory Reference: Sample Date: Sample Time: ANALYSIS	UNITS	LOR	M2 - S2 15/2031/4 02/04/2015 Not Stated	M2 - S16 15/2031/5 02/04/2015 Not Stated	M2 - S18 15/2031/6 02/04/2015 Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	<2	<2	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	3.5	3.1	2.1
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.79	0.70	0.47
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	0.8	0.7	0.5
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.11	0.11	0.11

Comments

Issued: 18/06/15

BATCH NO: 15/2031

RECEIVED: 10/06/15

APPROVED: 18/06/15

CLIENT:

TRC - Transport and Drainage

ORDER NO: 02.04.15

PO Box 3021 **REPORT NO:** 100615-2031-1

Toowoomba QLD 4350

ATTENTION: Scott Moffett

J.L. MILLS

Principal Scientist Laboratory Services

Issued: 18/06/15

BATCH NO: 15/2032

RECEIVED: 10/06/15

APPROVED: 18/06/15

CLIENT:

TRC - Transport and Drainage

ORDER NO: 03.04.15

PO Box 3021 **REPORT NO:** 100615-2032-1

Toowoomba QLD 4350

ATTENTION: Scott Moffett

METHOD	Client Reference: / Laboratory Reference: / Sample Date: / Sample Time: / ANALYSIS	UNITS	LOR	M1 - S1 / 15/2032/1 / 03/04/2015 / Not Stated	M1 - S11 / 15/2032/2 / 03/04/2015 / Not Stated	M1 - S18 / 15/2032/3 / 03/04/2015 / Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	2	8	10
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.6	0.4	0.5
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.14	0.09	0.11
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.15	0.15	0.14
METHOD	**Client Reference: / Laboratory Reference: / Sample Date: / Sample Time: / ANALYSIS**	**UNITS**	**LOR**	**M2 - S1 / 15/2032/4 / 03/04/2015 / Not Stated**	**M2 - S8 / 15/2032/5 / 03/04/2015 / Not Stated**	**M2 - S14 / 15/2032/6 / 03/04/2015 / Not Stated**
QP-KYN-009	Suspended Solids	mg/L	2	13	<2	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.5	4.4	3.7
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.11	0.99	0.84
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3	1.0	0.8
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.17	0.11	0.11

Comments

Issued: 18/06/15

BATCH NO: 15/2032

RECEIVED: 10/06/15

APPROVED: 18/06/15

CLIENT:

TRC - Transport and Drainage

ORDER NO: 03.04.15

PO Box 3021 **REPORT NO:** 100615-2032-1

Toowoomba QLD 4350

ATTENTION: Scott Moffett

J.L. MILLS

Principal Scientist Laboratory Services

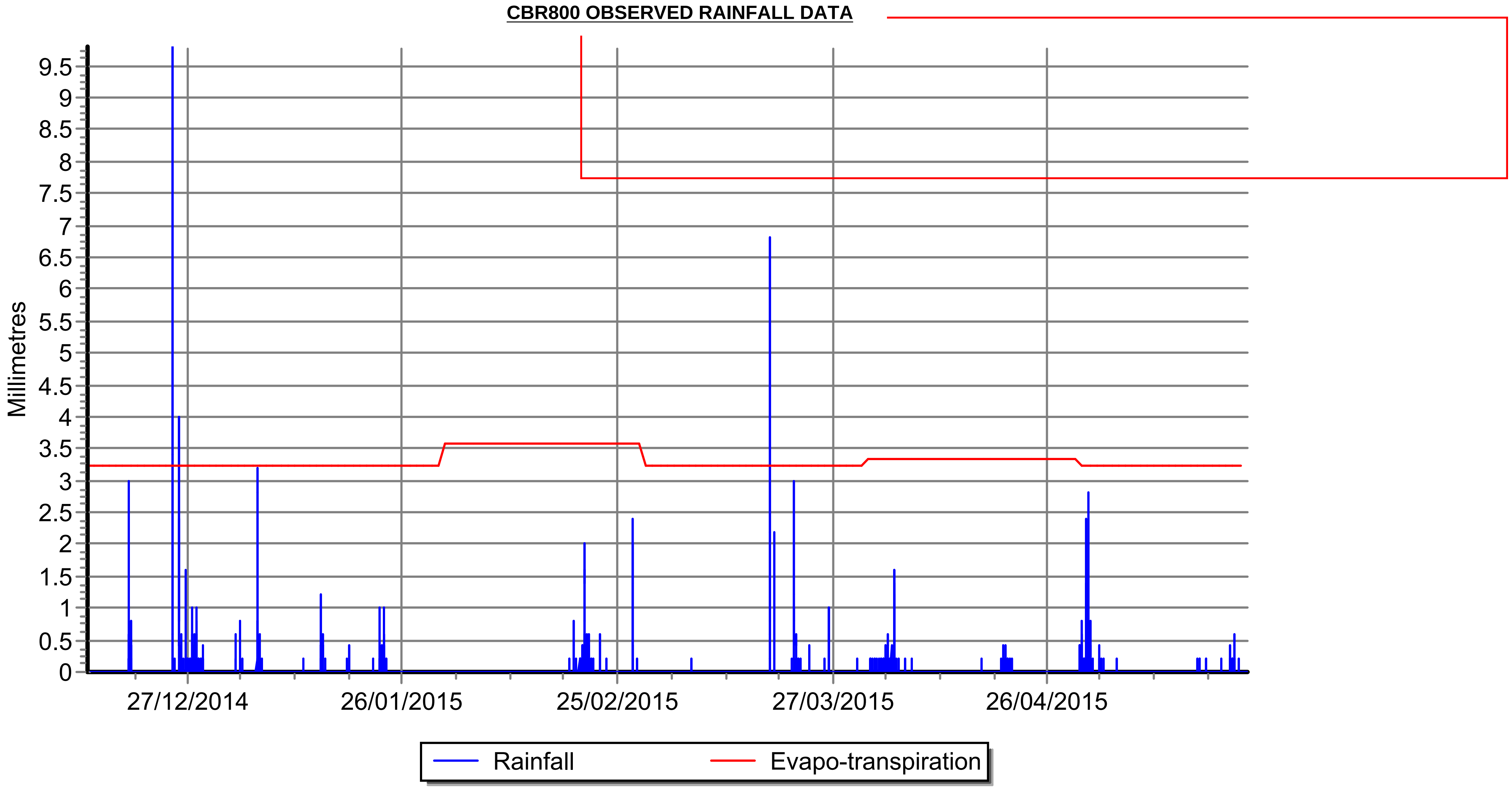
Issued: 18/06/15
BATCH NO: 15/2033
RECEIVED: 10/06/15
APPROVED: 18/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 01.05.15
PO Box 3021 **REPORT NO:** 100615-2033-1
Toowoomba QLD 4350
ATTENTION: Scott Moffett

METHOD	Client Reference: / Laboratory Reference: / Sample Date: / Sample Time: / ANALYSIS	UNITS	LOR	M1 - S8 / 15/2033/1 / 01/05/2015 / Not Stated	M1 - S12 / 15/2033/2 / 01/05/2015 / Not Stated	M1 - S15 / 15/2033/3 / 01/05/2015 / Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	<2	<2	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.4	0.4	0.3
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.09	0.09	0.07
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.13	0.12	0.13

METHOD	Client Reference: / Laboratory Reference: / Sample Date: / Sample Time: / ANALYSIS	UNITS	LOR	M2 - S7 / 15/2033/4 / 01/05/2015 / Not Stated	M2 - S13 / 15/2033/5 / 01/05/2015 / Not Stated	M2 - S20 / 15/2033/6 / 01/05/2015 / Not Stated
QP-KYN-009	Suspended Solids	mg/L	2	<2	<2	<2
QP-KYN-058	Nitrite	mg/L NO_2	0.1	<0.1	<0.1	<0.1
QP-KYN-058	Nitrate	mg/L NO_3	0.1	0.7	0.8	1.0
QP-KYN-058	Nitrite Nitrogen	mg/L	0.03	<0.03	<0.03	<0.03
QP-KYN-058	Nitrate Nitrogen	mg/L	0.03	0.16	0.18	0.23
QP-KYN-038	Total Kjeldahl Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
Derived*	Total Nitrogen	mg/L	0.3	<0.3	<0.3	<0.3
QP-KYN-039	Total Phosphorus	mg/L	0.02	0.25	0.29	0.31

Comments
Issued: 18/06/15
BATCH NO: 15/2033
RECEIVED: 10/06/15
APPROVED: 18/06/15
CLIENT:
TRC - Transport and Drainage
ORDER NO: 01.05.15
PO Box 3021 **REPORT NO:** 100615-2033-1
Toowoomba QLD 4350
ATTENTION: Scott Moffett
J.L. MILLS
Principal Scientist Laboratory Services

Appendix C - MUSIC and DRAINS Information


CBR800 OBSERVED RAINFALL DATA
Millimetres
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
27/12/2014
26/01/2015
25/02/2015
27/03/2015
26/04/2015
Rainfall
Evapo-transpiration

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0.493	0	0.493	0	20	0	01.05.2015 (Total)
Total Catchment	0.669	0.406	0.271	30	20	0	01.05.2015 (Total)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
01.05.2015 (Total)	55345.93	10911.06 (19.7%)	8358.40 (67.1%)	2552.66 (6.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 01.05.2015 (Total)

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	1646.88	1646.88	0	0
Total PostcatchmentN	9264.18	9264.18	0	0

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0	0	0	0	20	0	02.04.2015 (Daily)
Total Catchment	0.03	0.03	0	30	20	0	02.04.2015 (Daily)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
02.04.2015 (Daily)	1169.28	69.28 (5.9%)	69.28 (26.3%)	0.00 (0.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 02.04.2015 (Daily)

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	0	0	0	0
Total PostcatchmentN	69.28	69.28	0	0

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0	0	0	0	20	0	03.04.2015 (Daily)
Total Catchment	0.075	0.075	0	30	20	0	03.04.2015 (Daily)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
03.04.2015 (Daily)	2630.88	292.91 (11.1%)	292.91 (49.5%)	0.00 (0.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 03.04.2015 (Daily)

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	0	0	0	0
Total PostcatchmentN	292.91	292.91	0	0

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0	0	0	0	20	0	18.02.2015 (Daily)
Total Catchment	0.005	0.005	0	30	20	0	18.02.2015 (Daily)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
18.02.2015 (Daily)	779.52	9.65 (1.2%)	9.65 (5.5%)	0.00 (0.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 18.02.2015 (Daily)

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	0	0	0	0
Total PostcatchmentN	9.65	9.65	0	0

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0	0	0	0	20	0	21.02.2015 (Daily)
Total Catchment	0.058	0.058	0	30	20	0	21.02.2015 (Daily)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
21.02.2015 (Daily)	2143.68	218.36 (10.2%)	218.36 (45.3%)	0.00 (0.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 21.02.2015 (Daily)

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	0	0	0	0
Total PostcatchmentN	218.36	218.36	0	0

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0	0	0	0	20	0	26.03.2015 (Daily)
Total Catchment	0.088	0.088	0	30	20	0	26.03.2015 (Daily)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
26.03.2015 (Daily)	1851.36	173.64 (9.4%)	173.64 (41.7%)	0.00 (0.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 26.03.2015 (Daily)

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	0	0	0	0
Total PostcatchmentN	173.64	173.64	0	0

DRAINS results prepared from Version 2018.01

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
Predeveloped 24.36ha	0	0	0	0	20	0	27.02.2015 (Daily)
Total Catchment	0.224	0.224	0	30	20	0	27.02.2015 (Daily)

Outflow Volumes for Total Catchment (11.0 impervious + 37.8 pervious = 48.7 total ha)

Storm	Total Rainfall cu.m	Total Runoff cu.m (Runoff %)	Impervious Runoff cu.m (Runoff %)	Pervious Runoff cu.m (Runoff %)
27.02.2015 (Daily)	5554.08	740.15 (13.3%)	740.15 (59.2%)	0.00 (0.0%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm

CHANNEL DETAILS

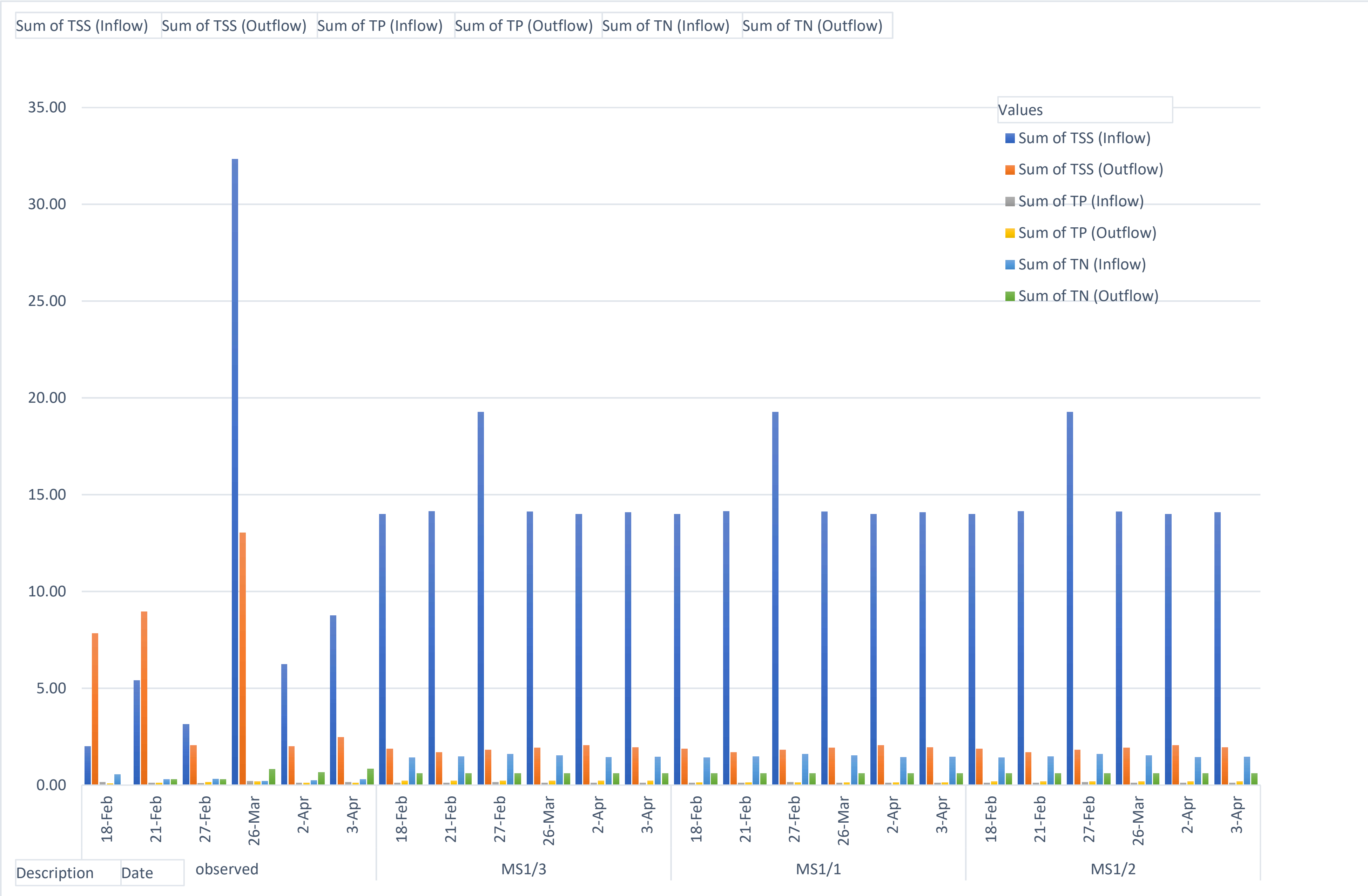
Name	Max Q (cu.m/s)	Max V (m/s)	Due to Storm

DETENTION BASIN DETAILS

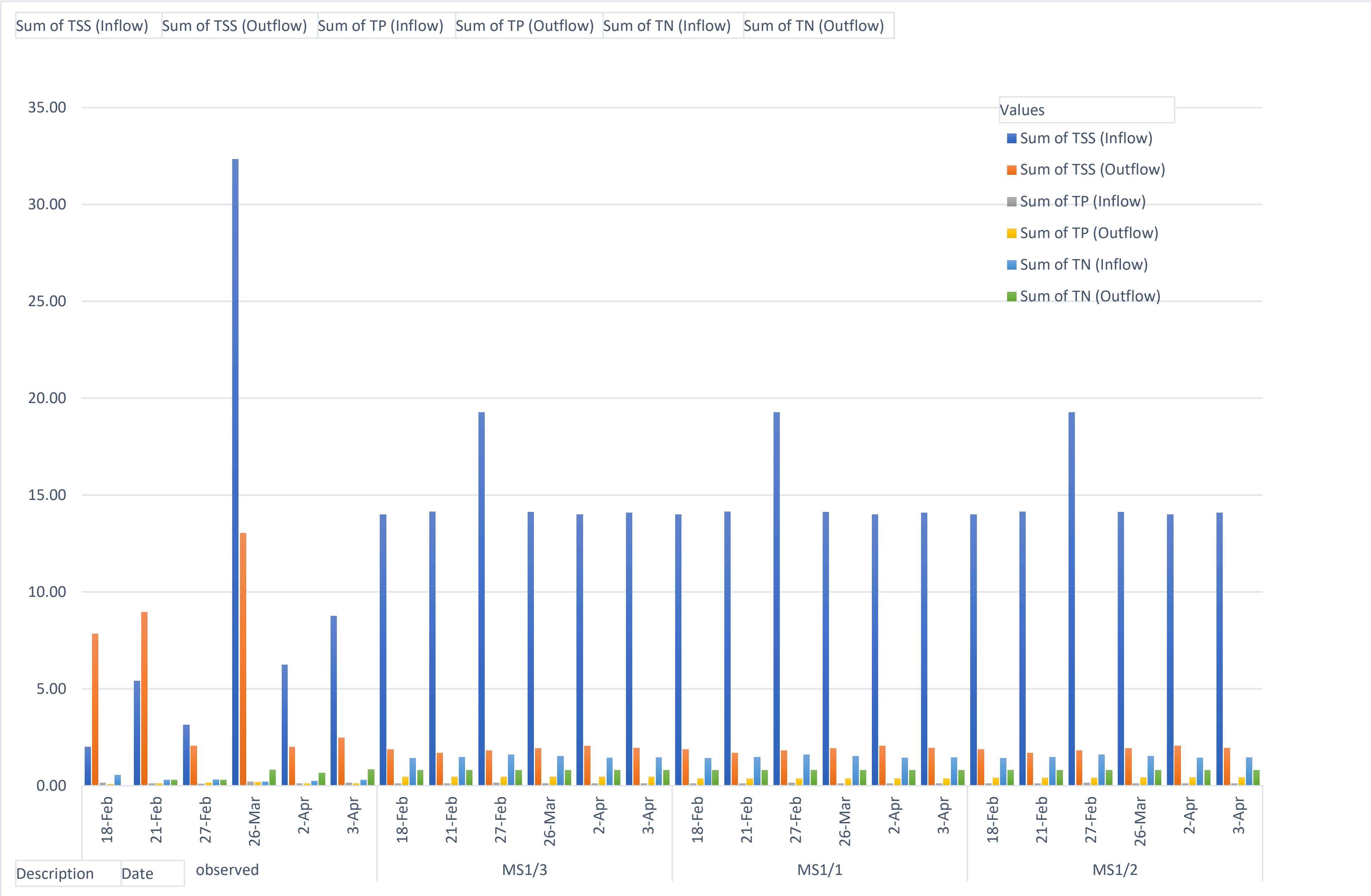
Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

CONTINUITY CHECK for 27.02.2015 (Daily)

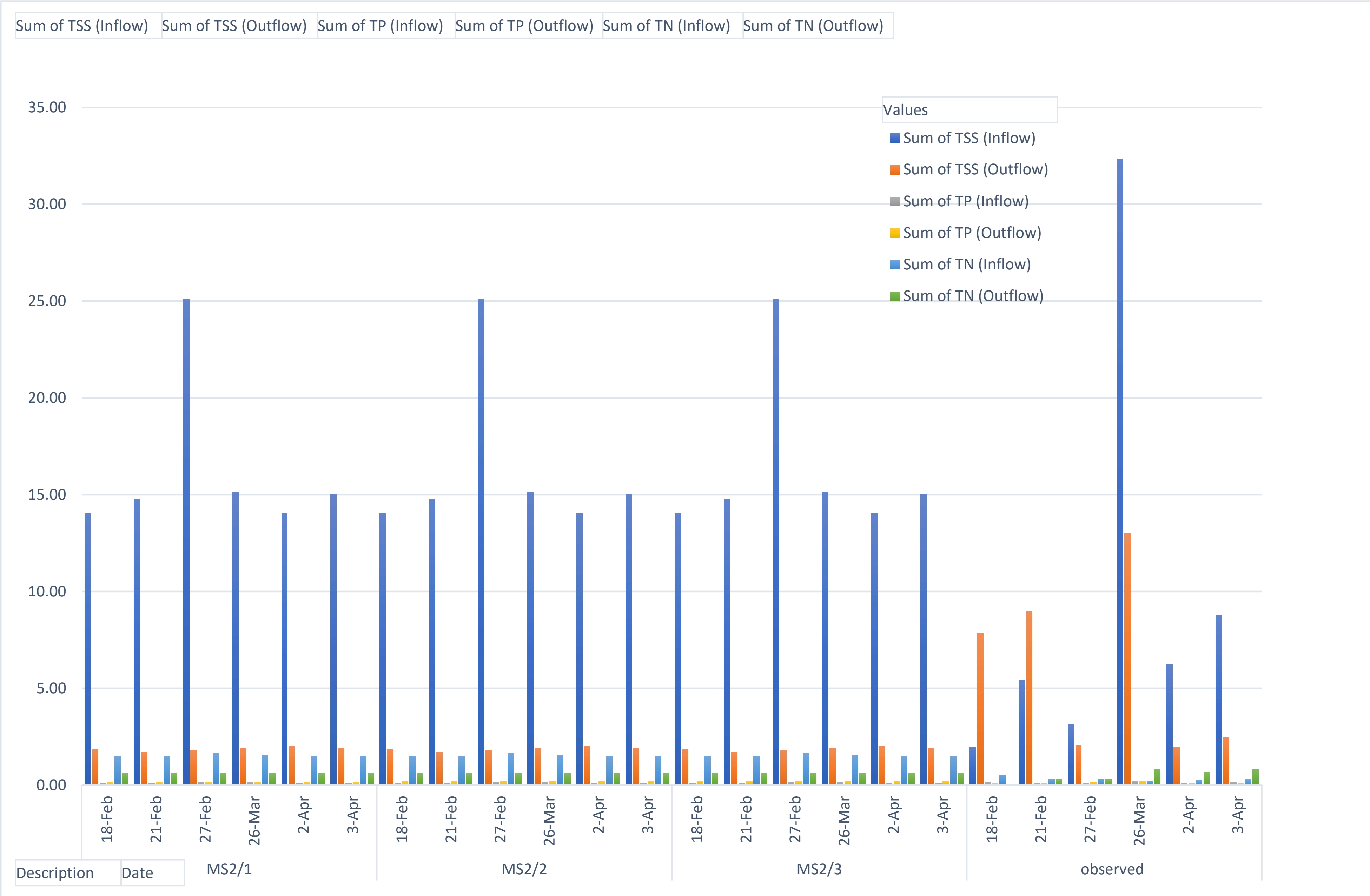
Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N-Predev	0	0	0	0
Total PostcatchmentN	740.15	740.15	0	0



