University of Southern Queensland

Faculty of Health, Engineering & Sciences

Analysis of Inflow and Infiltration in a Low-Pressure Sewer System

A dissertation submitted by

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Abstract

Inflow and Infiltration (I/I) have a significant impact on the hydraulic capacity of sewer systems. Whilst the impact this has on traditional gravity sewer system has well been researched in previous literature, the quantifiable impacts I/I has on Pressure Sewer System's (PSS) is largely unknown. The aim of this project was to quantify the I/I in an existing PSS within the Eurobodalla local government area, and determine the operational costs associated with the collection, transfer, and treatment of the I/I.

The existing methods for estimating the various components and parameters of sewage flows in PSS vary depending on the guideline used for the design of the PSS. Whilst these guidelines provide a good benchmark for design factors and objectives in greenfield systems, there is little evidence that the guidelines are relevant to retrofit of PSS in backlog sewerage areas.

The methodology for quantifying I/I followed existing methods used from previous literature related to management of I/I in sewerage systems. In this research, several methods which improve the accuracy and reliability of determining Dry Weather Flow (DWF) were implemented through an iterative process, with an improved technique for quantifying hourly and daily DWF recognised. This technique includes derivation of the diurnal flow pattern and an appropriate return to sewer factor for the system, based on analysis of existing flow monitoring data during dry weather periods. Daily water consumption data for the system is also used as a model input for determining the DWF values for a selected period.

Once an accurate and reliable DWF pattern had been established, a customised hydraulic model was developed to quantify the Rainfall Derived Inflow and Infiltration (RDII) that occurred during significant rainfall events. The model was calibrated, validated, and optimised to ensure a good representation of the RDII response to rainfall events was observed and appropriate outputs were quantified using the model.

The comparison of the model outputs with the values from relevant design and management guidelines demonstrated that further investigation into the sources of I/I is warranted, due to the high quantities of I/I flows entering the PSS. The I/I flows that can be expected during and after a rain event are consistent and predictable.

Whilst the increased I/I volumes may result in increased risk of environmental, public health, and social issues occurring, there is only a relatively minor economic impact associated with I/I in the PSS analysed.

The results from the research provide opportunity to develop appropriate design parameters for design and construction of pressure sewer systems in backlog sewerage areas. The key parameters for a PSS which were identified by this research were daily water consumption, and the percentage of water consumption being returned to sewer. These parameters should be included when establishing DWF values as part of analysis of the RDII component of I/I flows.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Billy Alves

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Glossary of Terms and Acronyms

ADWF – Average Dry Weather Flow

AEP – Annual Exceedance Probability

ARI – Annual Recurrence Interval

BK – Boundary Kit

BOM – Bureau of Meteorology

CAD – Computer Aided Drafting

CAPEX – Capital Expenditure

D – Dilution Factor

DPIE – Department of Primary Industries and Environment

DWF – Dry Weather Flow

ESC – Eurobodalla Shire Council

EP – Equivalent Population

ET – Equivalent Tenement

GIS – Geographical Information System

GWI – Ground Water Infiltration

HDPE – High Density Polyethylene

IFD - Intensity Frequency Duration

I/I – Inflow /Infiltration

IWCMS – Integrated Water Cycle Management Strategy

KPI – Key Performance Indicator

LGA – Local Government Area

LWU – Local Water Utility

MWRA – Melbourne Retail Water Agency

NOV – National Oilwell Varco

NSW – New South Wales

OPEX – Operational Expenditure

ORG – Overflow Relief Gully

OSSM – On Site Sewage Management

PCP – Pump Control Panel

PDWF - Peak Dry Weather Flow

PSS – Pressure Sewer System

PSU – Pressure Sewer Unit

PWC – Power and Water Corporation

PWWF – Peak Wet Weather Flow

RDI – Rainfall Dependent Inflow

RDII – Rainfall Derived Inflow and Infiltration

RSF - Return to Sewer Factor

SA – Storm Allowance

SCADA – Supervisory Control and Data Acquisition

SPS – Sewage Pumping Station

STP – Sewage Treatment Plant

USQ – University of Southern Queensland

WEF – Water Environment Federation

WSAA – Water Services Association of Australia

WTP – Water Treatment Plant

WWP1 – Wet Weather Period 1

WWP2 – Wet Weather Period 2

1 Introduction

1.1 Background

1.1.1 Eurobodalla Shire Council – Local Government Area

The Eurobodalla Shire Council (ESC) is a regional council located on the South Coast of New South Wales (NSW), the Council is responsible for providing infrastructure and services throughout the Eurobodalla Local Government Area (LGA). The Eurobodalla Shire encompasses an area of 3,422 square kilometres as shown in Figure 2 that extends along 143km of coastline between the neighbouring shires of Shoalhaven to the North and Bega Valley to the South, the geographical borders are Durras Lake and Dignam's Creek, respectively. About 72% of the land area is made up of 10 national parks and 15 state forests.(ESC 2021)

The responsibilities of ESC include management, construction, operation, and maintenance of transport infrastructure such as roads, pathways, and bridges; town planning and approvals; waste services; community services; libraries; recreation facilities and other essential services usually provided by Local Government. In addition to this, ESC is also responsible for the provision of water supply and sewerage services as one of 93 Local Water Utilities (LWUs) in NSW (BOM, 2022a, pg. 111)

ESC is responsible for managing $810 million dollars of water supply and sewerage infrastructure which includes:

- 919 kilometres of water mains
- 585 kilometres of sewer mains
- 137 Sewage Pumping Stations (SPS)
- 15 water pumping stations
- 6 Sewage Treatment Plants (STP)
- 5 pressure sewerage schemes
- 2 Water Treatment Plants (WTP)

Eurobodalla's estimated resident population was 38,952 in 2020 and is expected to reach 44,000 in the next 15 years. The Eurobodalla region experiences a transient population due to tourism, with 34% of property owners having a principal residential address outside the shire (ESC 2021) which results significant variations in the water supply and sewage treatment volumes fluctuating on a daily, monthly, and seasonal basis. It also contributes toward ESC having the lowest average annual residential water usage of 117kL per property (BOM 2022a).

The seasonal influx of tourists also results in a requirement to provide water supply and sewerage infrastructure capable of handling peak holiday loadings and harsh conditions such as drought or extreme rainfall events.