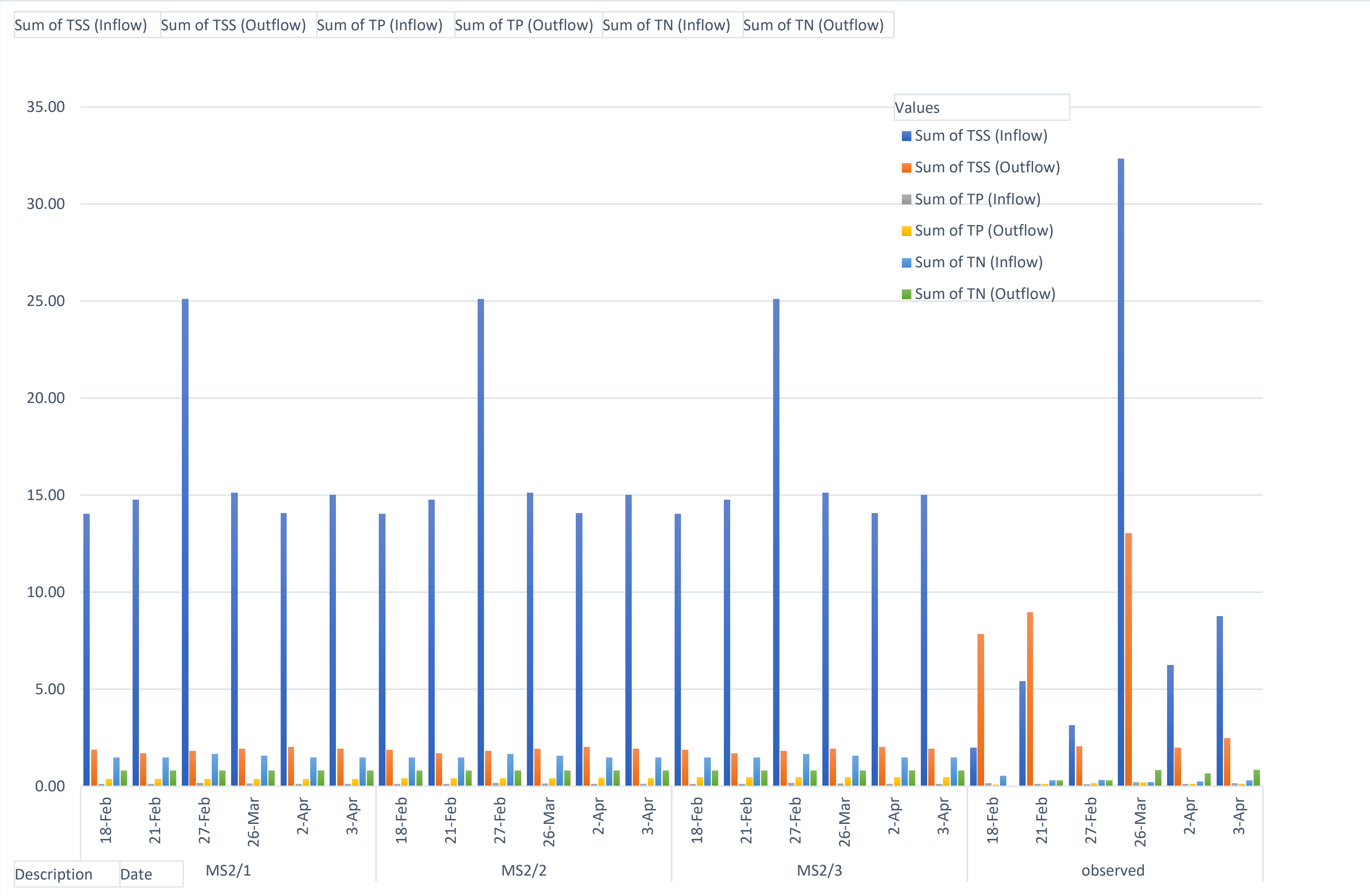
Sum of TSS (Inflow)
Sum of TSS (Outflow)
Sum of TP (Inflow)
Sum of TP (Outflow)
Sum of TN (Inflow)
Sum of TN (Outflow)
Values
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
18-Feb
21-Feb
27-Feb
26-Mar
2-Apr
3-Apr
Description
Date
observed
MS1/3
MS1/1
MS1/2



Sum of TSS (Inflow)
Sum of TSS (Outflow)
Sum of TP (Inflow)
Sum of TP (Outflow)
Sum of TN (Inflow)
Sum of TN (Outflow)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Values
18-Feb
21-Feb
27-Feb
26-Mar
2-Apr
3-Apr
Description
Date
observed
MS1/3
MS1/1
MS1/2



Sum of TSS (Inflow)
Sum of TSS (Outflow)
Sum of TP (Inflow)
Sum of TP (Outflow)
Sum of TN (Inflow)
Sum of TN (Outflow)
Values
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
18-Feb
21-Feb
27-Feb
26-Mar
2-Apr
3-Apr
Description
Date
MS2/1
MS2/2
MS2/3
observed



Sum of TSS (Inflow)
Sum of TSS (Outflow)
Sum of TP (Inflow)
Sum of TP (Outflow)
Sum of TN (Inflow)
Sum of TN (Outflow)
Values
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
18-Feb
21-Feb
27-Feb
26-Mar
2-Apr
3-Apr
Description
Date
MS2/1
MS2/2
MS2/3
observed

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	13.99999994	0.13000000	1.40000048	3.95522997	0.20999043	0.60000002
14/12/2014	14.00000008	0.12999999	1.40000048	3.26251989	0.20044799	0.60000003
15/12/2014	14.00000003	0.12999999	1.40000037	2.76416931	0.19358296	0.60000003
16/12/2014	14.00000005	0.12999999	1.40000024	2.44870684	0.18923730	0.60000002
17/12/2014	14.00000003	0.13000000	1.40000011	2.23428382	0.18628351	0.60000002
18/12/2014	15.23868267	0.13369152	1.55389899	2.03030723	0.18347363	0.60000003
19/12/2014	14.03974051	0.13014055	1.44484038	1.92157577	0.18197580	0.60000002
20/12/2014	14.00000010	0.12999999	1.40053142	1.81892508	0.18056174	0.60000003
21/12/2014	13.99999960	0.13000000	1.40042168	1.73194160	0.17936349	0.60000002
22/12/2014	14.00000001	0.12999999	1.40033351	1.67871865	0.17863032	0.60000003
23/12/2014	13.99999967	0.12999999	1.40026470	1.63909246	0.17808445	0.60000001
24/12/2014	75.93216135	0.23575487	1.68775438	1.60248377	0.17758015	0.60000003
25/12/2014	42.44543901	0.19010921	1.70571477	5.30840473	0.17535161	0.74023965
26/12/2014	15.68618121	0.13350988	1.53050423	2.99166268	0.17579260	0.66035231
27/12/2014	14.68039769	0.13217541	1.51388412	1.53525346	0.17665401	0.60000002
28/12/2014	17.49639629	0.13784825	1.59261634	1.53017522	0.17658406	0.60000002
29/12/2014	14.15327175	0.13068394	1.47819541	1.52941793	0.17657363	0.60000002
30/12/2014	14.00000000	0.13000000	1.40007541	1.51527112	0.17637875	0.60000003
31/12/2014	14.00000017	0.13000000	1.40005696	1.51744283	0.17640867	0.60000002
1/01/2015	14.00000007	0.12999999	1.40004294	1.52490109	0.17651141	0.60000001
2/01/2015	13.99999991	0.12999999	1.40003230	1.53211564	0.17661079	0.60000003

3/01/2015	14.00000020	0.13000001	1.40146852
1.53787216	0.17669009	0.60000002	
4/01/2015	13.99999996	0.13000000	1.40001941
1.54354098	0.17676818	0.60000003	
5/01/2015	60.94865747	0.16352640	1.63861853
1.54698728	0.17681565	0.60000002	
6/01/2015	13.99999986	0.13000000	1.40001734
1.53217808	0.17661165	0.60000002	
7/01/2015	14.00000001	0.12999999	1.40001151
1.52823466	0.17655733	0.60000002	
8/01/2015	14.00000009	0.13000000	1.40000898
1.54291874	0.17675961	0.60000002	
9/01/2015	13.99999992	0.12999999	1.40000702
1.55592526	0.17693878	0.60000003	
10/01/2015	14.00000007	0.12999999	1.40000549
1.56763400	0.17710007	0.60000003	
11/01/2015	14.00000012	0.12999999	1.40000429
1.57832076	0.17724729	0.60000003	
12/01/2015	14.00000007	0.13000000	1.40000337
1.58820766	0.17738349	0.60000003	
13/01/2015	14.00000005	0.12999999	1.40000265
1.59746922	0.17751107	0.60000002	
14/01/2015	14.60219696	0.13070030	1.53320577
1.59763288	0.17751332	0.60000002	
15/01/2015	13.99999996	0.13000000	1.40000205
1.57988208	0.17726880	0.60000003	
16/01/2015	13.99999995	0.13000000	1.40000154
1.58792716	0.17737962	0.60000002	
17/01/2015	14.00000006	0.13000000	1.40000121
1.60310313	0.17758868	0.60000003	
18/01/2015	14.00000001	0.13000000	1.40000094
1.61660156	0.17777463	0.60000003	
19/01/2015	13.99999995	0.12999999	1.40000072
1.62877869	0.17794237	0.60000002	
20/01/2015	14.00000001	0.12999999	1.40000056
1.63991425	0.17809577	0.60000002	
21/01/2015	13.99999988	0.13000000	1.40000046
1.65022930	0.17823786	0.60000002	
22/01/2015	13.99999713	0.13000008	1.40662357
1.65854489	0.17835242	0.60000002	
23/01/2015	17.47356450	0.13714039	1.58504569
1.62895872	0.17794485	0.60000002	
24/01/2015	14.00000007	0.13000000	1.40000043
1.59474101	0.17747349	0.60000002	

25/01/2015	14.00000007	0.13000000	1.40000033
1.58190647	0.17729668	0.60000003	
26/01/2015	13.99999992	0.13000000	1.40000022
1.61501332	0.17775275	0.60000002	
27/01/2015	14.00000017	0.13000000	1.40000022
1.63951772	0.17809031	0.60000003	
28/01/2015	13.99999985	0.13000000	1.40000011
1.66053397	0.17837982	0.60000002	
29/01/2015	14.00000004	0.12999999	1.40000009
1.67875568	0.17863083	0.60000002	
30/01/2015	14.00000010	0.13000000	1.40000009
1.69474636	0.17885111	0.60000003	
31/01/2015	14.00000009	0.13000000	1.39999999
1.70897227	0.17904708	0.60000002	
1/02/2015	14.00000016	0.13000000	1.39999999
1.72182977	0.17922420	0.60000002	
2/02/2015	14.00000008	0.13000000	1.39999997
1.73361951	0.17938661	0.60000002	
3/02/2015	13.99999993	0.12999999	1.39999998
1.74451942	0.17953676	0.60000002	
4/02/2015	13.99999994	0.13000000	1.39999998
1.75472525	0.17967735	0.60000002	
5/02/2015	14.00000009	0.12999999	1.39999997
1.76439537	0.17981056	0.60000002	
6/02/2015	13.99999990	0.12999999	1.39999999
1.77364381	0.17993796	0.60000002	
7/02/2015	13.99999988	0.13000000	1.39999998
1.78255852	0.18006077	0.60000003	
8/02/2015	13.99999998	0.13000000	1.39999999
1.79120453	0.18017987	0.60000003	
9/02/2015	13.99999995	0.13000000	1.39999999
1.79964119	0.18029609	0.60000002	
10/02/2015	13.99999995	0.13000000	1.39999999
1.80793099	0.18041029	0.60000002	
11/02/2015	14.00000001	0.12999999	1.39999999
1.81611211	0.18052299	0.60000003	
12/02/2015	14.00000015	0.12999999	1.39999999
1.82421079	0.18063455	0.60000003	
13/02/2015	14.00000003	0.12999999	1.39999997
1.83223543	0.18074509	0.60000003	
14/02/2015	14.00000001	0.13000000	1.39999998
1.84022994	0.18085522	0.60000002	
15/02/2015	14.00000011	0.13000000	1.39999998
1.84818575	0.18096482	0.60000002	

16/02/2015	14.00000008	0.13000000	1.39999997
1.85612537	0.18107419	0.60000002	
17/02/2015	14.00000001	0.12999999	1.39999997
1.86404274	0.18118325	0.60000002	
18/02/2015	14.00097418	0.13000737	1.43099795
1.87278911	0.18130374	0.60000003	
19/02/2015	14.00370704	0.13001896	1.43714363
1.84812929	0.18096404	0.60000002	
20/02/2015	23.08684679	0.14535733	1.57663067
1.77642039	0.17997621	0.60000002	
21/02/2015	14.15028934	0.13088850	1.46816321
1.70963176	0.17905616	0.60000002	
22/02/2015	14.00000007	0.13000000	1.39999998
1.66892638	0.17849543	0.60000002	
23/02/2015	14.00000004	0.13000000	1.39999998
1.71980359	0.17919629	0.60000002	
24/02/2015	14.00000007	0.12999999	1.39999998
1.76660884	0.17984105	0.60000003	
25/02/2015	14.00000010	0.13000000	1.39999998
1.80578761	0.18038076	0.60000003	
26/02/2015	13.99999998	0.12999999	1.39999999
1.83877970	0.18083524	0.60000003	
27/02/2015	19.26883388	0.14453712	1.59675716
1.81549038	0.18051442	0.60000003	
28/02/2015	13.99999994	0.13000000	1.39999998
1.76160052	0.17977206	0.60000002	
1/03/2015	14.00000003	0.13000000	1.39999997
1.79541793	0.18023791	0.60000002	
2/03/2015	14.00000000	0.12999999	1.39999997
1.83665441	0.18080597	0.60000002	
3/03/2015	14.00000005	0.12999999	1.39999997
1.87142314	0.18128492	0.60000002	
4/03/2015	14.00000007	0.13000000	1.39999996
1.90090689	0.18169108	0.60000003	
5/03/2015	13.99999987	0.13000000	1.39999998
1.92608949	0.18203798	0.60000003	
6/03/2015	13.99999999	0.13000000	1.39999998
1.94780726	0.18233715	0.60000002	
7/03/2015	14.00000002	0.13000000	1.39999999
1.96680096	0.18259880	0.60000002	
8/03/2015	14.00000000	0.12999999	1.39999998
1.98358356	0.18282999	0.60000002	
9/03/2015	13.99999993	0.12999999	1.39999998
1.99869066	0.18303810	0.60000003	

10/03/2015	14.00000000	0.13000000	1.39999997
2.01236673	0.18322649	0.60000003	
11/03/2015	14.00000012	0.13000000	1.39999998
2.02495739	0.18339994	0.60000002	
12/03/2015	13.99999991	0.12999999	1.39999999
2.03671282	0.18356187	0.60000002	
13/03/2015	14.00000000	0.13000000	1.39999999
2.04789652	0.18371593	0.60000002	
14/03/2015	13.99999989	0.12999999	1.39999997
2.05852755	0.18386238	0.60000002	
15/03/2015	14.00000023	0.13000000	1.39999997
2.06879552	0.18400383	0.60000002	
16/03/2015	14.00000006	0.13000000	1.39999999
2.07874478	0.18414089	0.60000002	
17/03/2015	14.00000008	0.13000000	1.39999998
2.08847885	0.18427498	0.60000003	
18/03/2015	26.86875770	0.16258160	1.60328732
2.04850650	0.18372434	0.60000002	
19/03/2015	13.99999998	0.13000000	1.41878597
1.93481906	0.18215823	0.60000002	
20/03/2015	14.00000006	0.13000000	1.39999998
1.86824535	0.18124115	0.60000002	
21/03/2015	21.44363065	0.16075474	1.63655949
1.91034527	0.18182110	0.60000002	
22/03/2015	13.99999991	0.12999999	1.39999998
1.84680765	0.18094583	0.60000002	
23/03/2015	14.00000003	0.13000000	1.39999998
1.78220887	0.18005595	0.60000002	
24/03/2015	13.99999989	0.12999999	1.39999995
1.83808267	0.18082564	0.60000002	
25/03/2015	14.00000017	0.12999999	1.39999999
1.90322335	0.18172299	0.60000002	
26/03/2015	14.12932073	0.13096434	1.53096616
1.94069943	0.18223924	0.60000002	
27/03/2015	14.00000000	0.13000000	1.39999998
1.91164684	0.18183902	0.60000002	
28/03/2015	14.00000008	0.12999999	1.39999997
1.95478364	0.18243326	0.60000002	
29/03/2015	13.99999999	0.13000000	1.39999998
2.01657164	0.18328442	0.60000002	
30/03/2015	14.00000009	0.12999999	1.39999997
2.07756459	0.18412463	0.60000002	
31/03/2015	13.99999994	0.13000000	1.39999998
2.12307873	0.18475161	0.60000002	

1/04/2015	13.99999562	0.13000006	1.40742733
2.12887893	0.18483151	0.60000003	
2/04/2015	14.00053978	0.13001023	1.44764011
2.05589424	0.18382611	0.60000002	
3/04/2015	14.09049310	0.13039596	1.45700343
1.95232062	0.18239933	0.60000002	
4/04/2015	21.13525012	0.14170099	1.59458156
1.83695472	0.18081010	0.60000002	
5/04/2015	14.00000003	0.13000000	1.39999998
1.77059117	0.17989591	0.60000002	
6/04/2015	14.00000008	0.12999999	1.39999999
1.73094265	0.17934973	0.60000003	
7/04/2015	14.00000010	0.13000000	1.39999998
1.81917830	0.18056522	0.60000002	
8/04/2015	14.00000012	0.13000000	1.39999998
1.90959921	0.18181082	0.60000002	
9/04/2015	14.00000002	0.13000000	1.39999998
1.99849679	0.18303543	0.60000003	
10/04/2015	14.00000014	0.13000000	1.39999997
2.07599222	0.18410297	0.60000002	
11/04/2015	14.00000004	0.12999999	1.39999998
2.14080811	0.18499584	0.60000002	
12/04/2015	13.99999994	0.13000000	1.39999998
2.19580033	0.18575338	0.60000003	
13/04/2015	13.99999990	0.13000000	1.39999996
2.24291965	0.18640248	0.60000003	
14/04/2015	14.00000006	0.12999999	1.39999999
2.28364590	0.18696350	0.60000003	
15/04/2015	14.00000004	0.13000000	1.39999999
2.31924343	0.18745388	0.60000002	
16/04/2015	13.99999987	0.13000000	1.39999998
2.35079065	0.18788846	0.60000003	
17/04/2015	13.99999995	0.13000000	1.39999996
2.37920036	0.18827981	0.60000002	
18/04/2015	14.00000000	0.12999999	1.39999997
2.40523902	0.18863851	0.60000002	
19/04/2015	13.99994783	0.13000016	1.41964718
2.41741477	0.18880624	0.60000003	
20/04/2015	14.00816438	0.13006795	1.44878558
2.26837644	0.18675316	0.60000002	
21/04/2015	13.99999999	0.12999999	1.39999998
2.13918303	0.18497345	0.60000002	
22/04/2015	13.99999990	0.12999999	1.39999998
2.11438702	0.18463187	0.60000002	

23/04/2015	14.00000006	0.12999999	1.39999999
2.14463476	0.18504855	0.60000002	
24/04/2015	14.00000023	0.12999999	1.39999997
2.18399191	0.18559072	0.60000003	
25/04/2015	13.99999997	0.12999999	1.39999998
2.22649536	0.18617622	0.60000002	
26/04/2015	13.99999992	0.13000000	1.39999999
2.26961375	0.18677020	0.60000003	
27/04/2015	13.99999989	0.13000000	1.39999996
2.31229789	0.18735820	0.60000002	
28/04/2015	13.99999998	0.13000000	1.39999998
2.35397793	0.18793236	0.60000002	
29/04/2015	14.00000008	0.13000000	1.39999999
2.39447357	0.18849021	0.60000003	
30/04/2015	14.29420924	0.13101702	1.50147301
2.35324376	0.18792225	0.60000002	
1/05/2015	65.05792130	0.21909751	1.75466873
47.65635996	0.19321600	1.61098833	
2/05/2015	17.01498464	0.13511781	1.57430745
4.02386121	0.18244833	0.65620216	
3/05/2015	14.00000027	0.13000000	1.40205830
1.89161284	0.18156305	0.60000002	
4/05/2015	14.00000004	0.13000000	1.40065068
1.83544373	0.18078929	0.60000002	
5/05/2015	14.00000007	0.13000000	1.39999996
1.88801050	0.18151342	0.60000002	
6/05/2015	14.00000010	0.13000000	1.39999997
1.96543710	0.18258001	0.60000002	
7/05/2015	14.00000013	0.13000000	1.39999999
2.04543782	0.18368206	0.60000002	
8/05/2015	14.00000006	0.12999999	1.39999999
2.12410952	0.18476581	0.60000002	
9/05/2015	14.00000004	0.12999999	1.39999999
2.20001926	0.18581150	0.60000002	
10/05/2015	14.00000003	0.12999999	1.39999998
2.27274374	0.18681332	0.60000003	
11/05/2015	13.99999995	0.12999999	1.39999999
2.34234325	0.18777209	0.60000002	
12/05/2015	13.99999982	0.13000000	1.39999999
2.40911890	0.18869196	0.60000002	
13/05/2015	13.99999996	0.13000000	1.39999997
2.47348606	0.18957865	0.60000002	
14/05/2015	13.99999993	0.13000000	1.39999996
2.53590726	0.19043853	0.60000002	