1.1.2 Pressure Sewer Systems

Pressure Sewer Systems (PSS) are an innovative alternative to traditional gravity sewer systems. A typical gravity sewer system consists of a series of gravity sewer mains, manholes, sewage pumping stations and sewer rising mains. Gravity sewers are subject to minimum pipe diameters and minimum grades to achieve self-cleansing velocity to prevent deposition of solids. This requirement often results in excessively deep excavations and high numbers of SPS's which also comes at significant capital cost.

PSS alleviate the significant capital costs associated with gravity sewer systems. These systems operate under a principle where each property has its own onsite pump unit in a small storage tank that collects the sewage from each property. This pumps into a small diameter pressure reticulation main which conveys sewage toward the STP. Depending on the circumstances of the system, SPS's may not be required. A typical on property pressure sewer installation is shown in Figure 1.

According to Water Services Association of Australia (WSAA) (2007, p.25), application of PSS should be considered in the following circumstances: where terrain is flat or undulating, in isolated low-density communities, in densely populated areas where construction is likely to be difficult, in low lying areas, in areas which experience seasonal flows and where it is necessary to minimise construction or environmental impact. Previous research findings by Opray & Grant (2006) support this claim, by their conclusion that construction of sewers that minimise excavation and infrastructure costs can lead to overall lower costs.

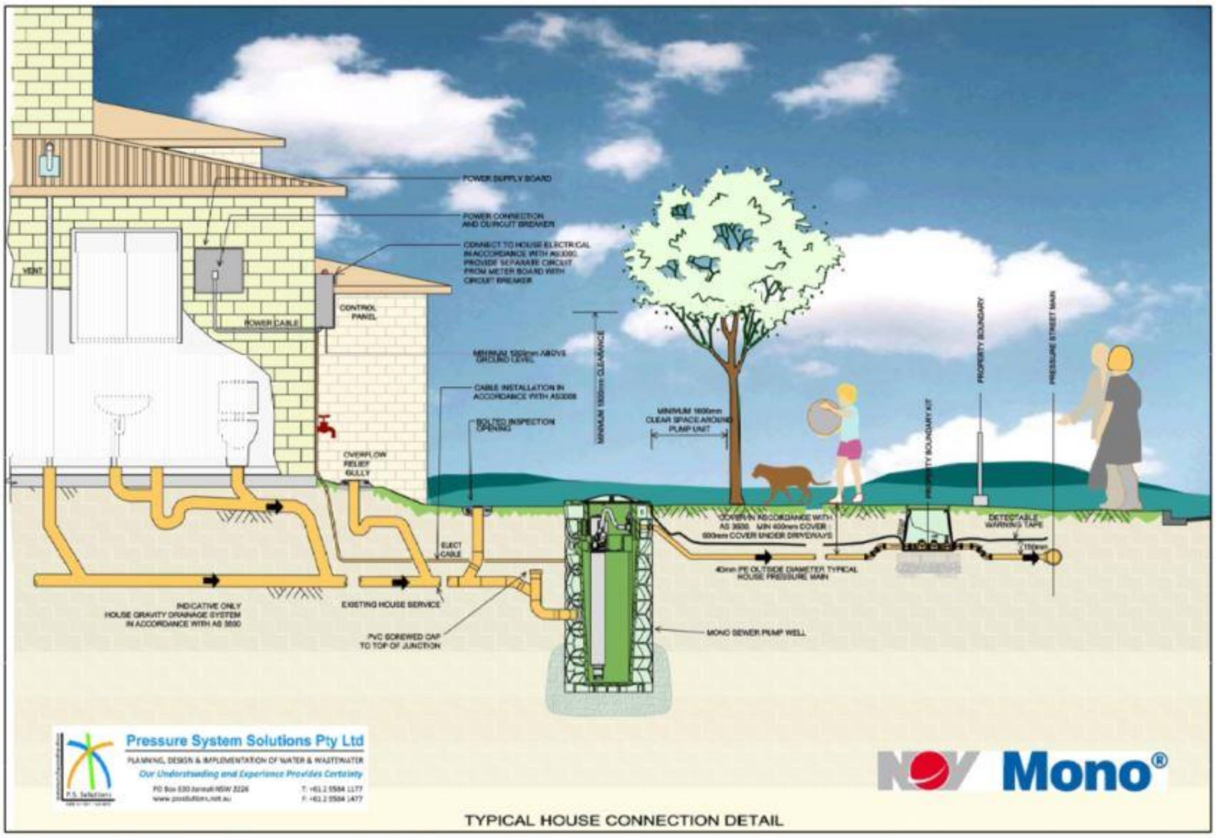

Figure 1 - Typical house connection detail for a PSS (Pressure System Solutions 2016)

1.1.3 Eurobodalla Shire Council's Pressure Sewer Systems

ESC's 2003 edition of the Integrated Water Cycle Management Strategy (IWCMS) identified unsewered residential villages that were considered to pose significant environmental, public health and social issues. The villages of Rosedale, Guerilla Bay, and Bodalla were rated as high priority for provision of a sewerage system, whilst the village of Potato Point was rated as low priority.

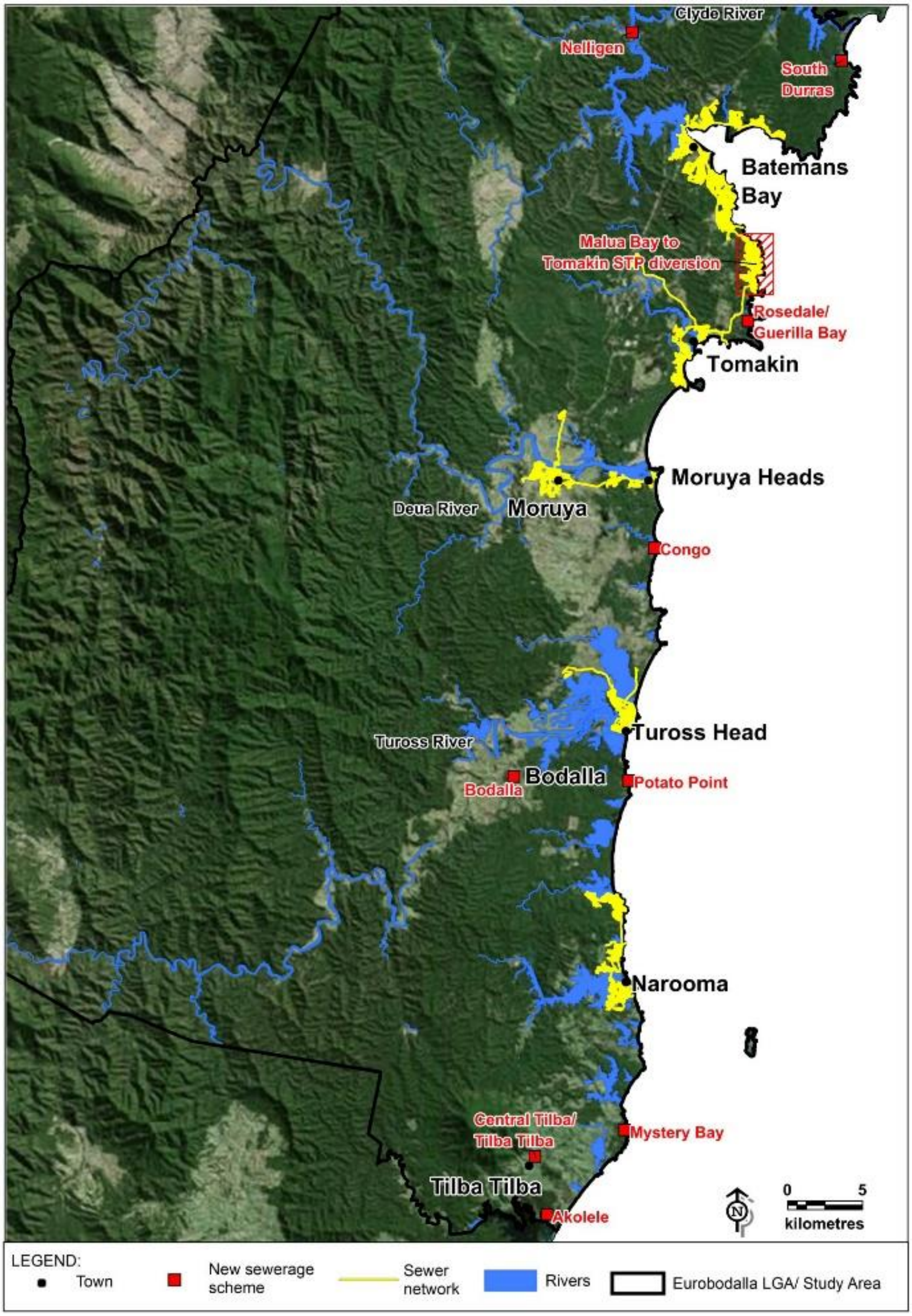

Figure 2 - ESC's sewerage augmentation strategy (Hydrosphere Consulting 2016)

All Pressure Sewer Unit's (PSU) in ESC's pressure sewerage schemes are InviziQ units supplied by NOV. The InviziQ system consists of three main components: the PSU, the Pump Control Panel (PCP) and the Boundary Kit (BK). The InviziQ pump unit is the only unit on the market that offers a design where the pump motor and working parts are situated in a dry well within the unit (NOV Mono 2013), which allows access to the working parts without being exposed to raw sewage.

Each of the pressure sewerage scheme projects complete by ESC in backlog sewerage areas have been retrofit projects, where each property was previously serviced by an On-Site Sewage Management (OSSM) System. A servicing strategic options report was undertaken for each of the unsewered villages. In each case both gravity sewer systems and PSS were considered, with PSS being the preferred option due to the minimal disruption to property owners and the community.

Prior to the PSS being installed, properties were serviced by OSMS systems where home owners are ideally minimising sewage loadings on the systems to reduce maintenance costs associated. Unless property owners have engaged a plumber to upgrade their plumbing to conform with current plumbing standards and ensure that all plumbing fixtures are directed to the PSU, greywater fixtures such as laundry tubs or washing machines may not be connected to the PSU, which may reduce percentage of water consumption entering the sewer system which is also known as the Return to Sewer Factor (RSF).

1.1.4 Potato Point Sewerage Scheme

The Potato Point Sewerage Scheme is the most recently constructed of ESC's pressure sewer systems. It comprises of 151 PSU's that pump to a receiving SPS on the outskirts of the village. This SPS pumps approximately 6.6 kilometres to the Bodalla STP. Flow is measured at the inlet to the SPS, outlet of the SPS and at the inlet of the STP. During commissioning in late 2021 and the initial stages of operation, significant increases in flow were measured. This provided the idea to analyse the wet weather flows as a research project. The masterplan for the Potato Point PSS is shown in Figure 3.

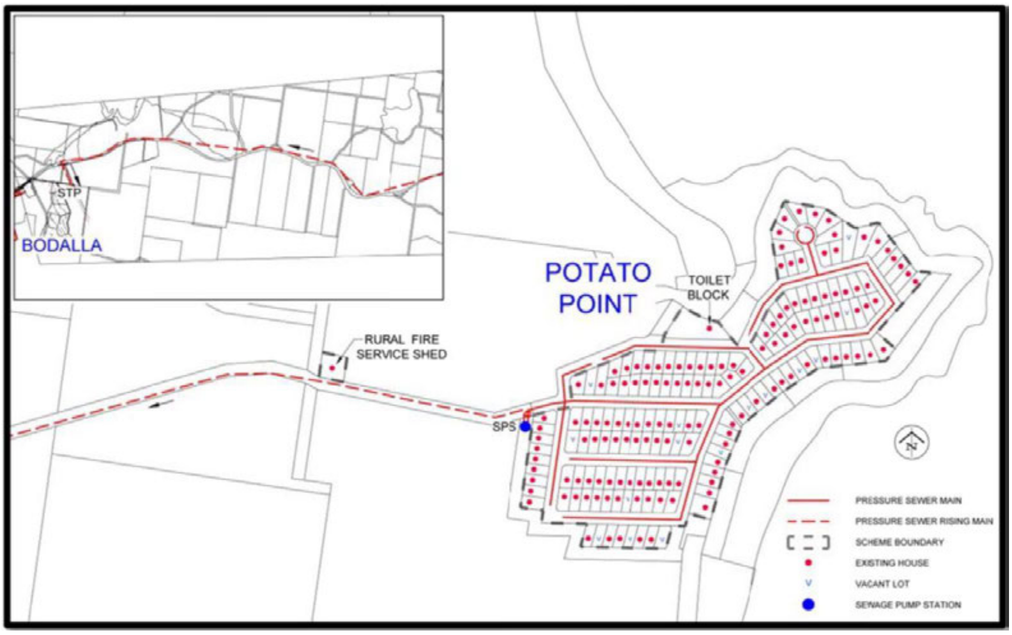

Figure 3 - Potato Point sewerage masterplan (Pressure System Solutions 2016)