15/05/2015	13.99999995	0.12999999	1.39999997
2.59684963	0.19127804	0.60000002	
16/05/2015	14.00000000	0.12999999	1.39999997
2.65676380	0.19210339	0.60000002	
17/05/2015	13.99999998	0.12999999	1.39999999
2.71607371	0.19292042	0.60000002	
18/05/2015	13.99999993	0.13000000	1.39999999
2.77516975	0.19373449	0.60000002	
19/05/2015	14.00000006	0.12999999	1.39999997
2.83440899	0.19455055	0.60000002	
20/05/2015	14.00000006	0.12999999	1.39999999
2.89411915	0.19537308	0.60000002	
21/05/2015	14.00126457	0.13001175	1.44312872
2.89769179	0.19542230	0.60000002	
22/05/2015	14.00110033	0.13000561	1.41921539
2.74554304	0.19332637	0.60000002	
23/05/2015	13.99999999	0.12999999	1.39999998
2.47580975	0.18961066	0.60000002	

S1 Ineffective - Lower.TXT

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	13.99999994	0.13000000	1.40000048	3.95522997	0.40699042	1.51530837
14/12/2014	14.00000008	0.12999999	1.40000048	3.26251989	0.39744798	0.80000001
15/12/2014	14.00000003	0.12999999	1.40000037	2.76416931	0.39058295	0.80000001
16/12/2014	14.00000005	0.12999999	1.40000024	2.44870684	0.38623730	0.80000001
17/12/2014	14.00000003	0.13000000	1.40000011	2.23428382	0.38328351	0.80000001
18/12/2014	15.23868267	0.13369152	1.55389899	2.03030723	0.38047363	0.80000001
19/12/2014	14.03974051	0.13014055	1.44484038	1.92157577	0.37897580	0.80000001
20/12/2014	14.00000010	0.12999999	1.40053142	1.81892508	0.37756173	0.80000001
21/12/2014	13.99999960	0.13000000	1.40042168	1.73194160	0.37636349	0.80000004
22/12/2014	14.00000001	0.12999999	1.40033351	1.67871865	0.37563031	0.80000002
23/12/2014	13.99999967	0.12999999	1.40026470	1.63909246	0.37508444	0.80000002
24/12/2014	75.93216135	0.23575487	1.68775438	1.60248377	0.37458014	0.80000002
25/12/2014	42.44543901	0.19010921	1.70571477	5.30840473	0.33964465	0.90703460
26/12/2014	15.68618121	0.13350988	1.53050423	2.99166268	0.35971435	0.84707489
27/12/2014	14.68039769	0.13217541	1.51388412	1.53525346	0.37365401	0.80000001
28/12/2014	17.49639629	0.13784825	1.59261634	1.53017522	0.37358405	0.80000002
29/12/2014	14.15327175	0.13068394	1.47819541	1.52941793	0.37357362	0.80000001
30/12/2014	14.00000000	0.13000000	1.40007541	1.51527112	0.37337874	0.80000001
31/12/2014	14.00000017	0.13000000	1.40005696	1.51744283	0.37340866	0.80000002
1/01/2015	14.00000007	0.12999999	1.40004294	1.52490109	0.37351140	0.80000000
2/01/2015	13.99999991	0.12999999	1.40003230	1.53211564	0.37361078	0.80000002

3/01/2015	14.00000020	0.13000001	1.40146852
1.53787216	0.37369008	0.80000002	
4/01/2015	13.99999996	0.13000000	1.40001941
1.54354098	0.37376817	0.80000002	
5/01/2015	60.94865747	0.16352640	1.63861853
1.54698728	0.37381565	0.80000001	
6/01/2015	13.99999986	0.13000000	1.40001734
1.53217808	0.37361164	0.80000001	
7/01/2015	14.00000001	0.12999999	1.40001151
1.52823466	0.37355732	0.80000002	
8/01/2015	14.00000009	0.13000000	1.40000898
1.54291874	0.37375960	0.80000002	
9/01/2015	13.99999992	0.12999999	1.40000702
1.55592526	0.37393877	0.80000001	
10/01/2015	14.00000007	0.12999999	1.40000549
1.56763400	0.37410006	0.80000001	
11/01/2015	14.00000012	0.12999999	1.40000429
1.57832076	0.37424728	0.80000002	
12/01/2015	14.00000007	0.13000000	1.40000337
1.58820766	0.37438348	0.80000002	
13/01/2015	14.00000005	0.12999999	1.40000265
1.59746922	0.37451106	0.80000001	
14/01/2015	14.60219696	0.13070030	1.53320577
1.59763288	0.37451332	0.80000001	
15/01/2015	13.99999996	0.13000000	1.40000205
1.57988208	0.37426879	0.80000001	
16/01/2015	13.99999995	0.13000000	1.40000154
1.58792716	0.37437962	0.80000001	
17/01/2015	14.00000006	0.13000000	1.40000121
1.60310313	0.37458867	0.80000002	
18/01/2015	14.00000001	0.13000000	1.40000094
1.61660156	0.37477462	0.80000003	
19/01/2015	13.99999995	0.12999999	1.40000072
1.62877869	0.37494237	0.80000002	
20/01/2015	14.00000001	0.12999999	1.40000056
1.63991425	0.37509576	0.80000001	
21/01/2015	13.99999988	0.13000000	1.40000046
1.65022930	0.37523786	0.80000001	
22/01/2015	13.99999713	0.13000008	1.40662357
1.65854489	0.37535241	0.80000001	
23/01/2015	17.47356450	0.13714039	1.58504569
1.62895872	0.37494485	0.80000001	
24/01/2015	14.00000007	0.13000000	1.40000043
1.59474101	0.37447348	0.80000001	

25/01/2015	14.00000007	0.13000000	1.40000033
1.58190647	0.37429667	0.80000001	
26/01/2015	13.99999992	0.13000000	1.40000022
1.61501332	0.37475274	0.80000001	
27/01/2015	14.00000017	0.13000000	1.40000022
1.63951772	0.37509030	0.80000002	
28/01/2015	13.99999985	0.13000000	1.40000011
1.66053397	0.37537981	0.80000002	
29/01/2015	14.00000004	0.12999999	1.40000009
1.67875568	0.37563082	0.80000001	
30/01/2015	14.00000010	0.13000000	1.40000009
1.69474636	0.37585110	0.80000002	
31/01/2015	14.00000009	0.13000000	1.39999999
1.70897227	0.37604707	0.80000001	
1/02/2015	14.00000016	0.13000000	1.39999999
1.72182977	0.37622419	0.80000001	
2/02/2015	14.00000008	0.13000000	1.39999997
1.73361951	0.37638660	0.80000001	
3/02/2015	13.99999993	0.12999999	1.39999998
1.74451942	0.37653675	0.80000001	
4/02/2015	13.99999994	0.13000000	1.39999998
1.75472525	0.37667734	0.80000001	
5/02/2015	14.00000009	0.12999999	1.39999997
1.76439537	0.37681055	0.80000001	
6/02/2015	13.99999990	0.12999999	1.39999999
1.77364381	0.37693796	0.80000001	
7/02/2015	13.99999988	0.13000000	1.39999998
1.78255852	0.37706076	0.80000001	
8/02/2015	13.99999998	0.13000000	1.39999999
1.79120453	0.37717986	0.80000001	
9/02/2015	13.99999995	0.13000000	1.39999999
1.79964119	0.37729608	0.80000001	
10/02/2015	13.99999995	0.13000000	1.39999999
1.80793099	0.37741028	0.80000002	
11/02/2015	14.00000001	0.12999999	1.39999999
1.81611211	0.37752298	0.80000002	
12/02/2015	14.00000015	0.12999999	1.39999999
1.82421079	0.37763454	0.80000002	
13/02/2015	14.00000003	0.12999999	1.39999997
1.83223543	0.37774509	0.80000002	
14/02/2015	14.00000001	0.13000000	1.39999998
1.84022994	0.37785521	0.80000001	
15/02/2015	14.00000011	0.13000000	1.39999998
1.84818575	0.37796481	0.80000001	

16/02/2015	14.00000008	0.13000000	1.39999997
1.85612537	0.37807418	0.80000001	
17/02/2015	14.00000001	0.12999999	1.39999997
1.86404274	0.37818325	0.80000001	
18/02/2015	14.00097418	0.13000737	1.43099795
1.87278911	0.37830373	0.80000002	
19/02/2015	14.00370704	0.13001896	1.43714363
1.84812929	0.37796403	0.80000001	
20/02/2015	23.08684679	0.14535733	1.57663067
1.77642039	0.37697620	0.80000001	
21/02/2015	14.15028934	0.13088850	1.46816321
1.70963176	0.37605616	0.80000001	
22/02/2015	14.00000007	0.13000000	1.39999998
1.66892638	0.37549542	0.80000001	
23/02/2015	14.00000004	0.13000000	1.39999998
1.71980359	0.37619628	0.80000002	
24/02/2015	14.00000007	0.12999999	1.39999998
1.76660884	0.37684105	0.80000002	
25/02/2015	14.00000010	0.13000000	1.39999998
1.80578761	0.37738075	0.80000002	
26/02/2015	13.99999998	0.12999999	1.39999999
1.83877970	0.37783524	0.80000002	
27/02/2015	19.26883388	0.14453712	1.59675716
1.81549038	0.37751441	0.80000001	
28/02/2015	13.99999994	0.13000000	1.39999998
1.76160052	0.37677205	0.80000001	
1/03/2015	14.00000003	0.13000000	1.39999997
1.79541793	0.37723791	0.80000001	
2/03/2015	14.00000000	0.12999999	1.39999997
1.83665441	0.37780596	0.80000001	
3/03/2015	14.00000005	0.12999999	1.39999997
1.87142314	0.37828492	0.80000001	
4/03/2015	14.00000007	0.13000000	1.39999996
1.90090689	0.37869107	0.80000001	
5/03/2015	13.99999987	0.13000000	1.39999998
1.92608949	0.37903797	0.80000001	
6/03/2015	13.99999999	0.13000000	1.39999998
1.94780726	0.37933715	0.80000001	
7/03/2015	14.00000002	0.13000000	1.39999999
1.96680096	0.37959880	0.80000002	
8/03/2015	14.00000000	0.12999999	1.39999998
1.98358356	0.37982998	0.80000002	
9/03/2015	13.99999993	0.12999999	1.39999998
1.99869066	0.38003809	0.80000002	

10/03/2015	14.00000000	0.13000000	1.39999997
2.01236673	0.38022649	0.80000001	
11/03/2015	14.00000012	0.13000000	1.39999998
2.02495739	0.38039993	0.80000001	
12/03/2015	13.99999991	0.12999999	1.39999999
2.03671282	0.38056187	0.80000001	
13/03/2015	14.00000000	0.13000000	1.39999999
2.04789652	0.38071593	0.80000001	
14/03/2015	13.99999989	0.12999999	1.39999997
2.05852755	0.38086238	0.80000001	
15/03/2015	14.00000023	0.13000000	1.39999997
2.06879552	0.38100382	0.80000001	
16/03/2015	14.00000006	0.13000000	1.39999999
2.07874478	0.38114088	0.80000001	
17/03/2015	14.00000008	0.13000000	1.39999998
2.08847885	0.38127497	0.80000001	
18/03/2015	26.86875770	0.16258160	1.60328732
2.04850650	0.38072433	0.80000001	
19/03/2015	13.99999998	0.13000000	1.41878597
1.93481906	0.37915823	0.80000001	
20/03/2015	14.00000006	0.13000000	1.39999998
1.86824535	0.37824114	0.80000001	
21/03/2015	21.44363065	0.16075474	1.63655949
1.91034527	0.37882109	0.80000002	
22/03/2015	13.99999991	0.12999999	1.39999998
1.84680765	0.37794582	0.80000001	
23/03/2015	14.00000003	0.13000000	1.39999998
1.78220887	0.37705594	0.80000001	
24/03/2015	13.99999989	0.12999999	1.39999995
1.83808267	0.37782563	0.80000001	
25/03/2015	14.00000017	0.12999999	1.39999999
1.90322335	0.37872298	0.80000002	
26/03/2015	14.12932073	0.13096434	1.53096616
1.94069943	0.37923923	0.80000001	
27/03/2015	14.00000000	0.13000000	1.39999998
1.91164684	0.37883902	0.80000001	
28/03/2015	14.00000008	0.12999999	1.39999997
1.95478364	0.37943325	0.80000001	
29/03/2015	13.99999999	0.13000000	1.39999998
2.01657164	0.38028441	0.80000001	
30/03/2015	14.00000009	0.12999999	1.39999997
2.07756459	0.38112462	0.80000001	
31/03/2015	13.99999994	0.13000000	1.39999998
2.12307873	0.38175160	0.80000001	

1/04/2015	13.99999562	0.13000006	1.40742733
2.12887893	0.38183150	0.80000002	
2/04/2015	14.00053978	0.13001023	1.44764011
2.05589424	0.38082610	0.80000001	
3/04/2015	14.09049310	0.13039596	1.45700343
1.95232062	0.37939932	0.80000001	
4/04/2015	21.13525012	0.14170099	1.59458156
1.83695472	0.37781010	0.80000001	
5/04/2015	14.00000003	0.13000000	1.39999998
1.77059117	0.37689590	0.80000001	
6/04/2015	14.00000008	0.12999999	1.39999999
1.73094265	0.37634973	0.80000001	
7/04/2015	14.00000010	0.13000000	1.39999998
1.81917830	0.37756522	0.80000001	
8/04/2015	14.00000012	0.13000000	1.39999998
1.90959921	0.37881081	0.80000001	
9/04/2015	14.00000002	0.13000000	1.39999998
1.99849679	0.38003542	0.80000002	
10/04/2015	14.00000014	0.13000000	1.39999997
2.07599222	0.38110296	0.80000001	
11/04/2015	14.00000004	0.12999999	1.39999998
2.14080811	0.38199583	0.80000001	
12/04/2015	13.99999994	0.13000000	1.39999998
2.19580033	0.38275338	0.80000001	
13/04/2015	13.99999990	0.13000000	1.39999996
2.24291965	0.38340247	0.80000001	
14/04/2015	14.00000006	0.12999999	1.39999999
2.28364590	0.38396350	0.80000001	
15/04/2015	14.00000004	0.13000000	1.39999999
2.31924343	0.38445387	0.80000002	
16/04/2015	13.99999987	0.13000000	1.39999998
2.35079065	0.38488845	0.80000002	
17/04/2015	13.99999995	0.13000000	1.39999996
2.37920036	0.38527981	0.80000001	
18/04/2015	14.00000000	0.12999999	1.39999997
2.40523902	0.38563850	0.80000001	
19/04/2015	13.99994783	0.13000016	1.41964718
2.41741477	0.38580623	0.80000001	
20/04/2015	14.00816438	0.13006795	1.44878558
2.26837644	0.38375315	0.80000001	
21/04/2015	13.99999999	0.12999999	1.39999998
2.13918303	0.38197345	0.80000001	
22/04/2015	13.99999990	0.12999999	1.39999998
2.11438702	0.38163187	0.80000001	

23/04/2015	14.00000006	0.12999999	1.39999999
2.14463476	0.38204855	0.80000001	
24/04/2015	14.00000023	0.12999999	1.39999997
2.18399191	0.38259071	0.80000001	
25/04/2015	13.99999997	0.12999999	1.39999998
2.22649536	0.38317622	0.80000001	
26/04/2015	13.99999992	0.13000000	1.39999999
2.26961375	0.38377020	0.80000001	
27/04/2015	13.99999989	0.13000000	1.39999996
2.31229789	0.38435819	0.80000001	
28/04/2015	13.99999998	0.13000000	1.39999998
2.35397793	0.38493235	0.80000001	
29/04/2015	14.00000008	0.13000000	1.39999999
2.39447357	0.38549020	0.80000002	
30/04/2015	14.29420924	0.13101702	1.50147301
2.35324376	0.38492224	0.80000001	
1/05/2015	65.05792130	0.21909751	1.75466873
47.65635996	0.21255683	1.63062369	
2/05/2015	17.01498464	0.13511781	1.57430745
4.02386121	0.36965254	0.84625719	
3/05/2015	14.00000027	0.13000000	1.40205830
1.89161284	0.37856304	0.80000001	
4/05/2015	14.00000004	0.13000000	1.40065068
1.83544373	0.37778928	0.80000001	
5/05/2015	14.00000007	0.13000000	1.39999996
1.88801050	0.37851342	0.80000001	
6/05/2015	14.00000010	0.13000000	1.39999997
1.96543710	0.37958001	0.80000001	
7/05/2015	14.00000013	0.13000000	1.39999999
2.04543782	0.38068206	0.80000001	
8/05/2015	14.00000006	0.12999999	1.39999999
2.12410952	0.38176580	0.80000001	
9/05/2015	14.00000004	0.12999999	1.39999999
2.20001926	0.38281150	0.80000001	
10/05/2015	14.00000003	0.12999999	1.39999998
2.27274374	0.38381331	0.80000001	
11/05/2015	13.99999995	0.12999999	1.39999999
2.34234325	0.38477208	0.80000001	
12/05/2015	13.99999982	0.13000000	1.39999999
2.40911890	0.38569195	0.80000001	
13/05/2015	13.99999996	0.13000000	1.39999997
2.47348606	0.38657864	0.80000001	
14/05/2015	13.99999993	0.13000000	1.39999996
2.53590726	0.38743853	0.80000002	

15/05/2015	13.99999995	0.12999999	1.39999997
2.59684963	0.38827804	0.80000001	
16/05/2015	14.00000000	0.12999999	1.39999997
2.65676380	0.38910339	0.80000001	
17/05/2015	13.99999998	0.12999999	1.39999999
2.71607371	0.38992041	0.80000001	
18/05/2015	13.99999993	0.13000000	1.39999999
2.77516975	0.39073449	0.80000001	
19/05/2015	14.00000006	0.12999999	1.39999997
2.83440899	0.39155054	0.80000001	
20/05/2015	14.00000006	0.12999999	1.39999999
2.89411915	0.39237308	0.80000001	
21/05/2015	14.00126457	0.13001175	1.44312872
2.89769179	0.39242229	0.80000001	
22/05/2015	14.00110033	0.13000561	1.41921539
2.74554304	0.39032636	0.80000001	
23/05/2015	13.99999999	0.12999999	1.39999998
2.47580975	0.38661065	0.80000002	

S1 Ineffective -Higher.TXT

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	13.99999994	0.13000000	1.40000048	3.95522997	0.49299042	4.01236798
14/12/2014	14.00000008	0.12999999	1.40000048	3.26251989	0.48344799	1.07210703
15/12/2014	14.00000003	0.12999999	1.40000037	2.76416931	0.47658295	0.80000001
16/12/2014	14.00000005	0.12999999	1.40000024	2.44870684	0.47223730	0.80000001
17/12/2014	14.00000003	0.13000000	1.40000011	2.23428382	0.46928351	0.80000001
18/12/2014	15.23868267	0.13369152	1.55389899	2.03030723	0.46647363	0.80000001
19/12/2014	14.03974051	0.13014055	1.44484038	1.92157577	0.46497580	0.80000001
20/12/2014	14.00000010	0.12999999	1.40053142	1.81892508	0.46356173	0.80000001
21/12/2014	13.99999960	0.13000000	1.40042168	1.73194160	0.46236349	0.80000004
22/12/2014	14.00000001	0.12999999	1.40033351	1.67871865	0.46163032	0.80000002
23/12/2014	13.99999967	0.12999999	1.40026470	1.63909246	0.46108445	0.80000002
24/12/2014	75.93216135	0.23575487	1.68775438	1.60248377	0.46058014	0.80000002
25/12/2014	42.44543901	0.19010921	1.70571477	5.30840473	0.41136649	0.90703460
26/12/2014	15.68618121	0.13350988	1.53050423	2.99166268	0.44000506	0.84707489
27/12/2014	14.68039769	0.13217541	1.51388412	1.53525346	0.45965401	0.80000001
28/12/2014	17.49639629	0.13784825	1.59261634	1.53017522	0.45958406	0.80000002
29/12/2014	14.15327175	0.13068394	1.47819541	1.52941793	0.45957362	0.80000001
30/12/2014	14.00000000	0.13000000	1.40007541	1.51527112	0.45937875	0.80000001
31/12/2014	14.00000017	0.13000000	1.40005696	1.51744283	0.45940866	0.80000002
1/01/2015	14.00000007	0.12999999	1.40004294	1.52490109	0.45951140	0.80000000
2/01/2015	13.99999991	0.12999999	1.40003230	1.53211564	0.45961079	0.80000002