1.1.5 Inflow and Infiltration

Managing Inflow and Infiltration (I/I) in sewer systems is a complex issue all sewerage utility providers are facing. The components of I/I can be defined in a multitude of methods, depending on the design guidelines for the area in question, which vary significantly throughout the world. I/I is typically related to stormwater; however, groundwater and seawater can also contribute to I/I.

In a sewer system, inflow can be defined as flows other than wastewater that enter a sewer system directly, inflow is typically related to stormwater. Infiltration can be defined as flows other than wastewater that enter a sewer system by infiltrating slowly through defects in sewer infrastructure, these flows are usually related to groundwater. Sources of infiltration are more difficult to identify than sources of inflow, as these defects have a longer response time to wet weather events and can also contribute to flows in the system for a longer period. I/I that enters a sewer system as a response to rainfall is known as Rainfall Derived Inflow and Infiltration (RDII).

The sources and effects of I/I have been studied extensively in the past in relation to gravity sewer systems, however, there is little relative literature that analyses the sources and effects I/I has in PSS, providing an opportunity for this project to extend the existing literature.

Carne & Le (2015a) provide a five-step method for reducing I/I which is shown in Figure 4. Steps 1 and 2 will be investigated thoroughly in relation to I/I in the Potato Point PSS. If successful, the research may provide future opportunities for the literature to be expanded in relation to steps 3, 4 and 5 focusing particularly on I/I in PSS.

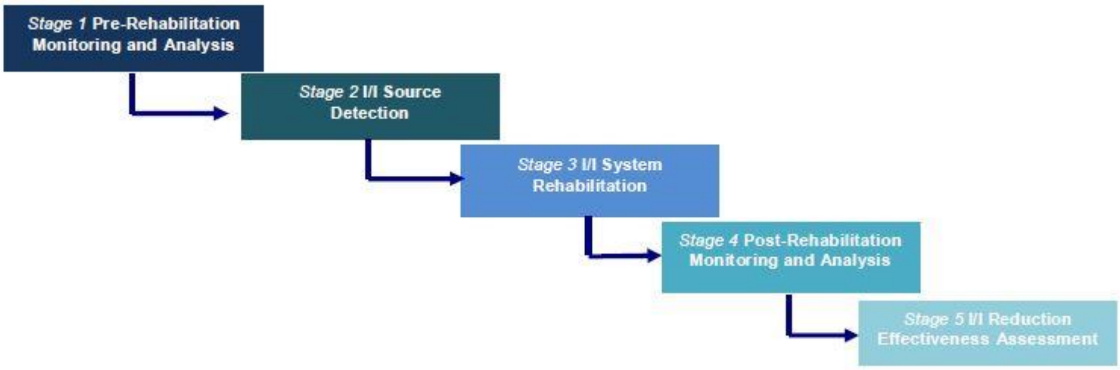

Figure 4 - Five step method for reducing I/I (Carne & Le 2015a)

1.2 Project Aim and Objectives

The overall aim of this project is to quantify the I/I in a pressure sewer system at Potato Point within the Eurobodalla Shire LGA. The project will also investigate and determine the operational costs associated with collecting and treating the I/I flows within the system. The objectives of this research are to develop a hydraulic model which provides outputs that can be used to determine whether the I/I issues in the PSS need further investigation or remediation. The model should also provide a better understanding of the impact of I/I in backlog sewerage areas. If successful, the research may provide better I/I design parameters for future PSS projects in the Eurobodalla, like those proposed at Nelligen and Akolele.

1.3 Project Scope

Research of existing design standards in Australia will be undertaken to determine whether current methods of quantifying I/I are suitable for the Potato Point PSS. A customised hydraulic model will be developed, and will be calibrated, validated, and optimised to effectively quantify I/I within the PSS.

In accordance with the project specification, the scope of works for the project includes the following:

- Conduct an extensive literature review on the sewer design guidelines adopted in various states of Australia, specifically on the methods in which I/I values are determined and incorporated into sewer design.
- Research the potential sources and effects of I/I in a PSS.
- Devise a sewer flow monitoring programme which confirms this system is suitable for I/I analysis.
- Gather baseline data relative to I/I within a PSS.
- Analyse and evaluate the gathered data from step 4, to extract any correlation with catchment parameters and meteorological patterns including rainfall and runoff.
- Develop a customised hydraulic model for quantifying the I/I in an operational PSS using EXCEL and define the assumptions and limitations of the model.
- Undertake calibration, validation, and optimisation of the customised model
- Compare the data from the model with the predicted values of I/I from various adopted sewer design guidelines.
- Complete a cost analysis to determine the additional operational costs of collecting and treating I/I within a PSS.

Due to time constraints, not all works specified in the project specification will be completed in this dissertation. A copy of the project specification is provided as Appendix A, and the initial project planning documents are provided as Appendix B.

Works that are not considered as part of this research include:

- Analysis of the cost and resource requirements to identify and remediate defective sewer infrastructure within private properties.
- Analysis of costs associated with determining if remediating private sewer infrastructure to reduce I/I is economically viable for Eurobodalla Shire Council
- Analysis of the capital construction costs associated with pressure sewer systems. All analysis related to costs will assume that existing sewage collection, transfer, and treatment infrastructure has been designed with appropriate capacities to handle existing I/I flows.

2 Literature Review

This chapter focuses on reviewing existing literature relevant to quantification, sources, effects, and operational costs associated with I/I in pressure sewer systems.

Water Services Association of Australia (WSAA) is the peak industry body for water and sewerage services in Australia and New Zealand. WSAA has developed codes which provide appropriate technical requirements for planning, design and construction of water supply and sewerage infrastructure. A sizeable portion of the literature review focuses on the various editions of WSAA codes. Other design codes and standards which are used by water and sewerage service providers in New South Wales, Queensland, Northern Territory and New Zealand have also been critically reviewed.

A pressure sewer system should have a low level of I/I, however, the lateral connections that connect to a pressure sewer system are a gravity sewer system owned and maintained by the property owners. This is justification for focusing a significant part of the literature review on gravity sewer systems.

2.1 Pressure Sewer Design Guidelines

Whilst water and sewerage service providers may have standalone pressure sewer design guidelines or their own version of WSAA's Pressure Sewerage Code of Australia (2007), there is limited adoption of I/I factors or allowances within these technical documents. Where these factors have been adopted, there is little or no supporting literature providing justification for these values.

2.1.1 WSAA

WSAA (2007) is the most widely adopted technical standard for design and construction of PSS in Australia, with many water and sewerage service providers using it as their standalone technical specification for pressure sewerage systems. Other service providers including Sydney Water, Hunter Water, and Melbourne Retail Water Agencies (MRWA) adopt the WSAA code as the foundation documentation for their technical standards and provide a supplementary manual or standard of which the requirements take precedence over the WSAA code.

The code states that I/I may occur within a customer's sanitary drainage, especially where the condition of the sanitary drains may have deteriorated. The code identifies the need to include an allowance for I/I that should be evaluated based on the following factors: sanitary drain age, material type, condition assessment, and testing requirements. In areas where a PSS is being retrofitted to existing properties, undertaking investigations of each of these factors can be intrusive and expensive, which is why these investigations are often not completed during design and construction of a PSS. Without these investigations, the allowance made for I/I during the design of a system may be inaccurate, which may result in calculation of design flows that have a high likelihood of error. The code states that the design flow equation may be varied to account for anticipated abnormal water consumption, to allow for a greater safety factor and I/I from customer sanitary drainage. It does not provide details of suggested values for allowances relevant to any of these factors.

2.1.2 Hunter Water

Hunter Water is a State Owned Corporation that provides drinking water, wastewater, recycled water, and stormwater services across the Lower Hunter region of New South Wales (NSW). Hunter Water's pressure sewer design guideline (2018) outlines the design requirements for PSS in the area serviced by Hunter Water. The design guideline is designed to be read in conjunction with WSAA (2007) and other relevant Hunter Water documents.

The Hunter Water design guideline provides more detail of the hydraulic design parameters in which the PSS should be designed than the comparative WSAA Pressure Sewerage Code. The assumed sewer loads for green-field single-dwelling residential subdivision is 150L/EP/day at an occupancy rate of 3.0 persons/dwelling, for a total design flow of 450 litres/property/day.

For brownfield sites or servicing of back-log sewer areas, the design flowrate is determined by analysing the historic water consumption rates for the serviced area. The guideline acknowledges that water consumption may increase when wastewater disposal is to the sewerage system rather than an OSSM system.

Of relevance in the Hunter Water guideline, is section 4.1 regarding wet-weather inflow and infiltration. In gravity sewer systems in the Hunter Water network, approximately 50% of I/I is contributed by pipework owned by the customer with the other 50% through the Hunter Water owned sewer infrastructure. It notes that the likely sources of the inflow contributed by the customer are illegal stormwater connections and inappropriately designed Overflow Relief Gullies' (ORG). The infiltration component of this usually occurs because of damaged or poorly sealed drainage lines.

The Hunter water guideline requires the hydraulics of a PSS to be modelled appropriately. As part of this modelling, it is required that the system be modelled under a wet-weather scenario to verify that the system performs satisfactorily when I/I flow enters the system during rainfall events. The guideline does not specify a factor or volume of I/I for this modelling, it requires designers to assume a reasonable representative volume of I/I.

This guideline also provides demand factors for each half hour period of the day which contribute to the residential diurnal sewer curve in the guidelines. The half hour demand factors from Hunter Waters guideline have been converted to hourly demand factors which are shown in Table 1.

Time to	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Demand Factor	0.2	0.13	0.11	0.11	0.28	0.78	1.68	2.16	2.13	1.92	1.61	1.34

Time to	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
Demand Factor	1.13	0.97	0.92	1.04	1.34	1.44	1.25	1.06	0.87	0.68	0.51	0.34

Table 1 – Hunter Water residential diurnal sewer demand factors

2.1.3 Power and Water Corporation

Power and Water Corporation (PWC) is a Northern Territory Government owned corporation responsible for transmitting and distributing electricity and providing water supply and sewerage services across the Northern Territory. They have adopted WSAA's code (2007) as the general basis for design and construction of pressure sewerage infrastructure, however, have provided a supplement of the code to provide details of the modifications and additions of WSAA's code which suit the requirements of PWC.

PWC's supplement uses a different equation for estimation of Peak Wet Weather Flow (PWWF) which includes a wet weather dilution factor (D). The factor used for design of pressure sewer systems is D = 2.0 for both tropical and arid areas, which is less than the dilution factor for gravity sewer systems of D = 3.0.

2.1.4 Queensland Department of Energy and Water Supply

The Queensland Department of Energy and Water Supply (2014) suggest peak flow (PWWF) is equal to 3 times Average Dry Weather Flow (ADWF) for pressure sewer systems.

2.1.5 Potato Point Pressure Sewerage Design Report

Pressure System Solutions (2016) completed the concept design and detailed design for ESC. In the design report for the system, the hydraulic loading conditions were modelled for the 149 existing lots and 164 ultimate lots to ensure the design of the system could cater for future growth and development. Details of the hydraulic loading conditionals and design assumptions are provided in Table 2.

Hydraulic Loadings		
Equivalent Persons L/d	150	L/d
ep/ET	3.6	
L/ET/d	540	L/ET/d

540 L/ET/day	Flow kL/day	Average Flow L/s	Peak Design Flow @ 10% Probability L/s	Peak Design Flow @ 20% Probability L/s	Wet Weather Flow Allowance for SPS L/s	Total PWWF to SPS @ 10% Probability L/s
149 Existing Lots	80.46	0.93	3.0	2.3	2.1	5.1
164 Ultimate Lots	88.56	1.03	3.0	2.3	2.4	5.4

Table 2 – Potato Point sewerage scheme hydraulic loading conditions (Pressure System Solutions, 2016)

Pressure System Solutions (2016) did not make a storm allowance for wet weather flow events; however, they noted that if high wet weather flows are recorded then assessments of individual properties should be undertaken to identify where the ingress is occurring.