3/01/2015	14.00000020	0.13000001	1.40146852
1.53787216	0.45969009	0.80000002	
4/01/2015	13.99999996	0.13000000	1.40001941
1.54354098	0.45976817	0.80000002	
5/01/2015	60.94865747	0.16352640	1.63861853
1.54698728	0.45981565	0.80000001	
6/01/2015	13.99999986	0.13000000	1.40001734
1.53217808	0.45961165	0.80000001	
7/01/2015	14.00000001	0.12999999	1.40001151
1.52823466	0.45955732	0.80000002	
8/01/2015	14.00000009	0.13000000	1.40000898
1.54291874	0.45975960	0.80000002	
9/01/2015	13.99999992	0.12999999	1.40000702
1.55592526	0.45993877	0.80000001	
10/01/2015	14.00000007	0.12999999	1.40000549
1.56763400	0.46010007	0.80000001	
11/01/2015	14.00000012	0.12999999	1.40000429
1.57832076	0.46024729	0.80000002	
12/01/2015	14.00000007	0.13000000	1.40000337
1.58820766	0.46038348	0.80000002	
13/01/2015	14.00000005	0.12999999	1.40000265
1.59746922	0.46051106	0.80000001	
14/01/2015	14.60219696	0.13070030	1.53320577
1.59763288	0.46051332	0.80000001	
15/01/2015	13.99999996	0.13000000	1.40000205
1.57988208	0.46026879	0.80000001	
16/01/2015	13.99999995	0.13000000	1.40000154
1.58792716	0.46037962	0.80000001	
17/01/2015	14.00000006	0.13000000	1.40000121
1.60310313	0.46058868	0.80000002	
18/01/2015	14.00000001	0.13000000	1.40000094
1.61660156	0.46077462	0.80000003	
19/01/2015	13.99999995	0.12999999	1.40000072
1.62877869	0.46094237	0.80000002	
20/01/2015	14.00000001	0.12999999	1.40000056
1.63991425	0.46109577	0.80000001	
21/01/2015	13.99999988	0.13000000	1.40000046
1.65022930	0.46123786	0.80000001	
22/01/2015	13.99999713	0.13000008	1.40662357
1.65854489	0.46135241	0.80000001	
23/01/2015	17.47356450	0.13714039	1.58504569
1.62895872	0.46094485	0.80000001	
24/01/2015	14.00000007	0.13000000	1.40000043
1.59474101	0.46047348	0.80000001	

25/01/2015	14.00000007	0.13000000	1.40000033
1.58190647	0.46029668	0.80000001	
26/01/2015	13.99999992	0.13000000	1.40000022
1.61501332	0.46075274	0.80000001	
27/01/2015	14.00000017	0.13000000	1.40000022
1.63951772	0.46109030	0.80000002	
28/01/2015	13.99999985	0.13000000	1.40000011
1.66053397	0.46137981	0.80000002	
29/01/2015	14.00000004	0.12999999	1.40000009
1.67875568	0.46163083	0.80000001	
30/01/2015	14.00000010	0.13000000	1.40000009
1.69474636	0.46185111	0.80000002	
31/01/2015	14.00000009	0.13000000	1.39999999
1.70897227	0.46204708	0.80000001	
1/02/2015	14.00000016	0.13000000	1.39999999
1.72182977	0.46222419	0.80000001	
2/02/2015	14.00000008	0.13000000	1.39999997
1.73361951	0.46238660	0.80000001	
3/02/2015	13.99999993	0.12999999	1.39999998
1.74451942	0.46253675	0.80000001	
4/02/2015	13.99999994	0.13000000	1.39999998
1.75472525	0.46267735	0.80000001	
5/02/2015	14.00000009	0.12999999	1.39999997
1.76439537	0.46281056	0.80000001	
6/02/2015	13.99999990	0.12999999	1.39999999
1.77364381	0.46293796	0.80000001	
7/02/2015	13.99999988	0.13000000	1.39999998
1.78255852	0.46306076	0.80000001	
8/02/2015	13.99999998	0.13000000	1.39999999
1.79120453	0.46317987	0.80000001	
9/02/2015	13.99999995	0.13000000	1.39999999
1.79964119	0.46329609	0.80000001	
10/02/2015	13.99999995	0.13000000	1.39999999
1.80793099	0.46341028	0.80000002	
11/02/2015	14.00000001	0.12999999	1.39999999
1.81611211	0.46352298	0.80000002	
12/02/2015	14.00000015	0.12999999	1.39999999
1.82421079	0.46363455	0.80000002	
13/02/2015	14.00000003	0.12999999	1.39999997
1.83223543	0.46374509	0.80000002	
14/02/2015	14.00000001	0.13000000	1.39999998
1.84022994	0.46385522	0.80000001	
15/02/2015	14.00000011	0.13000000	1.39999998
1.84818575	0.46396481	0.80000001	

16/02/2015	14.00000008	0.13000000	1.39999997
1.85612537	0.46407419	0.80000001	
17/02/2015	14.00000001	0.12999999	1.39999997
1.86404274	0.46418325	0.80000001	
18/02/2015	14.00097418	0.13000737	1.43099795
1.87278911	0.46430374	0.80000002	
19/02/2015	14.00370704	0.13001896	1.43714363
1.84812929	0.46396403	0.80000001	
20/02/2015	23.08684679	0.14535733	1.57663067
1.77642039	0.46297621	0.80000001	
21/02/2015	14.15028934	0.13088850	1.46816321
1.70963176	0.46205616	0.80000001	
22/02/2015	14.00000007	0.13000000	1.39999998
1.66892638	0.46149542	0.80000001	
23/02/2015	14.00000004	0.13000000	1.39999998
1.71980359	0.46219628	0.80000002	
24/02/2015	14.00000007	0.12999999	1.39999998
1.76660884	0.46284105	0.80000002	
25/02/2015	14.00000010	0.13000000	1.39999998
1.80578761	0.46338075	0.80000002	
26/02/2015	13.99999998	0.12999999	1.39999999
1.83877970	0.46383524	0.80000002	
27/02/2015	19.26883388	0.14453712	1.59675716
1.81549038	0.46351442	0.80000001	
28/02/2015	13.99999994	0.13000000	1.39999998
1.76160052	0.46277206	0.80000001	
1/03/2015	14.00000003	0.13000000	1.39999997
1.79541793	0.46323791	0.80000001	
2/03/2015	14.00000000	0.12999999	1.39999997
1.83665441	0.46380596	0.80000001	
3/03/2015	14.00000005	0.12999999	1.39999997
1.87142314	0.46428492	0.80000001	
4/03/2015	14.00000007	0.13000000	1.39999996
1.90090689	0.46469107	0.80000001	
5/03/2015	13.99999987	0.13000000	1.39999998
1.92608949	0.46503798	0.80000001	
6/03/2015	13.99999999	0.13000000	1.39999998
1.94780726	0.46533715	0.80000001	
7/03/2015	14.00000002	0.13000000	1.39999999
1.96680096	0.46559880	0.80000002	
8/03/2015	14.00000000	0.12999999	1.39999998
1.98358356	0.46582999	0.80000002	
9/03/2015	13.99999993	0.12999999	1.39999998
1.99869066	0.46603809	0.80000002	

10/03/2015	14.00000000	0.13000000	1.39999997
2.01236673	0.46622649	0.80000001	
11/03/2015	14.00000012	0.13000000	1.39999998
2.02495739	0.46639993	0.80000001	
12/03/2015	13.99999991	0.12999999	1.39999999
2.03671282	0.46656187	0.80000001	
13/03/2015	14.00000000	0.13000000	1.39999999
2.04789652	0.46671593	0.80000001	
14/03/2015	13.99999989	0.12999999	1.39999997
2.05852755	0.46686238	0.80000001	
15/03/2015	14.00000023	0.13000000	1.39999997
2.06879552	0.46700383	0.80000001	
16/03/2015	14.00000006	0.13000000	1.39999999
2.07874478	0.46714088	0.80000001	
17/03/2015	14.00000008	0.13000000	1.39999998
2.08847885	0.46727497	0.80000001	
18/03/2015	26.86875770	0.16258160	1.60328732
2.04850650	0.46672433	0.80000001	
19/03/2015	13.99999998	0.13000000	1.41878597
1.93481906	0.46515823	0.80000001	
20/03/2015	14.00000006	0.13000000	1.39999998
1.86824535	0.46424115	0.80000001	
21/03/2015	21.44363065	0.16075474	1.63655949
1.91034527	0.46482109	0.80000002	
22/03/2015	13.99999991	0.12999999	1.39999998
1.84680765	0.46394583	0.80000001	
23/03/2015	14.00000003	0.13000000	1.39999998
1.78220887	0.46305595	0.80000001	
24/03/2015	13.99999989	0.12999999	1.39999995
1.83808267	0.46382564	0.80000001	
25/03/2015	14.00000017	0.12999999	1.39999999
1.90322335	0.46472298	0.80000002	
26/03/2015	14.12932073	0.13096434	1.53096616
1.94069943	0.46523923	0.80000001	
27/03/2015	14.00000000	0.13000000	1.39999998
1.91164684	0.46483902	0.80000001	
28/03/2015	14.00000008	0.12999999	1.39999997
1.95478364	0.46543325	0.80000001	
29/03/2015	13.99999999	0.13000000	1.39999998
2.01657164	0.46628442	0.80000001	
30/03/2015	14.00000009	0.12999999	1.39999997
2.07756459	0.46712462	0.80000001	
31/03/2015	13.99999994	0.13000000	1.39999998
2.12307873	0.46775160	0.80000001	

1/04/2015	13.99999562	0.13000006	1.40742733
2.12887893	0.46783151	0.80000002	
2/04/2015	14.00053978	0.13001023	1.44764011
2.05589424	0.46682610	0.80000001	
3/04/2015	14.09049310	0.13039596	1.45700343
1.95232062	0.46539932	0.80000001	
4/04/2015	21.13525012	0.14170099	1.59458156
1.83695472	0.46381010	0.80000001	
5/04/2015	14.00000003	0.13000000	1.39999998
1.77059117	0.46289591	0.80000001	
6/04/2015	14.00000008	0.12999999	1.39999999
1.73094265	0.46234973	0.80000001	
7/04/2015	14.00000010	0.13000000	1.39999998
1.81917830	0.46356522	0.80000001	
8/04/2015	14.00000012	0.13000000	1.39999998
1.90959921	0.46481082	0.80000001	
9/04/2015	14.00000002	0.13000000	1.39999998
1.99849679	0.46603542	0.80000002	
10/04/2015	14.00000014	0.13000000	1.39999997
2.07599222	0.46710296	0.80000001	
11/04/2015	14.00000004	0.12999999	1.39999998
2.14080811	0.46799584	0.80000001	
12/04/2015	13.99999994	0.13000000	1.39999998
2.19580033	0.46875338	0.80000001	
13/04/2015	13.99999990	0.13000000	1.39999996
2.24291965	0.46940247	0.80000001	
14/04/2015	14.00000006	0.12999999	1.39999999
2.28364590	0.46996350	0.80000001	
15/04/2015	14.00000004	0.13000000	1.39999999
2.31924343	0.47045387	0.80000002	
16/04/2015	13.99999987	0.13000000	1.39999998
2.35079065	0.47088845	0.80000002	
17/04/2015	13.99999995	0.13000000	1.39999996
2.37920036	0.47127981	0.80000001	
18/04/2015	14.00000000	0.12999999	1.39999997
2.40523902	0.47163851	0.80000001	
19/04/2015	13.99994783	0.13000016	1.41964718
2.41741477	0.47180623	0.80000001	
20/04/2015	14.00816438	0.13006795	1.44878558
2.26837644	0.46975315	0.80000001	
21/04/2015	13.99999999	0.12999999	1.39999998
2.13918303	0.46797345	0.80000001	
22/04/2015	13.99999990	0.12999999	1.39999998
2.11438702	0.46763187	0.80000001	

23/04/2015	14.00000006	0.12999999	1.39999999
2.14463476	0.46804855	0.80000001	
24/04/2015	14.00000023	0.12999999	1.39999997
2.18399191	0.46859071	0.80000001	
25/04/2015	13.99999997	0.12999999	1.39999998
2.22649536	0.46917622	0.80000001	
26/04/2015	13.99999992	0.13000000	1.39999999
2.26961375	0.46977020	0.80000001	
27/04/2015	13.99999989	0.13000000	1.39999996
2.31229789	0.47035819	0.80000001	
28/04/2015	13.99999998	0.13000000	1.39999998
2.35397793	0.47093236	0.80000001	
29/04/2015	14.00000008	0.13000000	1.39999999
2.39447357	0.47149021	0.80000002	
30/04/2015	14.29420924	0.13101702	1.50147301
2.35324376	0.47092224	0.80000001	
1/05/2015	65.05792130	0.21909751	1.75466873
47.65635996	0.22100004	1.63062369	
2/05/2015	17.01498464	0.13511781	1.57430745
4.02386121	0.45137621	0.84625719	
3/05/2015	14.00000027	0.13000000	1.40205830
1.89161284	0.46456304	0.80000001	
4/05/2015	14.00000004	0.13000000	1.40065068
1.83544373	0.46378929	0.80000001	
5/05/2015	14.00000007	0.13000000	1.39999996
1.88801050	0.46451342	0.80000001	
6/05/2015	14.00000010	0.13000000	1.39999997
1.96543710	0.46558001	0.80000001	
7/05/2015	14.00000013	0.13000000	1.39999999
2.04543782	0.46668206	0.80000001	
8/05/2015	14.00000006	0.12999999	1.39999999
2.12410952	0.46776580	0.80000001	
9/05/2015	14.00000004	0.12999999	1.39999999
2.20001926	0.46881150	0.80000001	
10/05/2015	14.00000003	0.12999999	1.39999998
2.27274374	0.46981332	0.80000001	
11/05/2015	13.99999995	0.12999999	1.39999999
2.34234325	0.47077208	0.80000001	
12/05/2015	13.99999982	0.13000000	1.39999999
2.40911890	0.47169195	0.80000001	
13/05/2015	13.99999996	0.13000000	1.39999997
2.47348606	0.47257864	0.80000001	
14/05/2015	13.99999993	0.13000000	1.39999996
2.53590726	0.47343853	0.80000002	

15/05/2015	13.99999995	0.12999999	1.39999997
2.59684963	0.47427804	0.80000001	
16/05/2015	14.00000000	0.12999999	1.39999997
2.65676380	0.47510339	0.80000001	
17/05/2015	13.99999998	0.12999999	1.39999999
2.71607371	0.47592041	0.80000001	
18/05/2015	13.99999993	0.13000000	1.39999999
2.77516975	0.47673449	0.80000001	
19/05/2015	14.00000006	0.12999999	1.39999997
2.83440899	0.47755054	0.80000001	
20/05/2015	14.00000006	0.12999999	1.39999999
2.89411915	0.47837308	0.80000001	
21/05/2015	14.00126457	0.13001175	1.44312872
2.89769179	0.47842230	0.80000001	
22/05/2015	14.00110033	0.13000561	1.41921539
2.74554304	0.47632637	0.80000001	
23/05/2015	13.99999999	0.12999999	1.39999998
2.47580975	0.47261065	0.80000002	

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)
Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)	
13/12/2014	13.99999994	0.13000000	1.40000048
3.95522997	0.44999042	2.75236782	
14/12/2014	14.00000008	0.12999999	1.40000048
3.26251989	0.44044799	0.83886440	
15/12/2014	14.00000003	0.12999999	1.40000037
2.76416931	0.43358295	0.80000001	
16/12/2014	14.00000005	0.12999999	1.40000024
2.44870684	0.42923730	0.80000001	
17/12/2014	14.00000003	0.13000000	1.40000011
2.23428382	0.42628351	0.80000001	
18/12/2014	15.23868267	0.13369152	1.55389899
2.03030723	0.42347363	0.80000001	
19/12/2014	14.03974051	0.13014055	1.44484038
1.92157577	0.42197580	0.80000001	
20/12/2014	14.00000010	0.12999999	1.40053142
1.81892508	0.42056173	0.80000001	
21/12/2014	13.99999960	0.13000000	1.40042168
1.73194160	0.41936349	0.80000004	
22/12/2014	14.00000001	0.12999999	1.40033351
1.67871865	0.41863031	0.80000002	
23/12/2014	13.99999967	0.12999999	1.40026470
1.63909246	0.41808444	0.80000002	
24/12/2014	75.93216135	0.23575487	1.68775438
1.60248377	0.41758014	0.80000002	
25/12/2014	42.44543901	0.19010921	1.70571477
5.30840473	0.37550557	0.90703460	
26/12/2014	15.68618121	0.13350988	1.53050423
2.99166268	0.39985971	0.84707489	
27/12/2014	14.68039769	0.13217541	1.51388412
1.53525346	0.41665401	0.80000001	
28/12/2014	17.49639629	0.13784825	1.59261634
1.53017522	0.41658405	0.80000002	
29/12/2014	14.15327175	0.13068394	1.47819541
1.52941793	0.41657362	0.80000001	
30/12/2014	14.00000000	0.13000000	1.40007541
1.51527112	0.41637874	0.80000001	
31/12/2014	14.00000017	0.13000000	1.40005696
1.51744283	0.41640866	0.80000002	
1/01/2015	14.00000007	0.12999999	1.40004294
1.52490109	0.41651140	0.80000000	
2/01/2015	13.99999991	0.12999999	1.40003230
1.53211564	0.41661078	0.80000002	

3/01/2015	14.00000020	0.13000001	1.40146852
1.53787216	0.41669008	0.80000002	
4/01/2015	13.99999996	0.13000000	1.40001941
1.54354098	0.41676818	0.80000002	
5/01/2015	60.94865747	0.16352640	1.63861853
1.54698728	0.41681565	0.80000001	
6/01/2015	13.99999986	0.13000000	1.40001734
1.53217808	0.41661164	0.80000001	
7/01/2015	14.00000001	0.12999999	1.40001151
1.52823466	0.41655732	0.80000002	
8/01/2015	14.00000009	0.13000000	1.40000898
1.54291874	0.41675960	0.80000002	
9/01/2015	13.99999992	0.12999999	1.40000702
1.55592526	0.41693877	0.80000001	
10/01/2015	14.00000007	0.12999999	1.40000549
1.56763400	0.41710007	0.80000001	
11/01/2015	14.00000012	0.12999999	1.40000429
1.57832076	0.41724728	0.80000002	
12/01/2015	14.00000007	0.13000000	1.40000337
1.58820766	0.41738348	0.80000002	
13/01/2015	14.00000005	0.12999999	1.40000265
1.59746922	0.41751106	0.80000001	
14/01/2015	14.60219696	0.13070030	1.53320577
1.59763288	0.41751332	0.80000001	
15/01/2015	13.99999996	0.13000000	1.40000205
1.57988208	0.41726879	0.80000001	
16/01/2015	13.99999995	0.13000000	1.40000154
1.58792716	0.41737962	0.80000001	
17/01/2015	14.00000006	0.13000000	1.40000121
1.60310313	0.41758868	0.80000002	
18/01/2015	14.00000001	0.13000000	1.40000094
1.61660156	0.41777462	0.80000003	
19/01/2015	13.99999995	0.12999999	1.40000072
1.62877869	0.41794237	0.80000002	
20/01/2015	14.00000001	0.12999999	1.40000056
1.63991425	0.41809577	0.80000001	
21/01/2015	13.99999988	0.13000000	1.40000046
1.65022930	0.41823786	0.80000001	
22/01/2015	13.99999713	0.13000008	1.40662357
1.65854489	0.41835241	0.80000001	
23/01/2015	17.47356450	0.13714039	1.58504569
1.62895872	0.41794485	0.80000001	
24/01/2015	14.00000007	0.13000000	1.40000043
1.59474101	0.41747348	0.80000001	

25/01/2015	14.00000007	0.13000000	1.40000033
1.58190647	0.41729668	0.80000001	
26/01/2015	13.99999992	0.13000000	1.40000022
1.61501332	0.41775274	0.80000001	
27/01/2015	14.00000017	0.13000000	1.40000022
1.63951772	0.41809030	0.80000002	
28/01/2015	13.99999985	0.13000000	1.40000011
1.66053397	0.41837981	0.80000002	
29/01/2015	14.00000004	0.12999999	1.40000009
1.67875568	0.41863083	0.80000001	
30/01/2015	14.00000010	0.13000000	1.40000009
1.69474636	0.41885111	0.80000002	
31/01/2015	14.00000009	0.13000000	1.39999999
1.70897227	0.41904707	0.80000001	
1/02/2015	14.00000016	0.13000000	1.39999999
1.72182977	0.41922419	0.80000001	
2/02/2015	14.00000008	0.13000000	1.39999997
1.73361951	0.41938660	0.80000001	
3/02/2015	13.99999993	0.12999999	1.39999998
1.74451942	0.41953675	0.80000001	
4/02/2015	13.99999994	0.13000000	1.39999998
1.75472525	0.41967735	0.80000001	
5/02/2015	14.00000009	0.12999999	1.39999997
1.76439537	0.41981056	0.80000001	
6/02/2015	13.99999990	0.12999999	1.39999999
1.77364381	0.41993796	0.80000001	
7/02/2015	13.99999988	0.13000000	1.39999998
1.78255852	0.42006076	0.80000001	
8/02/2015	13.99999998	0.13000000	1.39999999
1.79120453	0.42017987	0.80000001	
9/02/2015	13.99999995	0.13000000	1.39999999
1.79964119	0.42029609	0.80000001	
10/02/2015	13.99999995	0.13000000	1.39999999
1.80793099	0.42041028	0.80000002	
11/02/2015	14.00000001	0.12999999	1.39999999
1.81611211	0.42052298	0.80000002	
12/02/2015	14.00000015	0.12999999	1.39999999
1.82421079	0.42063454	0.80000002	
13/02/2015	14.00000003	0.12999999	1.39999997
1.83223543	0.42074509	0.80000002	
14/02/2015	14.00000001	0.13000000	1.39999998
1.84022994	0.42085522	0.80000001	
15/02/2015	14.00000011	0.13000000	1.39999998
1.84818575	0.42096481	0.80000001	