2.2 Pressure Sewer Design Guidelines – Flow Calculations Summary

2.2.1 ADWF

Average Dry Weather Flow is the combined sanitary flow into a sewer which incorporates sanitary flow as well as Ground Water Infiltration (GWI), which are the infiltration flows that occur at all hours of the day. The ADWF values adopted by the various pressure sewer design guidelines are:

$$ADWF\ (Total) = ADWF\ \times EP \quad (2.1)$$

<u>WSAA (2007)</u>

$ADWF = 180L/EP/day$ $\quad$ $3.5\ EP/ET$

<u>Hunter Water (2018)</u>

$ADWF = 150L/EP/day$ $\quad$ $3\ EP/ET$

<u>PWC (2022)</u>

$ADWF = \ 300L/EP/day$ $\quad$ $3.5\ EP/ET$

<u>Pressure Sewer Solutions (2016)</u>

$ADWF = 150L/EP/day$ $\quad$ $3.6\ EP/ET$

2.2.2 PDWF

Peak Dry Weather Flow (PDWF) is the likely peak sanitary flow into a sewer during a normal day. The methods for estimating PDWF from the pressure sewer design guidelines are:

<u>PWC (2018)</u>

$$PDWF = \ ADWF\ \times\ r \qquad r = (1.74 + \frac{330}{EP^{0.55}})^{0.5} \quad (2.2)$$

<u>Queensland Department of Energy and Water Supply (2014)</u>

- Method 1 – Use actual system performance
- Method 2 – Use historical Queensland approach, which is

$$PDWF = \ C_2\ \times\ ADWF \qquad C_2 = 4.7\ \times\ (EP)^{-0.105} \quad (2.3)$$

2.2.3 PWWF

Peak Wet Weather Flow (PWWF) which is also known as design flow, is equal to PDWF + GWI + RDII. Methods for estimating PWWF from the various pressure sewer design guidelines reviewed include:

<u>WSAA (2007)</u>

$$Design\ Flow\ (PWWF), \quad Q \quad = \quad (AN + B) \quad (2.4)$$

$A = Coefficient\ specified\ by\ the\ system\ supplier, typically\ 1.9$

$N = Number\ of\ Lots$

$$B = Factor\ nominated\ by\ system\ supplier, typically\ 38\ to\ 76$$

Hunter Water (2018)

$$Design\ Flow\ (PWWF), \quad Q = (AN + B) \times \frac{3.785}{60} \tag{2.5}$$

$$A = Coefficient\ specified\ by\ the\ system\ supplier, typically\ 1.9$$

$$N = Number\ of\ Lots$$

$$B = Factor\ nominated\ by\ system\ supplier, typically\ 38\ to\ 76$$

PWC (2018)

$$PWWF = PDWF \times d, \quad d = 2.0\ for\ tropical\ and\ arid\ areas \tag{2.6}$$

Queensland Department of Energy and Water Supply (2014)

- Method 1 – Use Actual system performance
- Method 2 – Use WSAA Sewerage Code approach
- Method 3 – Use Queensland approach for pressure sewer

$$PWWF = (3 \times ADWF) \tag{2.7}$$

2.3 Gravity Sewer Design Guidelines

Gravity sewer design guidelines from various states in Australia have been critically reviewed because these guidelines have varying methods for quantifying the various components of flows within a sewerage system. They have relevance as all the I/I entering a PSS is through the private sewer laterals which are essentially a gravity sewer system.

2.3.1 WSAA's Gravity Sewerage Code of Australia

WSAA's Gravity Sewerage Code of Australia (WSAA 2022) is the most widely adopted technical standard by water and sewerage service providers in Australia for design and construction of gravity sewers.

The code states methods for determining design flow vary depending on whether calibrated models for the area under consideration are available. Although this statement is supporting the design of a gravity sewer systems, this approach is also relevant to the determination of design flows within a pressure sewer system if an appropriate model can be developed to represent the Peak Dry Weather Flows (PDWF), GWI & Rainfall Dependent Inflow (RDI) flows in the system.

Where calibrated models are not available, WSAA (2022) suggests that the method for determining the design flow should be in accordance with the methodology specified by the relevant water agency. WSAA provides an example of a traditional approach for design flow estimation which is elaborated on in detail in the code. This approach includes methods of calculating the estimated PDWF, GWI and RDI which have inputs that are relevant to the area under consideration.

2.3.2 Other Editions of WSAA’s Gravity Sewerage Code of Australia

The various editions of WSAA’s Gravity Sewerage Code have similarities to the original code. However, the review of these technical standards identified major differences in the methods in which PDWF, GWI and RDI are estimated, as well as minor differences in how ADWF is determined.

Hunter Water’s edition WSAA (2014) provides different methods for the estimating the PDWF, GWI and RDI components of the PWWF flows. Where flow gauging data is not available, PDWF is calculated in accordance with the NSW Public Works (1984) empirical method, where ADWF is multiplied by a factor ‘r’ which is equal to the ratio of peak flow to average flow. In this instance, the value for ADWF and the peaking factor ‘r’ is based on an Equivalent Tenement (ET) value rather than Equivalent Population (EP). PWWF is determined by combining the PDWF plus a Storm Allowance (SA).

This edition also provides a method for determining PDWF where flow gauging records are available. This method involves analysing historical rain and flow gauging records and determining a representative PDWF from relevant dry periods, the PDWF determined using this method is equal to the sum of the PDWF and GWI components for the dry period. The SA can then be determined as it is equal to PWWF minus PDWF.

Sydney Water’s version of WSAA (2002) replicates Hunter Water’s method for determining PDWF where flow gauging records are available. This version of WSAA (2002) also provides a method for determining Rainfall Dependant Inflow (RDI) where at least 12 months’ worth of rain and flow gauging records are available. The dry day diurnal pattern is subtracted from the corresponding day for the 20 largest storm events from a representative year to define a RDI flow hydrograph for each event. The 12th ranked RDI peak flow is adopted as the best estimate of the 1-month ARI RDI and is used to determine the RDI for this catchment.