16/02/2015	14.00000008	0.13000000	1.39999997
1.85612537	0.42107418	0.80000001	
17/02/2015	14.00000001	0.12999999	1.39999997
1.86404274	0.42118325	0.80000001	
18/02/2015	14.00097418	0.13000737	1.43099795
1.87278911	0.42130373	0.80000002	
19/02/2015	14.00370704	0.13001896	1.43714363
1.84812929	0.42096403	0.80000001	
20/02/2015	23.08684679	0.14535733	1.57663067
1.77642039	0.41997621	0.80000001	
21/02/2015	14.15028934	0.13088850	1.46816321
1.70963176	0.41905616	0.80000001	
22/02/2015	14.00000007	0.13000000	1.39999998
1.66892638	0.41849542	0.80000001	
23/02/2015	14.00000004	0.13000000	1.39999998
1.71980359	0.41919628	0.80000002	
24/02/2015	14.00000007	0.12999999	1.39999998
1.76660884	0.41984105	0.80000002	
25/02/2015	14.00000010	0.13000000	1.39999998
1.80578761	0.42038076	0.80000002	
26/02/2015	13.99999998	0.12999999	1.39999999
1.83877970	0.42083524	0.80000002	
27/02/2015	19.26883388	0.14453712	1.59675716
1.81549038	0.42051442	0.80000001	
28/02/2015	13.99999994	0.13000000	1.39999998
1.76160052	0.41977206	0.80000001	
1/03/2015	14.00000003	0.13000000	1.39999997
1.79541793	0.42023791	0.80000001	
2/03/2015	14.00000000	0.12999999	1.39999997
1.83665441	0.42080596	0.80000001	
3/03/2015	14.00000005	0.12999999	1.39999997
1.87142314	0.42128492	0.80000001	
4/03/2015	14.00000007	0.13000000	1.39999996
1.90090689	0.42169107	0.80000001	
5/03/2015	13.99999987	0.13000000	1.39999998
1.92608949	0.42203798	0.80000001	
6/03/2015	13.99999999	0.13000000	1.39999998
1.94780726	0.42233715	0.80000001	
7/03/2015	14.00000002	0.13000000	1.39999999
1.96680096	0.42259880	0.80000002	
8/03/2015	14.00000000	0.12999999	1.39999998
1.98358356	0.42282999	0.80000002	
9/03/2015	13.99999993	0.12999999	1.39999998
1.99869066	0.42303809	0.80000002	

10/03/2015	14.00000000	0.13000000	1.39999997
2.01236673	0.42322649	0.80000001	
11/03/2015	14.00000012	0.13000000	1.39999998
2.02495739	0.42339993	0.80000001	
12/03/2015	13.99999991	0.12999999	1.39999999
2.03671282	0.42356187	0.80000001	
13/03/2015	14.00000000	0.13000000	1.39999999
2.04789652	0.42371593	0.80000001	
14/03/2015	13.99999989	0.12999999	1.39999997
2.05852755	0.42386238	0.80000001	
15/03/2015	14.00000023	0.13000000	1.39999997
2.06879552	0.42400382	0.80000001	
16/03/2015	14.00000006	0.13000000	1.39999999
2.07874478	0.42414088	0.80000001	
17/03/2015	14.00000008	0.13000000	1.39999998
2.08847885	0.42427497	0.80000001	
18/03/2015	26.86875770	0.16258160	1.60328732
2.04850650	0.42372433	0.80000001	
19/03/2015	13.99999998	0.13000000	1.41878597
1.93481906	0.42215823	0.80000001	
20/03/2015	14.00000006	0.13000000	1.39999998
1.86824535	0.42124114	0.80000001	
21/03/2015	21.44363065	0.16075474	1.63655949
1.91034527	0.42182109	0.80000002	
22/03/2015	13.99999991	0.12999999	1.39999998
1.84680765	0.42094583	0.80000001	
23/03/2015	14.00000003	0.13000000	1.39999998
1.78220887	0.42005595	0.80000001	
24/03/2015	13.99999989	0.12999999	1.39999995
1.83808267	0.42082564	0.80000001	
25/03/2015	14.00000017	0.12999999	1.39999999
1.90322335	0.42172298	0.80000002	
26/03/2015	14.12932073	0.13096434	1.53096616
1.94069943	0.42223923	0.80000001	
27/03/2015	14.00000000	0.13000000	1.39999998
1.91164684	0.42183902	0.80000001	
28/03/2015	14.00000008	0.12999999	1.39999997
1.95478364	0.42243325	0.80000001	
29/03/2015	13.99999999	0.13000000	1.39999998
2.01657164	0.42328441	0.80000001	
30/03/2015	14.00000009	0.12999999	1.39999997
2.07756459	0.42412462	0.80000001	
31/03/2015	13.99999994	0.13000000	1.39999998
2.12307873	0.42475160	0.80000001	

1/04/2015	13.99999562	0.13000006	1.40742733
2.12887893	0.42483150	0.80000002	
2/04/2015	14.00053978	0.13001023	1.44764011
2.05589424	0.42382610	0.80000001	
3/04/2015	14.09049310	0.13039596	1.45700343
1.95232062	0.42239932	0.80000001	
4/04/2015	21.13525012	0.14170099	1.59458156
1.83695472	0.42081010	0.80000001	
5/04/2015	14.00000003	0.13000000	1.39999998
1.77059117	0.41989591	0.80000001	
6/04/2015	14.00000008	0.12999999	1.39999999
1.73094265	0.41934973	0.80000001	
7/04/2015	14.00000010	0.13000000	1.39999998
1.81917830	0.42056522	0.80000001	
8/04/2015	14.00000012	0.13000000	1.39999998
1.90959921	0.42181081	0.80000001	
9/04/2015	14.00000002	0.13000000	1.39999998
1.99849679	0.42303542	0.80000002	
10/04/2015	14.00000014	0.13000000	1.39999997
2.07599222	0.42410296	0.80000001	
11/04/2015	14.00000004	0.12999999	1.39999998
2.14080811	0.42499583	0.80000001	
12/04/2015	13.99999994	0.13000000	1.39999998
2.19580033	0.42575338	0.80000001	
13/04/2015	13.99999990	0.13000000	1.39999996
2.24291965	0.42640247	0.80000001	
14/04/2015	14.00000006	0.12999999	1.39999999
2.28364590	0.42696350	0.80000001	
15/04/2015	14.00000004	0.13000000	1.39999999
2.31924343	0.42745387	0.80000002	
16/04/2015	13.99999987	0.13000000	1.39999998
2.35079065	0.42788845	0.80000002	
17/04/2015	13.99999995	0.13000000	1.39999996
2.37920036	0.42827981	0.80000001	
18/04/2015	14.00000000	0.12999999	1.39999997
2.40523902	0.42863850	0.80000001	
19/04/2015	13.99994783	0.13000016	1.41964718
2.41741477	0.42880623	0.80000001	
20/04/2015	14.00816438	0.13006795	1.44878558
2.26837644	0.42675315	0.80000001	
21/04/2015	13.99999999	0.12999999	1.39999998
2.13918303	0.42497344	0.80000001	
22/04/2015	13.99999990	0.12999999	1.39999998
2.11438702	0.42463187	0.80000001	

23/04/2015	14.00000006	0.12999999	1.39999999
2.14463476	0.42504855	0.80000001	
24/04/2015	14.00000023	0.12999999	1.39999997
2.18399191	0.42559071	0.80000001	
25/04/2015	13.99999997	0.12999999	1.39999998
2.22649536	0.42617622	0.80000001	
26/04/2015	13.99999992	0.13000000	1.39999999
2.26961375	0.42677020	0.80000001	
27/04/2015	13.99999989	0.13000000	1.39999996
2.31229789	0.42735819	0.80000001	
28/04/2015	13.99999998	0.13000000	1.39999998
2.35397793	0.42793236	0.80000001	
29/04/2015	14.00000008	0.13000000	1.39999999
2.39447357	0.42849020	0.80000002	
30/04/2015	14.29420924	0.13101702	1.50147301
2.35324376	0.42792224	0.80000001	
1/05/2015	65.05792130	0.21909751	1.75466873
47.65635996	0.21677843	1.63062369	
2/05/2015	17.01498464	0.13511781	1.57430745
4.02386121	0.41051438	0.84625719	
3/05/2015	14.00000027	0.13000000	1.40205830
1.89161284	0.42156304	0.80000001	
4/05/2015	14.00000004	0.13000000	1.40065068
1.83544373	0.42078928	0.80000001	
5/05/2015	14.00000007	0.13000000	1.39999996
1.88801050	0.42151342	0.80000001	
6/05/2015	14.00000010	0.13000000	1.39999997
1.96543710	0.42258001	0.80000001	
7/05/2015	14.00000013	0.13000000	1.39999999
2.04543782	0.42368206	0.80000001	
8/05/2015	14.00000006	0.12999999	1.39999999
2.12410952	0.42476580	0.80000001	
9/05/2015	14.00000004	0.12999999	1.39999999
2.20001926	0.42581150	0.80000001	
10/05/2015	14.00000003	0.12999999	1.39999998
2.27274374	0.42681332	0.80000001	
11/05/2015	13.99999995	0.12999999	1.39999999
2.34234325	0.42777208	0.80000001	
12/05/2015	13.99999982	0.13000000	1.39999999
2.40911890	0.42869195	0.80000001	
13/05/2015	13.99999996	0.13000000	1.39999997
2.47348606	0.42957864	0.80000001	
14/05/2015	13.99999993	0.13000000	1.39999996
2.53590726	0.43043853	0.80000002	

15/05/2015	13.99999995	0.12999999	1.39999997
2.59684963	0.43127804	0.80000001	
16/05/2015	14.00000000	0.12999999	1.39999997
2.65676380	0.43210339	0.80000001	
17/05/2015	13.99999998	0.12999999	1.39999999
2.71607371	0.43292041	0.80000001	
18/05/2015	13.99999993	0.13000000	1.39999999
2.77516975	0.43373449	0.80000001	
19/05/2015	14.00000006	0.12999999	1.39999997
2.83440899	0.43455054	0.80000001	
20/05/2015	14.00000006	0.12999999	1.39999999
2.89411915	0.43537308	0.80000001	
21/05/2015	14.00126457	0.13001175	1.44312872
2.89769179	0.43542229	0.80000001	
22/05/2015	14.00110033	0.13000561	1.41921539
2.74554304	0.43332637	0.80000001	
23/05/2015	13.99999999	0.12999999	1.39999998
2.47580975	0.42961065	0.80000002	

S2 effective -lower.TXT

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	14.00000012	0.13000000	1.40182891	3.90278022	0.16626790	0.60061133
14/12/2014	13.99999999	0.13000000	1.40191815	3.10932456	0.15533765	0.60000004
15/12/2014	14.00000001	0.13000000	1.40130294	2.62092575	0.14860970	0.60000004
16/12/2014	14.00000024	0.12999999	1.40136477	2.30983624	0.14432429	0.60000003
17/12/2014	14.00000017	0.13000000	1.40123394	2.09739439	0.14139779	0.60000001
18/12/2014	19.36585807	0.13547830	1.59210877	1.92103396	0.13896834	0.60000002
19/12/2014	14.10442133	0.13084459	1.44958234	1.83135031	0.13773290	0.60000002
20/12/2014	13.99999959	0.12999999	1.40057621	1.74963683	0.13660725	0.60000002
21/12/2014	14.00000026	0.13000000	1.40051138	1.68131107	0.13566603	0.60000002
22/12/2014	14.00000001	0.13000000	1.40037566	1.63985113	0.13509490	0.60000002
23/12/2014	13.99999954	0.12999999	1.40031082	1.60906803	0.13467085	0.60000003
24/12/2014	67.14879034	0.25732430	1.72970625	1.58061324	0.13427887	0.60000002
25/12/2014	76.56218246	0.18809905	1.72413620	7.89489418	0.13705268	0.76741987
26/12/2014	15.14952428	0.13241421	1.53508430	3.53870074	0.13450529	0.66752964
27/12/2014	14.99268168	0.13336935	1.52255820	1.52419549	0.13350168	0.60000002
28/12/2014	17.90425477	0.14098019	1.60266841	1.52148994	0.13346441	0.60000002
29/12/2014	14.44710161	0.13171384	1.48203975	1.52247518	0.13347799	0.60000002
30/12/2014	14.00000023	0.13000000	1.40006156	1.50965918	0.13330144	0.60000003
31/12/2014	14.00000002	0.13000000	1.40005194	1.51320979	0.13335035	0.60000003
1/01/2015	14.00000001	0.12999999	1.40004757	1.52155866	0.13346536	0.60000003
2/01/2015	14.00000019	0.12999999	1.40004399	1.52947714	0.13357444	0.60000002

3/01/2015	14.00000702	0.13000002	1.40182638
1.53578953	0.13366140	0.60000003	
4/01/2015	13.99999996	0.13000000	1.40002484
1.54188881	0.13374542	0.60000003	
5/01/2015	66.11784916	0.18080544	1.68993104
1.54576343	0.13379879	0.60000003	
6/01/2015	13.99999999	0.13000000	1.40002216
1.53112934	0.13359720	0.60000002	
7/01/2015	14.00000008	0.13000000	1.40001474
1.52741777	0.13354607	0.60000003	
8/01/2015	13.99999999	0.13000000	1.40001329
1.54227005	0.13375067	0.60000003	
9/01/2015	13.99999998	0.13000000	1.40000869
1.55541032	0.13393168	0.60000003	
10/01/2015	13.99999990	0.13000000	1.40000672
1.56722400	0.13409442	0.60000002	
11/01/2015	14.00000002	0.13000000	1.40000657
1.57799510	0.13424280	0.60000002	
12/01/2015	14.00000010	0.13000000	1.40000499
1.58794968	0.13437993	0.60000003	
13/01/2015	14.00000012	0.13000000	1.40000424
1.59726740	0.13450829	0.60000002	
14/01/2015	17.74385625	0.13554351	1.58230296
1.59746968	0.13451107	0.60000002	
15/01/2015	13.99999999	0.13000000	1.40000289
1.57972240	0.13426660	0.60000002	
16/01/2015	13.99999994	0.13000000	1.40000218
1.58780581	0.13437795	0.60000003	
17/01/2015	13.99999987	0.13000000	1.40000159
1.60300529	0.13458733	0.60000003	
18/01/2015	13.99999999	0.13000000	1.40000157
1.61652584	0.13477358	0.60000003	
19/01/2015	14.00000012	0.13000000	1.40000147
1.62871843	0.13494154	0.60000002	
20/01/2015	14.00000005	0.13000000	1.40000096
1.63986399	0.13509508	0.60000003	
21/01/2015	13.99999991	0.12999999	1.40000079
1.65018627	0.13523727	0.60000002	
22/01/2015	14.00042976	0.13001542	1.41164031
1.65851181	0.13535196	0.60000002	
23/01/2015	21.07156868	0.14288403	1.63238409
1.62884377	0.13494327	0.60000002	
24/01/2015	14.00000010	0.13000000	1.40000047
1.59462176	0.13447184	0.60000002	

25/01/2015	13.99999991	0.13000000	1.40000035
1.58182782	0.13429560	0.60000003	
26/01/2015	14.00000000	0.13000000	1.40000024
1.61495169	0.13475190	0.60000002	
27/01/2015	13.99999993	0.13000000	1.40000024
1.63947119	0.13508967	0.60000002	
28/01/2015	14.00000008	0.13000000	1.40000018
1.66049457	0.13537927	0.60000002	
29/01/2015	13.99999983	0.12999999	1.40000013
1.67872433	0.13563040	0.60000002	
30/01/2015	14.00000015	0.13000000	1.40000009
1.69472817	0.13585086	0.60000003	
31/01/2015	14.00000005	0.12999999	1.40000008
1.70896366	0.13604696	0.60000003	
1/02/2015	14.00000006	0.13000000	1.40000004
1.72182642	0.13622415	0.60000002	
2/02/2015	14.00000010	0.12999999	1.40000001
1.73361734	0.13638658	0.60000002	
3/02/2015	13.99999990	0.12999999	1.40000000
1.74452421	0.13653682	0.60000002	
4/02/2015	13.99999989	0.13000000	1.40000000
1.75473663	0.13667751	0.60000002	
5/02/2015	13.99999995	0.12999999	1.39999999
1.76440240	0.13681066	0.60000002	
6/02/2015	13.99999994	0.13000000	1.39999998
1.77364158	0.13693793	0.60000003	
7/02/2015	14.00000007	0.13000000	1.39999998
1.78254743	0.13706061	0.60000003	
8/02/2015	13.99999998	0.12999999	1.39999997
1.79119447	0.13717973	0.60000003	
9/02/2015	14.00000009	0.12999999	1.39999999
1.79964169	0.13729610	0.60000002	
10/02/2015	13.99999998	0.12999999	1.39999996
1.80793601	0.13741035	0.60000002	
11/02/2015	13.99999991	0.13000000	1.39999996
1.81611331	0.13752300	0.60000003	
12/02/2015	13.99999989	0.13000000	1.39999999
1.82420165	0.13763442	0.60000003	
13/02/2015	14.00000009	0.13000000	1.39999998
1.83222646	0.13774497	0.60000003	
14/02/2015	13.99999986	0.13000000	1.39999999
1.84020452	0.13785487	0.60000002	
15/02/2015	14.00000009	0.13000000	1.39999998
1.84815206	0.13796435	0.60000002	

16/02/2015	14.00000002	0.13000000	1.39999999
1.85607969	0.13807356	0.60000002	
17/02/2015	13.99999989	0.12999999	1.39999997
1.86399664	0.13818262	0.60000002	
18/02/2015	14.03672397	0.13045528	1.47848827
1.87277725	0.13830358	0.60000002	
19/02/2015	14.09712893	0.13049069	1.48172489
1.84810924	0.13796376	0.60000002	
20/02/2015	26.45403862	0.15981218	1.64224359
1.77639789	0.13697590	0.60000002	
21/02/2015	14.76826677	0.13066901	1.48176171
1.70961446	0.13605592	0.60000002	
22/02/2015	13.99999999	0.13000000	1.39999998
1.66889863	0.13549504	0.60000002	
23/02/2015	13.99999995	0.12999999	1.39999999
1.71973552	0.13619535	0.60000002	
24/02/2015	13.99999987	0.12999999	1.39999999
1.76657441	0.13684058	0.60000003	
25/02/2015	13.99999987	0.13000000	1.39999999
1.80577093	0.13738053	0.60000003	
26/02/2015	13.99999997	0.13000000	1.39999998
1.83878891	0.13783537	0.60000003	
27/02/2015	25.12033336	0.17037375	1.65286790
1.81548475	0.13751434	0.60000003	
28/02/2015	13.99999998	0.13000000	1.39999998
1.76158881	0.13677190	0.60000002	
1/03/2015	13.99999990	0.12999999	1.39999997
1.79540034	0.13723767	0.60000002	
2/03/2015	13.99999989	0.12999999	1.39999997
1.83661352	0.13780540	0.60000002	
3/03/2015	13.99999996	0.13000000	1.39999997
1.87136686	0.13828415	0.60000002	
4/03/2015	13.99999996	0.13000000	1.39999999
1.90081866	0.13868986	0.60000003	
5/03/2015	13.99999994	0.13000000	1.39999998
1.92598849	0.13903659	0.60000003	
6/03/2015	14.00000001	0.13000000	1.39999998
1.94772391	0.13933600	0.60000002	
7/03/2015	14.00000009	0.12999999	1.39999997
1.96671633	0.13959763	0.60000002	
8/03/2015	14.00000001	0.13000000	1.39999999
1.98352631	0.13982920	0.60000003	
9/03/2015	13.99999995	0.12999999	1.39999999
1.99860818	0.14003696	0.60000003	

10/03/2015	14.00000012	0.13000000	1.39999998
2.01232406	0.14022590	0.60000003	
11/03/2015	14.00000012	0.12999999	1.39999997
2.02496626	0.14040006	0.60000002	
12/03/2015	14.00000016	0.12999999	1.39999998
2.03676545	0.14056260	0.60000002	
13/03/2015	14.00000010	0.13000000	1.39999999
2.04790986	0.14071612	0.60000002	
14/03/2015	13.99999980	0.12999999	1.39999997
2.05854965	0.14086269	0.60000002	
15/03/2015	14.00000002	0.12999999	1.39999999
2.06880081	0.14100390	0.60000002	
16/03/2015	13.99999995	0.13000000	1.39999998
2.07875916	0.14114108	0.60000003	
17/03/2015	14.00000007	0.12999999	1.39999999
2.08850011	0.14127527	0.60000003	
18/03/2015	63.56114568	0.17392397	1.70714474
2.04816972	0.14071970	0.60000002	
19/03/2015	13.99999991	0.13000000	1.42195915
1.93487312	0.13915898	0.60000002	
20/03/2015	13.99999989	0.12999999	1.39999997
1.86820942	0.13824065	0.60000002	
21/03/2015	27.78336885	0.16966046	1.69433389
1.91018029	0.13881882	0.60000003	
22/03/2015	14.00000002	0.12999999	1.39999999
1.84619957	0.13793745	0.60000002	
23/03/2015	14.00000007	0.13000000	1.39999998
1.78145183	0.13704552	0.60000002	
24/03/2015	13.99999996	0.13000000	1.39999999
1.83494049	0.13778235	0.60000002	
25/03/2015	13.99999984	0.12999999	1.39999999
1.90014983	0.13868065	0.60000003	
26/03/2015	15.12251032	0.13628209	1.57281303
1.93823956	0.13920535	0.60000002	
27/03/2015	13.99999999	0.13000000	1.39999998
1.90924923	0.13880600	0.60000002	
28/03/2015	13.99999986	0.12999999	1.39999998
1.94626679	0.13931593	0.60000002	
29/03/2015	14.00000001	0.12999999	1.39999997
1.99498583	0.13998706	0.60000002	
30/03/2015	13.99999999	0.12999999	1.39999998
2.04122764	0.14062407	0.60000003	
31/03/2015	14.00000004	0.12999999	1.39999997
2.08285454	0.14119750	0.60000002	