2.3.3 QLD Department of Energy and Water Supply

Queensland Department of Energy and Water Supply (2014) provides another method of calculating PWWF within a sewer system. In the historical Queensland approach, PDWF is related to ADWF by a factor of EP in the catchment and PWWF is determined either as PDWF multiplied by a constant of 5 or by a value related to EP in the catchment. ADWF is defined as a range between 150-275 L/EP/d. The Queensland planning guidelines state that GWI can be estimated as the flow between midnight and 4:00am during dry periods.

The guidelines also note that peaking factors for high transient or tourist populations must be considered for sewerage schemes where there is a significant component of non-permanent residential population which is the case for Potato Point.

2.4 Previous Case Studies

Carne (2011) reports that during a detailed analysis of a pressure sewer system in Tooradin, Victoria, there was a slight increase in flows during major wet weather events. The volume of which was the equivalent of 0.5% of properties within the system having their roof drainage connected to the sewerage system. They also noted that other Australian utilities have reported similar wet weather responses in their pressure sewer systems. Whilst details of the wet weather events analysed were not specified, there were key factors identified which contributed to the low reported incidence of I/I which are:

- House laterals are often renewed during installation in backlog sewerage areas
- The length of house laterals is short compared to areas serviced by gravity sewers

Haarhoff & van der Linde (2009) analysed the performance and efficiency of the PSS at Point Wells, New Zealand, over a 3-month period. They found that 3 PSU's out of 161 contributed approximately 60% (86kL) of the total inflow (144kL) during a 4 day rain event, where 140mm of rainfall occurred. This demonstrates that if there is direct sources of inflow connected to the pressure sewer system, it can have a significant impact on the RDII response to a rainfall event. Where there is evidence that a small number of PSU's are contributing a large amount of the inflow during rainfall, these units should be closely monitored to determine the source of inflow. This case study validates that having long-term flow monitoring data available is not essential to quantify the I/I within in a PSS.

Installation of PSSs in areas serviced by gravity sewer has been considered a potential solution to resolve the I/I issues in gravity sewer systems that are experiencing large volumes of I/I. Haarhoff (2011) suggests that where treatment and conveyance costs or volumes of I/I are very high there is economic benefits to replacing gravity sewer systems with pressure or vacuum systems. Whilst this research is not analysing the same scenario, it provides confidence that installation of PSS results in low incidence and volumes of I/I.

Carne (2014) states that peaking factors of 1.2 on normal dry weather flows are usually applied where pressure sewer systems have been retrofitted to existing villages. This is significantly less than what is normally accepted using empirical design techniques. It is interesting to note that the peaking factors suggested are much lower than those from the pressure sewer design guidelines reviewed.

Because property owners are responsible for the pumping costs of the PSU, there is some economic disincentive to prevent property owners from connecting stormwater directly to the PSU (Carne, 2014). However, given that pumping costs are minimal based on normal pumping (<$50 annually), where properties do not have suitable stormwater disposal methods owners may see the costs of additional pumping as less of an inconvenience than having a saturated yard.

2.5 Sources and Effects of I/I

2.5.1 Sources of I/I

It is important to identify the sources of I/I in a system prior to quantifying I/I. A major difference between a PSS and a gravity sewer system is that all the I/I into a PSS is caused by sources of I/I within private properties. Figure 5 depicts typical sources of I/I within private properties, which include:

- Illegal stormwater connections
- Overflow relief gullies (ORG) that are in low lying areas or function as drainage points
- ORG's that are damaged or poorly constructed
- Cross connections to stormwater drainage pipes
- Inspection openings with loose caps
- Cracked or damaged private lateral sewer pipes
- Leaking lateral connections to the pressure sewer unit

Sources of I/I within private properties generally increase as the age of the lateral assets age. Typical modes of failure for private laterals include cracking, deflection, sag & offset joints. The extent of the I/I issues are exacerbated by factors including the size of the defect, soil type, groundwater conditions, root intrusion, external loading, and trench-bedding material (WEF 2016)

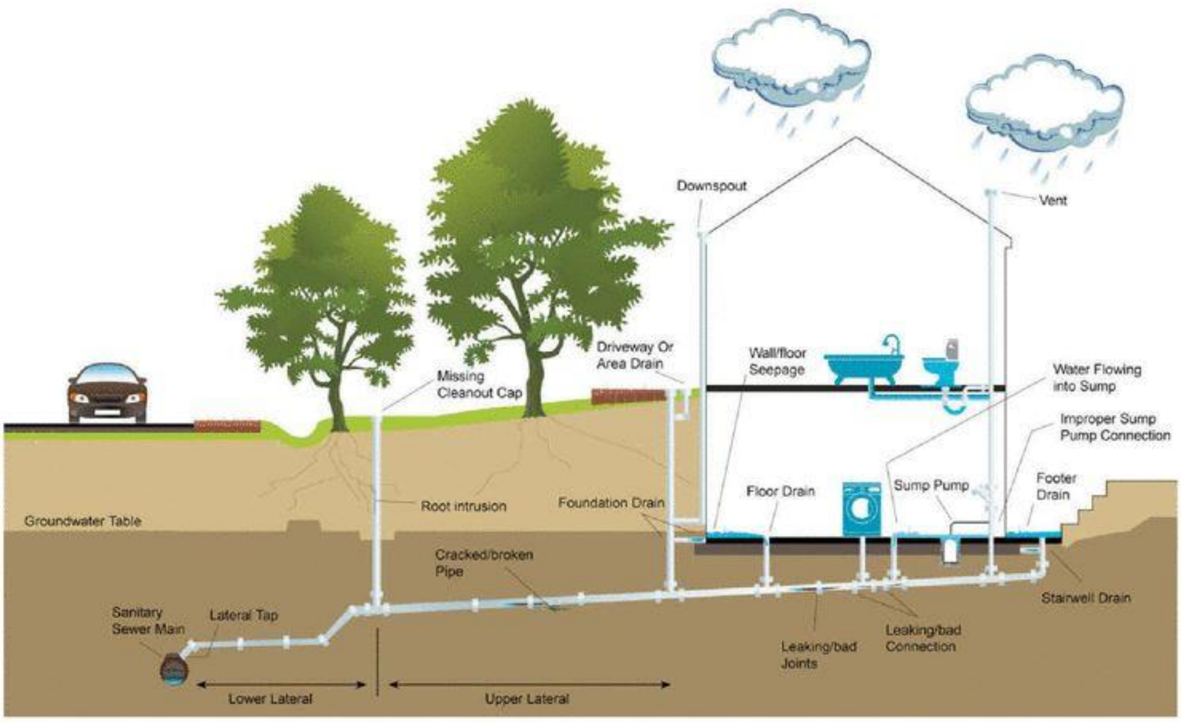

Figure 5 - Typical sources of I/I in private laterals (WEF 2016)