1/04/2015	14.00045483	0.13000213	1.41248200
2.09091312	0.14130851	0.60000002	
2/04/2015	14.07542388	0.13019468	1.48001032
2.02604379	0.14041490	0.60000002	
3/04/2015	15.02761027	0.13187838	1.48944541
1.93001513	0.13909206	0.60000002	
4/04/2015	26.48579508	0.15621685	1.64318271
1.82098322	0.13759009	0.60000002	
5/04/2015	13.99999995	0.13000000	1.39999998
1.75760683	0.13671704	0.60000002	
6/04/2015	13.99999993	0.13000000	1.39999996
1.72054308	0.13620647	0.60000002	
7/04/2015	14.00000007	0.12999999	1.39999998
1.80716957	0.13739980	0.60000002	
8/04/2015	13.99999996	0.12999999	1.39999998
1.89086369	0.13855273	0.60000003	
9/04/2015	13.99999988	0.13000000	1.39999998
1.96851543	0.13962242	0.60000002	
10/04/2015	14.00000014	0.13000000	1.39999997
2.03848588	0.14058630	0.60000003	
11/04/2015	14.00000012	0.13000000	1.39999999
2.10067074	0.14144293	0.60000003	
12/04/2015	14.00000006	0.12999999	1.39999998
2.15561579	0.14219982	0.60000003	
13/04/2015	14.00000008	0.13000000	1.39999996
2.20412742	0.14286809	0.60000002	
14/04/2015	14.00000010	0.12999999	1.39999997
2.24709123	0.14345994	0.60000002	
15/04/2015	14.00000000	0.12999999	1.40000000
2.28537732	0.14398735	0.60000003	
16/04/2015	13.99999997	0.13000000	1.39999999
2.31979488	0.14446147	0.60000002	
17/04/2015	14.00000000	0.12999999	1.39999998
2.35106901	0.14489229	0.60000002	
18/04/2015	13.99999999	0.12999999	1.39999998
2.37983821	0.14528860	0.60000002	
19/04/2015	14.00687449	0.13004804	1.44169895
2.39598409	0.14551102	0.60000002	
20/04/2015	14.22179731	0.13045049	1.48671639
2.25080258	0.14351107	0.60000002	
21/04/2015	14.00000005	0.13000000	1.39999998
2.12481834	0.14177557	0.60000002	
22/04/2015	13.99999986	0.12999999	1.39999998
2.10307286	0.14147601	0.60000002	

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23/04/2015      13.99999993      0.13000000      1.39999999
2.13523112       0.14191901      0.60000002
24/04/2015      13.99999999      0.12999999      1.39999999
2.17620728       0.14248348      0.60000003
25/04/2015      13.99999995      0.12999999      1.39999998
2.22011571       0.14308834      0.60000002
26/04/2015      14.00000004      0.12999999      1.39999997
2.26447820       0.14369946      0.60000002
27/04/2015      14.00000005      0.12999999      1.39999997
2.30815248       0.14430109      0.60000002
28/04/2015      13.99999998      0.12999999      1.39999997
2.35064906       0.14488650      0.60000002
29/04/2015      14.00000007      0.13000000      1.39999997
2.39182604       0.14545374      0.60000002
30/04/2015      15.42383676      0.13449370      1.56029677
2.35304323       0.14491948      0.60000002
1/05/2015      78.37529723      0.21056436      1.75970680
50.37241309       0.17947190      1.62689556
2/05/2015      14.94051401      0.13172145      1.55875802
3.15284655       0.14071204      0.64893735
3/05/2015      14.00000660      0.13000009      1.41143257
1.89921454       0.13866776      0.60000002
4/05/2015      14.00000004      0.13000000      1.40203143
1.83964913       0.13784722      0.60000003
5/05/2015      13.99999986      0.13000000      1.39999997
1.88860557       0.13852162      0.60000003
6/05/2015      14.00000006      0.12999999      1.39999998
1.96360187       0.13955473      0.60000002
7/05/2015      13.99999990      0.12999999      1.39999998
2.04036119       0.14061213      0.60000002
8/05/2015      13.99999994      0.12999999      1.39999998
2.11499635       0.14164027      0.60000002
9/05/2015      14.00000003      0.12999999      1.39999998
2.18611779       0.14262000      0.60000002
10/05/2015      14.00000008      0.13000000      1.39999998
2.25335117       0.14354617      0.60000002
11/05/2015      13.99999996      0.12999999      1.39999997
2.31680475       0.14442028      0.60000002
12/05/2015      13.99999995      0.12999999      1.39999998
2.37682450       0.14524708      0.60000002
13/05/2015      13.99999996      0.13000000      1.39999999
2.43386705       0.14603287      0.60000002
14/05/2015      14.00000001      0.12999999      1.39999999
2.48843091       0.14678452      0.60000002
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15/05/2015	13.99999993	0.13000000	1.39999998
2.54101511	0.14750889	0.60000003	
16/05/2015	14.00000010	0.12999999	1.39999997
2.59209771	0.14821258	0.60000002	
17/05/2015	14.00000011	0.12999999	1.39999997
2.64212272	0.14890170	0.60000002	
18/05/2015	13.99999994	0.13000000	1.39999999
2.69149894	0.14958188	0.60000002	
19/05/2015	14.00000013	0.12999999	1.39999998
2.74059502	0.15025821	0.60000003	
20/05/2015	14.00000002	0.13000000	1.39999999
2.78974385	0.15093526	0.60000002	
21/05/2015	14.07073546	0.13032623	1.48481680
2.78630069	0.15088783	0.60000002	
22/05/2015	14.01113270	0.13004450	1.43951719
2.64946167	0.14900280	0.60000002	
23/05/2015	13.99999993	0.12999999	1.39999998
2.41097030	0.14571746	0.60000002	

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	14.00000012	0.13000000	1.40182891	3.90278022	0.20926790	0.65074648
14/12/2014	13.99999999	0.13000000	1.40191815	3.10932456	0.19833765	0.60000004
15/12/2014	14.00000001	0.13000000	1.40130294	2.62092575	0.19160970	0.60000004
16/12/2014	14.00000024	0.12999999	1.40136477	2.30983624	0.18732429	0.60000003
17/12/2014	14.00000017	0.13000000	1.40123394	2.09739439	0.18439779	0.60000001
18/12/2014	19.36585807	0.13547830	1.59210877	1.92103396	0.18196834	0.60000002
19/12/2014	14.10442133	0.13084459	1.44958234	1.83135031	0.18073290	0.60000002
20/12/2014	13.99999959	0.12999999	1.40057621	1.74963683	0.17960725	0.60000002
21/12/2014	14.00000026	0.13000000	1.40051138	1.68131107	0.17866603	0.60000002
22/12/2014	14.00000001	0.13000000	1.40037566	1.63985113	0.17809490	0.60000002
23/12/2014	13.99999954	0.12999999	1.40031082	1.60906803	0.17767085	0.60000003
24/12/2014	67.14879034	0.25732430	1.72970625	1.58061324	0.17727887	0.60000002
25/12/2014	76.56218246	0.18809905	1.72413620	7.89489418	0.17287525	0.76741987
26/12/2014	15.14952428	0.13241421	1.53508430	3.53870074	0.17469526	0.66752964
27/12/2014	14.99268168	0.13336935	1.52255820	1.52419549	0.17650169	0.60000002
28/12/2014	17.90425477	0.14098019	1.60266841	1.52148994	0.17646441	0.60000002
29/12/2014	14.44710161	0.13171384	1.48203975	1.52247518	0.17647799	0.60000002
30/12/2014	14.00000023	0.13000000	1.40006156	1.50965918	0.17630144	0.60000003
31/12/2014	14.00000002	0.13000000	1.40005194	1.51320979	0.17635035	0.60000003
1/01/2015	14.00000001	0.12999999	1.40004757	1.52155866	0.17646536	0.60000003
2/01/2015	14.00000019	0.12999999	1.40004399	1.52947714	0.17657444	0.60000002

3/01/2015	14.00000702	0.13000002	1.40182638
1.53578953	0.17666140	0.60000003	
4/01/2015	13.99999996	0.13000000	1.40002484
1.54188881	0.17674542	0.60000003	
5/01/2015	66.11784916	0.18080544	1.68993104
1.54576343	0.17679879	0.60000003	
6/01/2015	13.99999999	0.13000000	1.40002216
1.53112934	0.17659720	0.60000002	
7/01/2015	14.00000008	0.13000000	1.40001474
1.52741777	0.17654607	0.60000003	
8/01/2015	13.99999999	0.13000000	1.40001329
1.54227005	0.17675067	0.60000003	
9/01/2015	13.99999998	0.13000000	1.40000869
1.55541032	0.17693169	0.60000003	
10/01/2015	13.99999990	0.13000000	1.40000672
1.56722400	0.17709443	0.60000002	
11/01/2015	14.00000002	0.13000000	1.40000657
1.57799510	0.17724280	0.60000002	
12/01/2015	14.00000010	0.13000000	1.40000499
1.58794968	0.17737993	0.60000003	
13/01/2015	14.00000012	0.13000000	1.40000424
1.59726740	0.17750829	0.60000002	
14/01/2015	17.74385625	0.13554351	1.58230296
1.59746968	0.17751107	0.60000002	
15/01/2015	13.99999999	0.13000000	1.40000289
1.57972240	0.17726660	0.60000002	
16/01/2015	13.99999994	0.13000000	1.40000218
1.58780581	0.17737795	0.60000003	
17/01/2015	13.99999987	0.13000000	1.40000159
1.60300529	0.17758733	0.60000003	
18/01/2015	13.99999999	0.13000000	1.40000157
1.61652584	0.17777358	0.60000003	
19/01/2015	14.00000012	0.13000000	1.40000147
1.62871843	0.17794154	0.60000002	
20/01/2015	14.00000005	0.13000000	1.40000096
1.63986399	0.17809508	0.60000003	
21/01/2015	13.99999991	0.12999999	1.40000079
1.65018627	0.17823727	0.60000002	
22/01/2015	14.00042976	0.13001542	1.41164031
1.65851181	0.17835196	0.60000002	
23/01/2015	21.07156868	0.14288403	1.63238409
1.62884377	0.17794327	0.60000002	
24/01/2015	14.00000010	0.13000000	1.40000047
1.59462176	0.17747184	0.60000002	

25/01/2015	13.99999991	0.13000000	1.40000035
1.58182782	0.17729560	0.60000003	
26/01/2015	14.00000000	0.13000000	1.40000024
1.61495169	0.17775190	0.60000002	
27/01/2015	13.99999993	0.13000000	1.40000024
1.63947119	0.17808967	0.60000002	
28/01/2015	14.00000008	0.13000000	1.40000018
1.66049457	0.17837927	0.60000002	
29/01/2015	13.99999983	0.12999999	1.40000013
1.67872433	0.17863040	0.60000002	
30/01/2015	14.00000015	0.13000000	1.40000009
1.69472817	0.17885086	0.60000003	
31/01/2015	14.00000005	0.12999999	1.40000008
1.70896366	0.17904696	0.60000003	
1/02/2015	14.00000006	0.13000000	1.40000004
1.72182642	0.17922415	0.60000002	
2/02/2015	14.00000010	0.12999999	1.40000001
1.73361734	0.17938658	0.60000002	
3/02/2015	13.99999990	0.12999999	1.40000000
1.74452421	0.17953683	0.60000002	
4/02/2015	13.99999989	0.13000000	1.40000000
1.75473663	0.17967751	0.60000002	
5/02/2015	13.99999995	0.12999999	1.39999999
1.76440240	0.17981066	0.60000002	
6/02/2015	13.99999994	0.13000000	1.39999998
1.77364158	0.17993793	0.60000003	
7/02/2015	14.00000007	0.13000000	1.39999998
1.78254743	0.18006062	0.60000003	
8/02/2015	13.99999998	0.12999999	1.39999997
1.79119447	0.18017973	0.60000003	
9/02/2015	14.00000009	0.12999999	1.39999999
1.79964169	0.18029610	0.60000002	
10/02/2015	13.99999998	0.12999999	1.39999996
1.80793601	0.18041036	0.60000002	
11/02/2015	13.99999991	0.13000000	1.39999996
1.81611331	0.18052300	0.60000003	
12/02/2015	13.99999989	0.13000000	1.39999999
1.82420165	0.18063442	0.60000003	
13/02/2015	14.00000009	0.13000000	1.39999998
1.83222646	0.18074497	0.60000003	
14/02/2015	13.99999986	0.13000000	1.39999999
1.84020452	0.18085487	0.60000002	
15/02/2015	14.00000009	0.13000000	1.39999998
1.84815206	0.18096435	0.60000002	

16/02/2015	14.00000002	0.13000000	1.39999999
1.85607969	0.18107356	0.60000002	
17/02/2015	13.99999989	0.12999999	1.39999997
1.86399664	0.18118262	0.60000002	
18/02/2015	14.03672397	0.13045528	1.47848827
1.87277725	0.18130358	0.60000002	
19/02/2015	14.09712893	0.13049069	1.48172489
1.84810924	0.18096376	0.60000002	
20/02/2015	26.45403862	0.15981218	1.64224359
1.77639789	0.17997590	0.60000002	
21/02/2015	14.76826677	0.13066901	1.48176171
1.70961446	0.17905593	0.60000002	
22/02/2015	13.99999999	0.13000000	1.39999998
1.66889863	0.17849505	0.60000002	
23/02/2015	13.99999995	0.12999999	1.39999999
1.71973552	0.17919535	0.60000002	
24/02/2015	13.99999987	0.12999999	1.39999999
1.76657441	0.17984058	0.60000003	
25/02/2015	13.99999987	0.13000000	1.39999999
1.80577093	0.18038053	0.60000003	
26/02/2015	13.99999997	0.13000000	1.39999998
1.83878891	0.18083537	0.60000003	
27/02/2015	25.12033336	0.17037375	1.65286790
1.81548475	0.18051434	0.60000003	
28/02/2015	13.99999998	0.13000000	1.39999998
1.76158881	0.17977190	0.60000002	
1/03/2015	13.99999990	0.12999999	1.39999997
1.79540034	0.18023767	0.60000002	
2/03/2015	13.99999989	0.12999999	1.39999997
1.83661352	0.18080540	0.60000002	
3/03/2015	13.99999996	0.13000000	1.39999997
1.87136686	0.18128415	0.60000002	
4/03/2015	13.99999996	0.13000000	1.39999999
1.90081866	0.18168986	0.60000003	
5/03/2015	13.99999994	0.13000000	1.39999998
1.92598849	0.18203659	0.60000003	
6/03/2015	14.00000001	0.13000000	1.39999998
1.94772391	0.18233601	0.60000002	
7/03/2015	14.00000009	0.12999999	1.39999997
1.96671633	0.18259764	0.60000002	
8/03/2015	14.00000001	0.13000000	1.39999999
1.98352631	0.18282920	0.60000003	
9/03/2015	13.99999995	0.12999999	1.39999999
1.99860818	0.18303696	0.60000003	

10/03/2015	14.00000012	0.13000000	1.39999998
2.01232406	0.18322591	0.60000003	
11/03/2015	14.00000012	0.12999999	1.39999997
2.02496626	0.18340006	0.60000002	
12/03/2015	14.00000016	0.12999999	1.39999998
2.03676545	0.18356260	0.60000002	
13/03/2015	14.00000010	0.13000000	1.39999999
2.04790986	0.18371612	0.60000002	
14/03/2015	13.99999980	0.12999999	1.39999997
2.05854965	0.18386269	0.60000002	
15/03/2015	14.00000002	0.12999999	1.39999999
2.06880081	0.18400390	0.60000002	
16/03/2015	13.99999995	0.13000000	1.39999998
2.07875916	0.18414108	0.60000003	
17/03/2015	14.00000007	0.12999999	1.39999999
2.08850011	0.18427527	0.60000003	
18/03/2015	63.56114568	0.17392397	1.70714474
2.04816972	0.18371970	0.60000002	
19/03/2015	13.99999991	0.13000000	1.42195915
1.93487312	0.18215898	0.60000002	
20/03/2015	13.99999989	0.12999999	1.39999997
1.86820942	0.18124065	0.60000002	
21/03/2015	27.78336885	0.16966046	1.69433389
1.91018029	0.18181882	0.60000003	
22/03/2015	14.00000002	0.12999999	1.39999999
1.84619957	0.18093746	0.60000002	
23/03/2015	14.00000007	0.13000000	1.39999998
1.78145183	0.18004552	0.60000002	
24/03/2015	13.99999996	0.13000000	1.39999999
1.83494049	0.18078236	0.60000002	
25/03/2015	13.99999984	0.12999999	1.39999999
1.90014983	0.18168065	0.60000003	
26/03/2015	15.12251032	0.13628209	1.57281303
1.93823956	0.18220535	0.60000002	
27/03/2015	13.99999999	0.13000000	1.39999998
1.90924923	0.18180600	0.60000002	
28/03/2015	13.99999986	0.12999999	1.39999998
1.94626679	0.18231593	0.60000002	
29/03/2015	14.00000001	0.12999999	1.39999997
1.99498583	0.18298706	0.60000002	
30/03/2015	13.99999999	0.12999999	1.39999998
2.04122764	0.18362407	0.60000003	
31/03/2015	14.00000004	0.12999999	1.39999997
2.08285454	0.18419750	0.60000002	

1/04/2015	14.00045483	0.13000213	1.41248200
2.09091312	0.18430851	0.60000002	
2/04/2015	14.07542388	0.13019468	1.48001032
2.02604379	0.18341490	0.60000002	
3/04/2015	15.02761027	0.13187838	1.48944541
1.93001513	0.18209206	0.60000002	
4/04/2015	26.48579508	0.15621685	1.64318271
1.82098322	0.18059009	0.60000002	
5/04/2015	13.99999995	0.13000000	1.39999998
1.75760683	0.17971705	0.60000002	
6/04/2015	13.99999993	0.13000000	1.39999996
1.72054308	0.17920647	0.60000002	
7/04/2015	14.00000007	0.12999999	1.39999998
1.80716957	0.18039980	0.60000002	
8/04/2015	13.99999996	0.12999999	1.39999998
1.89086369	0.18155273	0.60000003	
9/04/2015	13.99999988	0.13000000	1.39999998
1.96851543	0.18262242	0.60000002	
10/04/2015	14.00000014	0.13000000	1.39999997
2.03848588	0.18358630	0.60000003	
11/04/2015	14.00000012	0.13000000	1.39999999
2.10067074	0.18444293	0.60000003	
12/04/2015	14.00000006	0.12999999	1.39999998
2.15561579	0.18519982	0.60000003	
13/04/2015	14.00000008	0.13000000	1.39999996
2.20412742	0.18586809	0.60000002	
14/04/2015	14.00000010	0.12999999	1.39999997
2.24709123	0.18645994	0.60000002	
15/04/2015	14.00000000	0.12999999	1.40000000
2.28537732	0.18698735	0.60000003	
16/04/2015	13.99999997	0.13000000	1.39999999
2.31979488	0.18746147	0.60000002	
17/04/2015	14.00000000	0.12999999	1.39999998
2.35106901	0.18789229	0.60000002	
18/04/2015	13.99999999	0.12999999	1.39999998
2.37983821	0.18828860	0.60000002	
19/04/2015	14.00687449	0.13004804	1.44169895
2.39598409	0.18851102	0.60000002	
20/04/2015	14.22179731	0.13045049	1.48671639
2.25080258	0.18651107	0.60000002	
21/04/2015	14.00000005	0.13000000	1.39999998
2.12481834	0.18477557	0.60000002	
22/04/2015	13.99999986	0.12999999	1.39999998
2.10307286	0.18447602	0.60000002	

23/04/2015	13.99999993	0.13000000	1.39999999
2.13523112	0.18491901	0.60000002	
24/04/2015	13.99999999	0.12999999	1.39999999
2.17620728	0.18548348	0.60000003	
25/04/2015	13.99999995	0.12999999	1.39999998
2.22011571	0.18608834	0.60000002	
26/04/2015	14.00000004	0.12999999	1.39999997
2.26447820	0.18669946	0.60000002	
27/04/2015	14.00000005	0.12999999	1.39999997
2.30815248	0.18730109	0.60000002	
28/04/2015	13.99999998	0.12999999	1.39999997
2.35064906	0.18788650	0.60000002	
29/04/2015	14.00000007	0.13000000	1.39999997
2.39182604	0.18845374	0.60000002	
30/04/2015	15.42383676	0.13449370	1.56029677
2.35304323	0.18791949	0.60000002	
1/05/2015	78.37529723	0.21056436	1.75970680
50.37241309	0.18369271	1.62689556	
2/05/2015	14.94051401	0.13172145	1.55875802
3.15284655	0.18186213	0.64893735	
3/05/2015	14.00000660	0.13000009	1.41143257
1.89921454	0.18166776	0.60000002	
4/05/2015	14.00000004	0.13000000	1.40203143
1.83964913	0.18084722	0.60000003	
5/05/2015	13.99999986	0.13000000	1.39999997
1.88860557	0.18152162	0.60000003	
6/05/2015	14.00000006	0.12999999	1.39999998
1.96360187	0.18255473	0.60000002	
7/05/2015	13.99999990	0.12999999	1.39999998
2.04036119	0.18361213	0.60000002	
8/05/2015	13.99999994	0.12999999	1.39999998
2.11499635	0.18464027	0.60000002	
9/05/2015	14.00000003	0.12999999	1.39999998
2.18611779	0.18562000	0.60000002	
10/05/2015	14.00000008	0.13000000	1.39999998
2.25335117	0.18654618	0.60000002	
11/05/2015	13.99999996	0.12999999	1.39999997
2.31680475	0.18742028	0.60000002	
12/05/2015	13.99999995	0.12999999	1.39999998
2.37682450	0.18824709	0.60000002	
13/05/2015	13.99999996	0.13000000	1.39999999
2.43386705	0.18903288	0.60000002	
14/05/2015	14.00000001	0.12999999	1.39999999
2.48843091	0.18978452	0.60000002	

15/05/2015	13.99999993	0.13000000	1.39999998
2.54101511	0.19050889	0.60000003	
16/05/2015	14.00000010	0.12999999	1.39999997
2.59209771	0.19121258	0.60000002	
17/05/2015	14.00000011	0.12999999	1.39999997
2.64212272	0.19190170	0.60000002	
18/05/2015	13.99999994	0.13000000	1.39999999
2.69149894	0.19258189	0.60000002	
19/05/2015	14.00000013	0.12999999	1.39999998
2.74059502	0.19325821	0.60000003	
20/05/2015	14.00000002	0.13000000	1.39999999
2.78974385	0.19393526	0.60000002	
21/05/2015	14.07073546	0.13032623	1.48481680
2.78630069	0.19388783	0.60000002	
22/05/2015	14.01113270	0.13004450	1.43951719
2.64946167	0.19200280	0.60000002	
23/05/2015	13.99999993	0.12999999	1.39999998
2.41097030	0.18871746	0.60000002	

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	14.00000012	0.13000000	1.40182891	3.90278022	0.49226790	4.44828269
14/12/2014	13.99999999	0.13000000	1.40191815	3.10932456	0.48133764	0.90713743
15/12/2014	14.00000001	0.13000000	1.40130294	2.62092575	0.47460970	0.80000002
16/12/2014	14.00000024	0.12999999	1.40136477	2.30983624	0.47032428	0.80000002
17/12/2014	14.00000017	0.13000000	1.40123394	2.09739439	0.46739779	0.80000000
18/12/2014	19.36585807	0.13547830	1.59210877	1.92103396	0.46496833	0.80000002
19/12/2014	14.10442133	0.13084459	1.44958234	1.83135031	0.46373290	0.80000001
20/12/2014	13.99999959	0.12999999	1.40057621	1.74963683	0.46260725	0.80000002
21/12/2014	14.00000026	0.13000000	1.40051138	1.68131107	0.46166603	0.80000000
22/12/2014	14.00000001	0.13000000	1.40037566	1.63985113	0.46109490	0.80000000
23/12/2014	13.99999954	0.12999999	1.40031082	1.60906803	0.46067084	0.80000002
24/12/2014	67.14879034	0.25732430	1.72970625	1.58061324	0.46027887	0.80000001
25/12/2014	76.56218246	0.18809905	1.72413620	7.89489418	0.40863772	0.93403646
26/12/2014	15.14952428	0.13241421	1.53508430	3.53870074	0.43920132	0.85445971
27/12/2014	14.99268168	0.13336935	1.52255820	1.52419549	0.45950168	0.80000001
28/12/2014	17.90425477	0.14098019	1.60266841	1.52148994	0.45946441	0.80000001
29/12/2014	14.44710161	0.13171384	1.48203975	1.52247518	0.45947798	0.80000001
30/12/2014	14.00000023	0.13000000	1.40006156	1.50965918	0.45930144	0.80000002
31/12/2014	14.00000002	0.13000000	1.40005194	1.51320979	0.45935035	0.80000001
1/01/2015	14.00000001	0.12999999	1.40004757	1.52155866	0.45946536	0.80000001
2/01/2015	14.00000019	0.12999999	1.40004399	1.52947714	0.45957444	0.80000000

3/01/2015	14.00000702	0.13000002	1.40182638
1.53578953	0.45966139	0.80000002	
4/01/2015	13.99999996	0.13000000	1.40002484
1.54188881	0.45974542	0.80000002	
5/01/2015	66.11784916	0.18080544	1.68993104
1.54576343	0.45979879	0.80000001	
6/01/2015	13.99999999	0.13000000	1.40002216
1.53112934	0.45959720	0.80000001	
7/01/2015	14.00000008	0.13000000	1.40001474
1.52741777	0.45954607	0.80000001	
8/01/2015	13.99999999	0.13000000	1.40001329
1.54227005	0.45975067	0.80000001	
9/01/2015	13.99999998	0.13000000	1.40000869
1.55541032	0.45993168	0.80000001	
10/01/2015	13.99999990	0.13000000	1.40000672
1.56722400	0.46009442	0.80000002	
11/01/2015	14.00000002	0.13000000	1.40000657
1.57799510	0.46024280	0.80000002	
12/01/2015	14.00000010	0.13000000	1.40000499
1.58794968	0.46037993	0.80000001	
13/01/2015	14.00000012	0.13000000	1.40000424
1.59726740	0.46050828	0.80000001	
14/01/2015	17.74385625	0.13554351	1.58230296
1.59746968	0.46051107	0.80000001	
15/01/2015	13.99999999	0.13000000	1.40000289
1.57972240	0.46026659	0.80000002	
16/01/2015	13.99999994	0.13000000	1.40000218
1.58780581	0.46037795	0.80000001	
17/01/2015	13.99999987	0.13000000	1.40000159
1.60300529	0.46058733	0.80000002	
18/01/2015	13.99999999	0.13000000	1.40000157
1.61652584	0.46077358	0.80000002	
19/01/2015	14.00000012	0.13000000	1.40000147
1.62871843	0.46094154	0.80000001	
20/01/2015	14.00000005	0.13000000	1.40000096
1.63986399	0.46109507	0.80000001	
21/01/2015	13.99999991	0.12999999	1.40000079
1.65018627	0.46123727	0.80000001	
22/01/2015	14.00042976	0.13001542	1.41164031
1.65851181	0.46135196	0.80000001	
23/01/2015	21.07156868	0.14288403	1.63238409
1.62884377	0.46094326	0.80000001	
24/01/2015	14.00000010	0.13000000	1.40000047
1.59462176	0.46047184	0.80000001	

25/01/2015	13.99999991	0.13000000	1.40000035
1.58182782	0.46029560	0.80000001	
26/01/2015	14.00000000	0.13000000	1.40000024
1.61495169	0.46075189	0.80000002	
27/01/2015	13.99999993	0.13000000	1.40000024
1.63947119	0.46108966	0.80000002	
28/01/2015	14.00000008	0.13000000	1.40000018
1.66049457	0.46137927	0.80000002	
29/01/2015	13.99999983	0.12999999	1.40000013
1.67872433	0.46163040	0.80000001	
30/01/2015	14.00000015	0.13000000	1.40000009
1.69472817	0.46185086	0.80000001	
31/01/2015	14.00000005	0.12999999	1.40000008
1.70896366	0.46204696	0.80000002	
1/02/2015	14.00000006	0.13000000	1.40000004
1.72182642	0.46222415	0.80000001	
2/02/2015	14.00000010	0.12999999	1.40000001
1.73361734	0.46238657	0.80000001	
3/02/2015	13.99999990	0.12999999	1.40000000
1.74452421	0.46253682	0.80000001	
4/02/2015	13.99999989	0.13000000	1.40000000
1.75473663	0.46267750	0.80000001	
5/02/2015	13.99999995	0.12999999	1.39999999
1.76440240	0.46281065	0.80000001	
6/02/2015	13.99999994	0.13000000	1.39999998
1.77364158	0.46293793	0.80000001	
7/02/2015	14.00000007	0.13000000	1.39999998
1.78254743	0.46306061	0.80000001	
8/02/2015	13.99999998	0.12999999	1.39999997
1.79119447	0.46317973	0.80000002	
9/02/2015	14.00000009	0.12999999	1.39999999
1.79964169	0.46329609	0.80000002	
10/02/2015	13.99999998	0.12999999	1.39999996
1.80793601	0.46341035	0.80000001	
11/02/2015	13.99999991	0.13000000	1.39999996
1.81611331	0.46352300	0.80000002	
12/02/2015	13.99999989	0.13000000	1.39999999
1.82420165	0.46363442	0.80000002	
13/02/2015	14.00000009	0.13000000	1.39999998
1.83222646	0.46374496	0.80000002	
14/02/2015	13.99999986	0.13000000	1.39999999
1.84020452	0.46385487	0.80000001	
15/02/2015	14.00000009	0.13000000	1.39999998
1.84815206	0.46396435	0.80000001	

16/02/2015	14.00000002	0.13000000	1.39999999
1.85607969	0.46407355	0.80000001	
17/02/2015	13.99999989	0.12999999	1.39999997
1.86399664	0.46418262	0.80000001	
18/02/2015	14.03672397	0.13045528	1.47848827
1.87277725	0.46430357	0.80000001	
19/02/2015	14.09712893	0.13049069	1.48172489
1.84810924	0.46396376	0.80000001	
20/02/2015	26.45403862	0.15981218	1.64224359
1.77639789	0.46297590	0.80000001	
21/02/2015	14.76826677	0.13066901	1.48176171
1.70961446	0.46205592	0.80000001	
22/02/2015	13.99999999	0.13000000	1.39999998
1.66889863	0.46149504	0.80000001	
23/02/2015	13.99999995	0.12999999	1.39999999
1.71973552	0.46219534	0.80000002	
24/02/2015	13.99999987	0.12999999	1.39999999
1.76657441	0.46284057	0.80000002	
25/02/2015	13.99999987	0.13000000	1.39999999
1.80577093	0.46338053	0.80000002	
26/02/2015	13.99999997	0.13000000	1.39999998
1.83878891	0.46383537	0.80000002	
27/02/2015	25.12033336	0.17037375	1.65286790
1.81548475	0.46351434	0.80000002	
28/02/2015	13.99999998	0.13000000	1.39999998
1.76158881	0.46277189	0.80000001	
1/03/2015	13.99999990	0.12999999	1.39999997
1.79540034	0.46323767	0.80000001	
2/03/2015	13.99999989	0.12999999	1.39999997
1.83661352	0.46380540	0.80000001	
3/03/2015	13.99999996	0.13000000	1.39999997
1.87136686	0.46428415	0.80000001	
4/03/2015	13.99999996	0.13000000	1.39999999
1.90081866	0.46468986	0.80000001	
5/03/2015	13.99999994	0.13000000	1.39999998
1.92598849	0.46503658	0.80000001	
6/03/2015	14.00000001	0.13000000	1.39999998
1.94772391	0.46533600	0.80000001	
7/03/2015	14.00000009	0.12999999	1.39999997
1.96671633	0.46559763	0.80000001	
8/03/2015	14.00000001	0.13000000	1.39999999
1.98352631	0.46582920	0.80000002	
9/03/2015	13.99999995	0.12999999	1.39999999
1.99860818	0.46603696	0.80000002	

10/03/2015	14.00000012	0.13000000	1.39999998
2.01232406	0.46622590	0.80000002	
11/03/2015	14.00000012	0.12999999	1.39999997
2.02496626	0.46640006	0.80000001	
12/03/2015	14.00000016	0.12999999	1.39999998
2.03676545	0.46656259	0.80000001	
13/03/2015	14.00000010	0.13000000	1.39999999
2.04790986	0.46671611	0.80000001	
14/03/2015	13.99999980	0.12999999	1.39999997
2.05854965	0.46686268	0.80000001	
15/03/2015	14.00000002	0.12999999	1.39999999
2.06880081	0.46700390	0.80000001	
16/03/2015	13.99999995	0.13000000	1.39999998
2.07875916	0.46714108	0.80000001	
17/03/2015	14.00000007	0.12999999	1.39999999
2.08850011	0.46727527	0.80000001	
18/03/2015	63.56114568	0.17392397	1.70714474
2.04816972	0.46671969	0.80000001	
19/03/2015	13.99999991	0.13000000	1.42195915
1.93487312	0.46515898	0.80000001	
20/03/2015	13.99999989	0.12999999	1.39999997
1.86820942	0.46424065	0.80000002	
21/03/2015	27.78336885	0.16966046	1.69433389
1.91018029	0.46481882	0.80000001	
22/03/2015	14.00000002	0.12999999	1.39999999
1.84619957	0.46393745	0.80000001	
23/03/2015	14.00000007	0.13000000	1.39999998
1.78145183	0.46304552	0.80000001	
24/03/2015	13.99999996	0.13000000	1.39999999
1.83494049	0.46378235	0.80000001	
25/03/2015	13.99999984	0.12999999	1.39999999
1.90014983	0.46468064	0.80000002	
26/03/2015	15.12251032	0.13628209	1.57281303
1.93823956	0.46520535	0.80000001	
27/03/2015	13.99999999	0.13000000	1.39999998
1.90924923	0.46480599	0.80000002	
28/03/2015	13.99999986	0.12999999	1.39999998
1.94626679	0.46531593	0.80000002	
29/03/2015	14.00000001	0.12999999	1.39999997
1.99498583	0.46598706	0.80000001	
30/03/2015	13.99999999	0.12999999	1.39999998
2.04122764	0.46662406	0.80000002	
31/03/2015	14.00000004	0.12999999	1.39999997
2.08285454	0.46719750	0.80000002	

1/04/2015	14.00045483	0.13000213	1.41248200
2.09091312	0.46730851	0.80000001	
2/04/2015	14.07542388	0.13019468	1.48001032
2.02604379	0.46641490	0.80000001	
3/04/2015	15.02761027	0.13187838	1.48944541
1.93001513	0.46509206	0.80000001	
4/04/2015	26.48579508	0.15621685	1.64318271
1.82098322	0.46359008	0.80000001	
5/04/2015	13.99999995	0.13000000	1.39999998
1.75760683	0.46271704	0.80000001	
6/04/2015	13.99999993	0.13000000	1.39999996
1.72054308	0.46220647	0.80000001	
7/04/2015	14.00000007	0.12999999	1.39999998
1.80716957	0.46339979	0.80000001	
8/04/2015	13.99999996	0.12999999	1.39999998
1.89086369	0.46455272	0.80000002	
9/04/2015	13.99999988	0.13000000	1.39999998
1.96851543	0.46562242	0.80000001	
10/04/2015	14.00000014	0.13000000	1.39999997
2.03848588	0.46658629	0.80000001	
11/04/2015	14.00000012	0.13000000	1.39999999
2.10067074	0.46744292	0.80000001	
12/04/2015	14.00000006	0.12999999	1.39999998
2.15561579	0.46819982	0.80000002	
13/04/2015	14.00000008	0.13000000	1.39999996
2.20412742	0.46886809	0.80000001	
14/04/2015	14.00000010	0.12999999	1.39999997
2.24709123	0.46945994	0.80000001	
15/04/2015	14.00000000	0.12999999	1.40000000
2.28537732	0.46998735	0.80000001	
16/04/2015	13.99999997	0.13000000	1.39999999
2.31979488	0.47046147	0.80000002	
17/04/2015	14.00000000	0.12999999	1.39999998
2.35106901	0.47089229	0.80000002	
18/04/2015	13.99999999	0.12999999	1.39999998
2.37983821	0.47128860	0.80000001	
19/04/2015	14.00687449	0.13004804	1.44169895
2.39598409	0.47151102	0.80000002	
20/04/2015	14.22179731	0.13045049	1.48671639
2.25080258	0.46951106	0.80000002	
21/04/2015	14.00000005	0.13000000	1.39999998
2.12481834	0.46777557	0.80000001	
22/04/2015	13.99999986	0.12999999	1.39999998
2.10307286	0.46747601	0.80000001	

23/04/2015	13.99999993	0.13000000	1.39999999
2.13523112	0.46791901	0.80000001	
24/04/2015	13.99999999	0.12999999	1.39999999
2.17620728	0.46848348	0.80000002	
25/04/2015	13.99999995	0.12999999	1.39999998
2.22011571	0.46908834	0.80000001	
26/04/2015	14.00000004	0.12999999	1.39999997
2.26447820	0.46969945	0.80000001	
27/04/2015	14.00000005	0.12999999	1.39999997
2.30815248	0.47030109	0.80000001	
28/04/2015	13.99999998	0.12999999	1.39999997
2.35064906	0.47088650	0.80000001	
29/04/2015	14.00000007	0.13000000	1.39999997
2.39182604	0.47145373	0.80000001	
30/04/2015	15.42383676	0.13449370	1.56029677
2.35304323	0.47091948	0.80000001	
1/05/2015	78.37529723	0.21056436	1.75970680
50.37241309	0.21147149	1.64652721	
2/05/2015	14.94051401	0.13172145	1.55875802
3.15284655	0.45268714	0.84033311	
3/05/2015	14.00000660	0.13000009	1.41143257
1.89921454	0.46466776	0.80000002	
4/05/2015	14.00000004	0.13000000	1.40203143
1.83964913	0.46384722	0.80000001	
5/05/2015	13.99999986	0.13000000	1.39999997
1.88860557	0.46452162	0.80000002	
6/05/2015	14.00000006	0.12999999	1.39999998
1.96360187	0.46555473	0.80000001	
7/05/2015	13.99999990	0.12999999	1.39999998
2.04036119	0.46661213	0.80000001	
8/05/2015	13.99999994	0.12999999	1.39999998
2.11499635	0.46764027	0.80000001	
9/05/2015	14.00000003	0.12999999	1.39999998
2.18611779	0.46862000	0.80000001	
10/05/2015	14.00000008	0.13000000	1.39999998
2.25335117	0.46954617	0.80000001	
11/05/2015	13.99999996	0.12999999	1.39999997
2.31680475	0.47042028	0.80000002	
12/05/2015	13.99999995	0.12999999	1.39999998
2.37682450	0.47124708	0.80000001	
13/05/2015	13.99999996	0.13000000	1.39999999
2.43386705	0.47203287	0.80000002	
14/05/2015	14.00000001	0.12999999	1.39999999
2.48843091	0.47278452	0.80000001	

15/05/2015	13.99999993	0.13000000	1.39999998
2.54101511	0.47350889	0.80000002	
16/05/2015	14.00000010	0.12999999	1.39999997
2.59209771	0.47421258	0.80000002	
17/05/2015	14.00000011	0.12999999	1.39999997
2.64212272	0.47490170	0.80000001	
18/05/2015	13.99999994	0.13000000	1.39999999
2.69149894	0.47558188	0.80000002	
19/05/2015	14.00000013	0.12999999	1.39999998
2.74059502	0.47625821	0.80000001	
20/05/2015	14.00000002	0.13000000	1.39999999
2.78974385	0.47693526	0.80000002	
21/05/2015	14.07073546	0.13032623	1.48481680
2.78630069	0.47688782	0.80000001	
22/05/2015	14.01113270	0.13004450	1.43951719
2.64946167	0.47500280	0.80000001	
23/05/2015	13.99999993	0.12999999	1.39999998
2.41097030	0.47171746	0.80000002	

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	14.00000012	0.13000000	1.40182891	3.90278022	0.40626790	2.02820985
14/12/2014	13.99999999	0.13000000	1.40191815	3.10932456	0.39533764	0.80000002
15/12/2014	14.00000001	0.13000000	1.40130294	2.62092575	0.38860970	0.80000002
16/12/2014	14.00000024	0.12999999	1.40136477	2.30983624	0.38432428	0.80000002
17/12/2014	14.00000017	0.13000000	1.40123394	2.09739439	0.38139779	0.80000000
18/12/2014	19.36585807	0.13547830	1.59210877	1.92103396	0.37896833	0.80000002
19/12/2014	14.10442133	0.13084459	1.44958234	1.83135031	0.37773289	0.80000001
20/12/2014	13.99999959	0.12999999	1.40057621	1.74963683	0.37660725	0.80000002
21/12/2014	14.00000026	0.13000000	1.40051138	1.68131107	0.37566603	0.80000000
22/12/2014	14.00000001	0.13000000	1.40037566	1.63985113	0.37509489	0.80000000
23/12/2014	13.99999954	0.12999999	1.40031082	1.60906803	0.37467084	0.80000002
24/12/2014	67.14879034	0.25732430	1.72970625	1.58061324	0.37427886	0.80000001
25/12/2014	76.56218246	0.18809905	1.72413620	7.89489418	0.33699259	0.93403646
26/12/2014	15.14952428	0.13241421	1.53508430	3.53870074	0.35882138	0.85445971
27/12/2014	14.99268168	0.13336935	1.52255820	1.52419549	0.37350168	0.80000001
28/12/2014	17.90425477	0.14098019	1.60266841	1.52148994	0.37346441	0.80000001
29/12/2014	14.44710161	0.13171384	1.48203975	1.52247518	0.37347798	0.80000001
30/12/2014	14.00000023	0.13000000	1.40006156	1.50965918	0.37330143	0.80000002
31/12/2014	14.00000002	0.13000000	1.40005194	1.51320979	0.37335034	0.80000001
1/01/2015	14.00000001	0.12999999	1.40004757	1.52155866	0.37346536	0.80000001
2/01/2015	14.00000019	0.12999999	1.40004399	1.52947714	0.37357444	0.80000000

3/01/2015	14.00000702	0.13000002	1.40182638
1.53578953	0.37366139	0.80000002	
4/01/2015	13.99999996	0.13000000	1.40002484
1.54188881	0.37374541	0.80000002	
5/01/2015	66.11784916	0.18080544	1.68993104
1.54576343	0.37379879	0.80000001	
6/01/2015	13.99999999	0.13000000	1.40002216
1.53112934	0.37359720	0.80000001	
7/01/2015	14.00000008	0.13000000	1.40001474
1.52741777	0.37354607	0.80000001	
8/01/2015	13.99999999	0.13000000	1.40001329
1.54227005	0.37375066	0.80000001	
9/01/2015	13.99999998	0.13000000	1.40000869
1.55541032	0.37393168	0.80000001	
10/01/2015	13.99999990	0.13000000	1.40000672
1.56722400	0.37409442	0.80000002	
11/01/2015	14.00000002	0.13000000	1.40000657
1.57799510	0.37424280	0.80000002	
12/01/2015	14.00000010	0.13000000	1.40000499
1.58794968	0.37437993	0.80000001	
13/01/2015	14.00000012	0.13000000	1.40000424
1.59726740	0.37450828	0.80000001	
14/01/2015	17.74385625	0.13554351	1.58230296
1.59746968	0.37451107	0.80000001	
15/01/2015	13.99999999	0.13000000	1.40000289
1.57972240	0.37426659	0.80000002	
16/01/2015	13.99999994	0.13000000	1.40000218
1.58780581	0.37437794	0.80000001	
17/01/2015	13.99999987	0.13000000	1.40000159
1.60300529	0.37458732	0.80000002	
18/01/2015	13.99999999	0.13000000	1.40000157
1.61652584	0.37477358	0.80000002	
19/01/2015	14.00000012	0.13000000	1.40000147
1.62871843	0.37494154	0.80000001	
20/01/2015	14.00000005	0.13000000	1.40000096
1.63986399	0.37509507	0.80000001	
21/01/2015	13.99999991	0.12999999	1.40000079
1.65018627	0.37523727	0.80000001	
22/01/2015	14.00042976	0.13001542	1.41164031
1.65851181	0.37535195	0.80000001	
23/01/2015	21.07156868	0.14288403	1.63238409
1.62884377	0.37494326	0.80000001	
24/01/2015	14.00000010	0.13000000	1.40000047
1.59462176	0.37447184	0.80000001	

25/01/2015	13.99999991	0.13000000	1.40000035
1.58182782	0.37429559	0.80000001	
26/01/2015	14.00000000	0.13000000	1.40000024
1.61495169	0.37475189	0.80000002	
27/01/2015	13.99999993	0.13000000	1.40000024
1.63947119	0.37508966	0.80000002	
28/01/2015	14.00000008	0.13000000	1.40000018
1.66049457	0.37537927	0.80000002	
29/01/2015	13.99999983	0.12999999	1.40000013
1.67872433	0.37563039	0.80000001	
30/01/2015	14.00000015	0.13000000	1.40000009
1.69472817	0.37585085	0.80000001	
31/01/2015	14.00000005	0.12999999	1.40000008
1.70896366	0.37604696	0.80000002	
1/02/2015	14.00000006	0.13000000	1.40000004
1.72182642	0.37622414	0.80000001	
2/02/2015	14.00000010	0.12999999	1.40000001
1.73361734	0.37638657	0.80000001	
3/02/2015	13.99999990	0.12999999	1.40000000
1.74452421	0.37653682	0.80000001	
4/02/2015	13.99999989	0.13000000	1.40000000
1.75473663	0.37667750	0.80000001	
5/02/2015	13.99999995	0.12999999	1.39999999
1.76440240	0.37681065	0.80000001	
6/02/2015	13.99999994	0.13000000	1.39999998
1.77364158	0.37693793	0.80000001	
7/02/2015	14.00000007	0.13000000	1.39999998
1.78254743	0.37706061	0.80000001	
8/02/2015	13.99999998	0.12999999	1.39999997
1.79119447	0.37717973	0.80000002	
9/02/2015	14.00000009	0.12999999	1.39999999
1.79964169	0.37729609	0.80000002	
10/02/2015	13.99999998	0.12999999	1.39999996
1.80793601	0.37741035	0.80000001	
11/02/2015	13.99999991	0.13000000	1.39999996
1.81611331	0.37752300	0.80000002	
12/02/2015	13.99999989	0.13000000	1.39999999
1.82420165	0.37763442	0.80000002	
13/02/2015	14.00000009	0.13000000	1.39999998
1.83222646	0.37774496	0.80000002	
14/02/2015	13.99999986	0.13000000	1.39999999
1.84020452	0.37785486	0.80000001	
15/02/2015	14.00000009	0.13000000	1.39999998
1.84815206	0.37796435	0.80000001	

16/02/2015	14.00000002	0.13000000	1.39999999
1.85607969	0.37807355	0.80000001	
17/02/2015	13.99999989	0.12999999	1.39999997
1.86399664	0.37818261	0.80000001	
18/02/2015	14.03672397	0.13045528	1.47848827
1.87277725	0.37830357	0.80000001	
19/02/2015	14.09712893	0.13049069	1.48172489
1.84810924	0.37796376	0.80000001	
20/02/2015	26.45403862	0.15981218	1.64224359
1.77639789	0.37697590	0.80000001	
21/02/2015	14.76826677	0.13066901	1.48176171
1.70961446	0.37605592	0.80000001	
22/02/2015	13.99999999	0.13000000	1.39999998
1.66889863	0.37549504	0.80000001	
23/02/2015	13.99999995	0.12999999	1.39999999
1.71973552	0.37619534	0.80000002	
24/02/2015	13.99999987	0.12999999	1.39999999
1.76657441	0.37684057	0.80000002	
25/02/2015	13.99999987	0.13000000	1.39999999
1.80577093	0.37738052	0.80000002	
26/02/2015	13.99999997	0.13000000	1.39999998
1.83878891	0.37783536	0.80000002	
27/02/2015	25.12033336	0.17037375	1.65286790
1.81548475	0.37751434	0.80000002	
28/02/2015	13.99999998	0.13000000	1.39999998
1.76158881	0.37677189	0.80000001	
1/03/2015	13.99999990	0.12999999	1.39999997
1.79540034	0.37723766	0.80000001	
2/03/2015	13.99999989	0.12999999	1.39999997
1.83661352	0.37780540	0.80000001	
3/03/2015	13.99999996	0.13000000	1.39999997
1.87136686	0.37828414	0.80000001	
4/03/2015	13.99999996	0.13000000	1.39999999
1.90081866	0.37868986	0.80000001	
5/03/2015	13.99999994	0.13000000	1.39999998
1.92598849	0.37903658	0.80000001	
6/03/2015	14.00000001	0.13000000	1.39999998
1.94772391	0.37933600	0.80000001	
7/03/2015	14.00000009	0.12999999	1.39999997
1.96671633	0.37959763	0.80000001	
8/03/2015	14.00000001	0.13000000	1.39999999
1.98352631	0.37982920	0.80000002	
9/03/2015	13.99999995	0.12999999	1.39999999
1.99860818	0.38003695	0.80000002	

10/03/2015	14.00000012	0.13000000	1.39999998
2.01232406	0.38022590	0.80000002	
11/03/2015	14.00000012	0.12999999	1.39999997
2.02496626	0.38040005	0.80000001	
12/03/2015	14.00000016	0.12999999	1.39999998
2.03676545	0.38056259	0.80000001	
13/03/2015	14.00000010	0.13000000	1.39999999
2.04790986	0.38071611	0.80000001	
14/03/2015	13.99999980	0.12999999	1.39999997
2.05854965	0.38086268	0.80000001	
15/03/2015	14.00000002	0.12999999	1.39999999
2.06880081	0.38100390	0.80000001	
16/03/2015	13.99999995	0.13000000	1.39999998
2.07875916	0.38114108	0.80000001	
17/03/2015	14.00000007	0.12999999	1.39999999
2.08850011	0.38127526	0.80000001	
18/03/2015	63.56114568	0.17392397	1.70714474
2.04816972	0.38071969	0.80000001	
19/03/2015	13.99999991	0.13000000	1.42195915
1.93487312	0.37915897	0.80000001	
20/03/2015	13.99999989	0.12999999	1.39999997
1.86820942	0.37824065	0.80000002	
21/03/2015	27.78336885	0.16966046	1.69433389
1.91018029	0.37881882	0.80000001	
22/03/2015	14.00000002	0.12999999	1.39999999
1.84619957	0.37793745	0.80000001	
23/03/2015	14.00000007	0.13000000	1.39999998
1.78145183	0.37704551	0.80000001	
24/03/2015	13.99999996	0.13000000	1.39999999
1.83494049	0.37778235	0.80000001	
25/03/2015	13.99999984	0.12999999	1.39999999
1.90014983	0.37868064	0.80000002	
26/03/2015	15.12251032	0.13628209	1.57281303
1.93823956	0.37920535	0.80000001	
27/03/2015	13.99999999	0.13000000	1.39999998
1.90924923	0.37880599	0.80000002	
28/03/2015	13.99999986	0.12999999	1.39999998
1.94626679	0.37931593	0.80000002	
29/03/2015	14.00000001	0.12999999	1.39999997
1.99498583	0.37998706	0.80000001	
30/03/2015	13.99999999	0.12999999	1.39999998
2.04122764	0.38062406	0.80000002	
31/03/2015	14.00000004	0.12999999	1.39999997
2.08285454	0.38119749	0.80000002	

1/04/2015	14.00045483	0.13000213	1.41248200
2.09091312	0.38130851	0.80000001	
2/04/2015	14.07542388	0.13019468	1.48001032
2.02604379	0.38041490	0.80000001	
3/04/2015	15.02761027	0.13187838	1.48944541
1.93001513	0.37909205	0.80000001	
4/04/2015	26.48579508	0.15621685	1.64318271
1.82098322	0.37759008	0.80000001	
5/04/2015	13.99999995	0.13000000	1.39999998
1.75760683	0.37671704	0.80000001	
6/04/2015	13.99999993	0.13000000	1.39999996
1.72054308	0.37620647	0.80000001	
7/04/2015	14.00000007	0.12999999	1.39999998
1.80716957	0.37739979	0.80000001	
8/04/2015	13.99999996	0.12999999	1.39999998
1.89086369	0.37855272	0.80000002	
9/04/2015	13.99999988	0.13000000	1.39999998
1.96851543	0.37962241	0.80000001	
10/04/2015	14.00000014	0.13000000	1.39999997
2.03848588	0.38058629	0.80000001	
11/04/2015	14.00000012	0.13000000	1.39999999
2.10067074	0.38144292	0.80000001	
12/04/2015	14.00000006	0.12999999	1.39999998
2.15561579	0.38219981	0.80000002	
13/04/2015	14.00000008	0.13000000	1.39999996
2.20412742	0.38286809	0.80000001	
14/04/2015	14.00000010	0.12999999	1.39999997
2.24709123	0.38345994	0.80000001	
15/04/2015	14.00000000	0.12999999	1.40000000
2.28537732	0.38398735	0.80000001	
16/04/2015	13.99999997	0.13000000	1.39999999
2.31979488	0.38446147	0.80000002	
17/04/2015	14.00000000	0.12999999	1.39999998
2.35106901	0.38489228	0.80000002	
18/04/2015	13.99999999	0.12999999	1.39999998
2.37983821	0.38528859	0.80000001	
19/04/2015	14.00687449	0.13004804	1.44169895
2.39598409	0.38551101	0.80000002	
20/04/2015	14.22179731	0.13045049	1.48671639
2.25080258	0.38351106	0.80000002	
21/04/2015	14.00000005	0.13000000	1.39999998
2.12481834	0.38177557	0.80000001	
22/04/2015	13.99999986	0.12999999	1.39999998
2.10307286	0.38147601	0.80000001	

23/04/2015	13.99999993	0.13000000	1.39999999
2.13523112	0.38191900	0.80000001	
24/04/2015	13.99999999	0.12999999	1.39999999
2.17620728	0.38248347	0.80000002	
25/04/2015	13.99999995	0.12999999	1.39999998
2.22011571	0.38308833	0.80000001	
26/04/2015	14.00000004	0.12999999	1.39999997
2.26447820	0.38369945	0.80000001	
27/04/2015	14.00000005	0.12999999	1.39999997
2.30815248	0.38430109	0.80000001	
28/04/2015	13.99999998	0.12999999	1.39999997
2.35064906	0.38488650	0.80000001	
29/04/2015	14.00000007	0.13000000	1.39999997
2.39182604	0.38545373	0.80000001	
30/04/2015	15.42383676	0.13449370	1.56029677
2.35304323	0.38491948	0.80000001	
1/05/2015	78.37529723	0.21056436	1.75970680
50.37241309	0.20302988	1.64652721	
2/05/2015	14.94051401	0.13172145	1.55875802
3.15284655	0.37038696	0.84033311	
3/05/2015	14.00000660	0.13000009	1.41143257
1.89921454	0.37866776	0.80000002	
4/05/2015	14.00000004	0.13000000	1.40203143
1.83964913	0.37784721	0.80000001	
5/05/2015	13.99999986	0.13000000	1.39999997
1.88860557	0.37852161	0.80000002	
6/05/2015	14.00000006	0.12999999	1.39999998
1.96360187	0.37955473	0.80000001	
7/05/2015	13.99999990	0.12999999	1.39999998
2.04036119	0.38061212	0.80000001	
8/05/2015	13.99999994	0.12999999	1.39999998
2.11499635	0.38164026	0.80000001	
9/05/2015	14.00000003	0.12999999	1.39999998
2.18611779	0.38262000	0.80000001	
10/05/2015	14.00000008	0.13000000	1.39999998
2.25335117	0.38354617	0.80000001	
11/05/2015	13.99999996	0.12999999	1.39999997
2.31680475	0.38442027	0.80000002	
12/05/2015	13.99999995	0.12999999	1.39999998
2.37682450	0.38524708	0.80000001	
13/05/2015	13.99999996	0.13000000	1.39999999
2.43386705	0.38603287	0.80000002	
14/05/2015	14.00000001	0.12999999	1.39999999
2.48843091	0.38678451	0.80000001	

15/05/2015	13.99999993	0.13000000	1.39999998
2.54101511	0.38750889	0.80000002	
16/05/2015	14.00000010	0.12999999	1.39999997
2.59209771	0.38821257	0.80000002	
17/05/2015	14.00000011	0.12999999	1.39999997
2.64212272	0.38890170	0.80000001	
18/05/2015	13.99999994	0.13000000	1.39999999
2.69149894	0.38958188	0.80000002	
19/05/2015	14.00000013	0.12999999	1.39999998
2.74059502	0.39025820	0.80000001	
20/05/2015	14.00000002	0.13000000	1.39999999
2.78974385	0.39093525	0.80000002	
21/05/2015	14.07073546	0.13032623	1.48481680
2.78630069	0.39088782	0.80000001	
22/05/2015	14.01113270	0.13004450	1.43951719
2.64946167	0.38900279	0.80000001	
23/05/2015	13.99999993	0.12999999	1.39999998
2.41097030	0.38571745	0.80000002	

Date	Inflow [TSS] (mg/L)	Inflow [TP] (mg/L)	Inflow [TN] (mg/L)	Outflow [TSS] (mg/L)	Outflow [TP] (mg/L)	Outflow [TN] (mg/L)
13/12/2014	14.00000012	0.13000000	1.40182891	3.90278022	0.44926790	3.18828282
14/12/2014	13.99999999	0.13000000	1.40191815	3.10932456	0.43833764	0.80016180
15/12/2014	14.00000001	0.13000000	1.40130294	2.62092575	0.43160970	0.80000002
16/12/2014	14.00000024	0.12999999	1.40136477	2.30983624	0.42732428	0.80000002
17/12/2014	14.00000017	0.13000000	1.40123394	2.09739439	0.42439779	0.80000000
18/12/2014	19.36585807	0.13547830	1.59210877	1.92103396	0.42196833	0.80000002
19/12/2014	14.10442133	0.13084459	1.44958234	1.83135031	0.42073289	0.80000001
20/12/2014	13.99999959	0.12999999	1.40057621	1.74963683	0.41960725	0.80000002
21/12/2014	14.00000026	0.13000000	1.40051138	1.68131107	0.41866603	0.80000000
22/12/2014	14.00000001	0.13000000	1.40037566	1.63985113	0.41809490	0.80000000
23/12/2014	13.99999954	0.12999999	1.40031082	1.60906803	0.41767084	0.80000002
24/12/2014	67.14879034	0.25732430	1.72970625	1.58061324	0.41727886	0.80000001
25/12/2014	76.56218246	0.18809905	1.72413620	7.89489418	0.37281515	0.93403646
26/12/2014	15.14952428	0.13241421	1.53508430	3.53870074	0.39901135	0.85445971
27/12/2014	14.99268168	0.13336935	1.52255820	1.52419549	0.41650168	0.80000001
28/12/2014	17.90425477	0.14098019	1.60266841	1.52148994	0.41646441	0.80000001
29/12/2014	14.44710161	0.13171384	1.48203975	1.52247518	0.41647798	0.80000001
30/12/2014	14.00000023	0.13000000	1.40006156	1.50965918	0.41630143	0.80000002
31/12/2014	14.00000002	0.13000000	1.40005194	1.51320979	0.41635035	0.80000001
1/01/2015	14.00000001	0.12999999	1.40004757	1.52155866	0.41646536	0.80000001
2/01/2015	14.00000019	0.12999999	1.40004399	1.52947714	0.41657444	0.80000000

3/01/2015	14.00000702	0.13000002	1.40182638
1.53578953	0.41666139	0.80000002	
4/01/2015	13.99999996	0.13000000	1.40002484
1.54188881	0.41674541	0.80000002	
5/01/2015	66.11784916	0.18080544	1.68993104
1.54576343	0.41679879	0.80000001	
6/01/2015	13.99999999	0.13000000	1.40002216
1.53112934	0.41659720	0.80000001	
7/01/2015	14.00000008	0.13000000	1.40001474
1.52741777	0.41654607	0.80000001	
8/01/2015	13.99999999	0.13000000	1.40001329
1.54227005	0.41675067	0.80000001	
9/01/2015	13.99999998	0.13000000	1.40000869
1.55541032	0.41693168	0.80000001	
10/01/2015	13.99999990	0.13000000	1.40000672
1.56722400	0.41709442	0.80000002	
11/01/2015	14.00000002	0.13000000	1.40000657
1.57799510	0.41724280	0.80000002	
12/01/2015	14.00000010	0.13000000	1.40000499
1.58794968	0.41737992	0.80000001	
13/01/2015	14.00000012	0.13000000	1.40000424
1.59726740	0.41750828	0.80000001	
14/01/2015	17.74385625	0.13554351	1.58230296
1.59746968	0.41751107	0.80000001	
15/01/2015	13.99999999	0.13000000	1.40000289
1.57972240	0.41726659	0.80000002	
16/01/2015	13.99999994	0.13000000	1.40000218
1.58780581	0.41737794	0.80000001	
17/01/2015	13.99999987	0.13000000	1.40000159
1.60300529	0.41758733	0.80000002	
18/01/2015	13.99999999	0.13000000	1.40000157
1.61652584	0.41777358	0.80000002	
19/01/2015	14.00000012	0.13000000	1.40000147
1.62871843	0.41794154	0.80000001	
20/01/2015	14.00000005	0.13000000	1.40000096
1.63986399	0.41809507	0.80000001	
21/01/2015	13.99999991	0.12999999	1.40000079
1.65018627	0.41823727	0.80000001	
22/01/2015	14.00042976	0.13001542	1.41164031
1.65851181	0.41835196	0.80000001	
23/01/2015	21.07156868	0.14288403	1.63238409
1.62884377	0.41794326	0.80000001	
24/01/2015	14.00000010	0.13000000	1.40000047
1.59462176	0.41747184	0.80000001	

25/01/2015	13.99999991	0.13000000	1.40000035
1.58182782	0.41729559	0.80000001	
26/01/2015	14.00000000	0.13000000	1.40000024
1.61495169	0.41775189	0.80000002	
27/01/2015	13.99999993	0.13000000	1.40000024
1.63947119	0.41808966	0.80000002	
28/01/2015	14.00000008	0.13000000	1.40000018
1.66049457	0.41837927	0.80000002	
29/01/2015	13.99999983	0.12999999	1.40000013
1.67872433	0.41863039	0.80000001	
30/01/2015	14.00000015	0.13000000	1.40000009
1.69472817	0.41885085	0.80000001	
31/01/2015	14.00000005	0.12999999	1.40000008
1.70896366	0.41904696	0.80000002	
1/02/2015	14.00000006	0.13000000	1.40000004
1.72182642	0.41922415	0.80000001	
2/02/2015	14.00000010	0.12999999	1.40000001
1.73361734	0.41938657	0.80000001	
3/02/2015	13.99999990	0.12999999	1.40000000
1.74452421	0.41953682	0.80000001	
4/02/2015	13.99999989	0.13000000	1.40000000
1.75473663	0.41967750	0.80000001	
5/02/2015	13.99999995	0.12999999	1.39999999
1.76440240	0.41981065	0.80000001	
6/02/2015	13.99999994	0.13000000	1.39999998
1.77364158	0.41993793	0.80000001	
7/02/2015	14.00000007	0.13000000	1.39999998
1.78254743	0.42006061	0.80000001	
8/02/2015	13.99999998	0.12999999	1.39999997
1.79119447	0.42017973	0.80000002	
9/02/2015	14.00000009	0.12999999	1.39999999
1.79964169	0.42029609	0.80000002	
10/02/2015	13.99999998	0.12999999	1.39999996
1.80793601	0.42041035	0.80000001	
11/02/2015	13.99999991	0.13000000	1.39999996
1.81611331	0.42052300	0.80000002	
12/02/2015	13.99999989	0.13000000	1.39999999
1.82420165	0.42063442	0.80000002	
13/02/2015	14.00000009	0.13000000	1.39999998
1.83222646	0.42074496	0.80000002	
14/02/2015	13.99999986	0.13000000	1.39999999
1.84020452	0.42085486	0.80000001	
15/02/2015	14.00000009	0.13000000	1.39999998
1.84815206	0.42096435	0.80000001	

16/02/2015	14.00000002	0.13000000	1.39999999
1.85607969	0.42107356	0.80000001	
17/02/2015	13.99999989	0.12999999	1.39999997
1.86399664	0.42118261	0.80000001	
18/02/2015	14.03672397	0.13045528	1.47848827
1.87277725	0.42130357	0.80000001	
19/02/2015	14.09712893	0.13049069	1.48172489
1.84810924	0.42096376	0.80000001	
20/02/2015	26.45403862	0.15981218	1.64224359
1.77639789	0.41997590	0.80000001	
21/02/2015	14.76826677	0.13066901	1.48176171
1.70961446	0.41905592	0.80000001	
22/02/2015	13.99999999	0.13000000	1.39999998
1.66889863	0.41849504	0.80000001	
23/02/2015	13.99999995	0.12999999	1.39999999
1.71973552	0.41919534	0.80000002	
24/02/2015	13.99999987	0.12999999	1.39999999
1.76657441	0.41984057	0.80000002	
25/02/2015	13.99999987	0.13000000	1.39999999
1.80577093	0.42038053	0.80000002	
26/02/2015	13.99999997	0.13000000	1.39999998
1.83878891	0.42083536	0.80000002	
27/02/2015	25.12033336	0.17037375	1.65286790
1.81548475	0.42051434	0.80000002	
28/02/2015	13.99999998	0.13000000	1.39999998
1.76158881	0.41977189	0.80000001	
1/03/2015	13.99999990	0.12999999	1.39999997
1.79540034	0.42023766	0.80000001	
2/03/2015	13.99999989	0.12999999	1.39999997
1.83661352	0.42080540	0.80000001	
3/03/2015	13.99999996	0.13000000	1.39999997
1.87136686	0.42128414	0.80000001	
4/03/2015	13.99999996	0.13000000	1.39999999
1.90081866	0.42168986	0.80000001	
5/03/2015	13.99999994	0.13000000	1.39999998
1.92598849	0.42203658	0.80000001	
6/03/2015	14.00000001	0.13000000	1.39999998
1.94772391	0.42233600	0.80000001	
7/03/2015	14.00000009	0.12999999	1.39999997
1.96671633	0.42259763	0.80000001	
8/03/2015	14.00000001	0.13000000	1.39999999
1.98352631	0.42282920	0.80000002	
9/03/2015	13.99999995	0.12999999	1.39999999
1.99860818	0.42303696	0.80000002	