2.5.2 Effects of I/I

WEF (2016) identifies that the effects that I/I have on a sewerage system are typically related to economic, environmental & public health, or regulatory issues.

Economic related effects are one of the drivers for utilities to commence investigations related to I/I, the costs associated with sewerage systems include:

- Operational costs - costs associated with transferring and treating I/I such as power for pumping, aeration, and chemical usage.
- Maintenance costs – More frequent pump maintenance due to higher run hours and accumulation of grit which causes excessive pump wear
- Investigation costs – costs associated with investigating the sources of I/I within a system and developing strategies to address these issues.
- Capital costs – costs associated with upgrading or constructing storage infrastructure to ensure that overflows are avoided during wet weather events.

Environmental and public health issues are usually related to sewage spills which can pose a risk to public health and safety. Spills can occur outside on private properties due to a pressure sewer unit not being able to discharge into the street main, this would typically occur at ORG’s or inspection openings within the private property. Spills can occur inside the house if the ORG is absent or does not meet the required standard. SPS’s and STP’s are also subject to sewage spills, which can impact adjacent properties and potentially affect waterways. Sewage spills of any nature are likely to create negative perception toward the service provide within the affected community.

Where I/I is identified within a sewer system, it is customary practice for a utility provider to commence investigations to determine the source of I/I. Whilst private laterals may have been constructed in accordance with the relevant regulations, as the assets ages defects may have arisen that contribute toward the I/I. In Australia, legislation allows an enforcement officer to inspect the character and condition of any pipe, sewer, drain or fitting within a premises. This gives the regulator the ability to determine whether there are any defects within a property which contribute to I/I. If a utility decides to undertake an investigation of I/I within private properties, there may be defects identified which need to be repaired. This then causes legal and regulatory issues as to who is responsible for undertaking and paying for the repairs.

Carne (2011) notes that there is no evidence of examples where comprehensive legal and financial arrangements have been made to address the private property I/I. Several options are considered in the guidelines, where undertaking the works may be the responsibility of the water authority or the property owner, however, in each scenario the property owner is responsible for funding the works.

2.6 Quantifying I/I

Whilst different water and wastewater utility providers have different methods of quantifying the major components of wastewater flows, there is no widely adopted method for quantifying these flows. Carne (2011) and Carne & Le (2015a) consider the sewage flows into a system as three different components, these components of flows which are illustrated in a simple hydrograph in Figure 6 include:

- RDII
- GWI
- Dry Weather Flows (DWF)

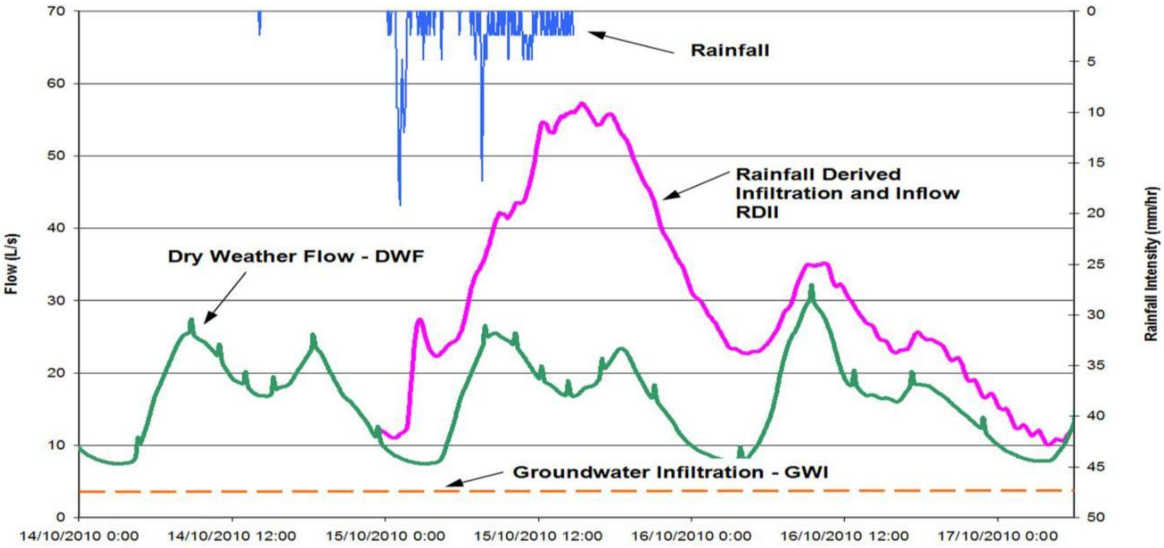

Figure 6 - Hydrograph showing increased flows as a response to rainfall (Carne 2011)

To quantify the different flow components, flow monitoring and rainfall data needs to be available for the area under consideration. Carne’s (2011) method for initial quantification of the different components of flow is completed in the following steps:

- Determine the DWF inclusive of GWI for dry periods, if the daily flow pattern varies due to transient populations on weekends, then representative hydrographs should be developed for both scenarios. This should be completed similarly for seasonal populations. Figure 7 provides an example of different dry weather hydrographs for weekday/weekend flows.
- Estimate the quantity of GWI by analysing the minimum night-time flows
- Calculate the RDII by subtracting the DWF hydrograph from the recorded wet weather hydrograph. The comparison should be continued until the recorded flows return to normal, the area under the RDII hydrograph provides the total volume of RDII for the given rainfall event.
- Calculate the Average Recurrence Interval (ARI) for the storm event

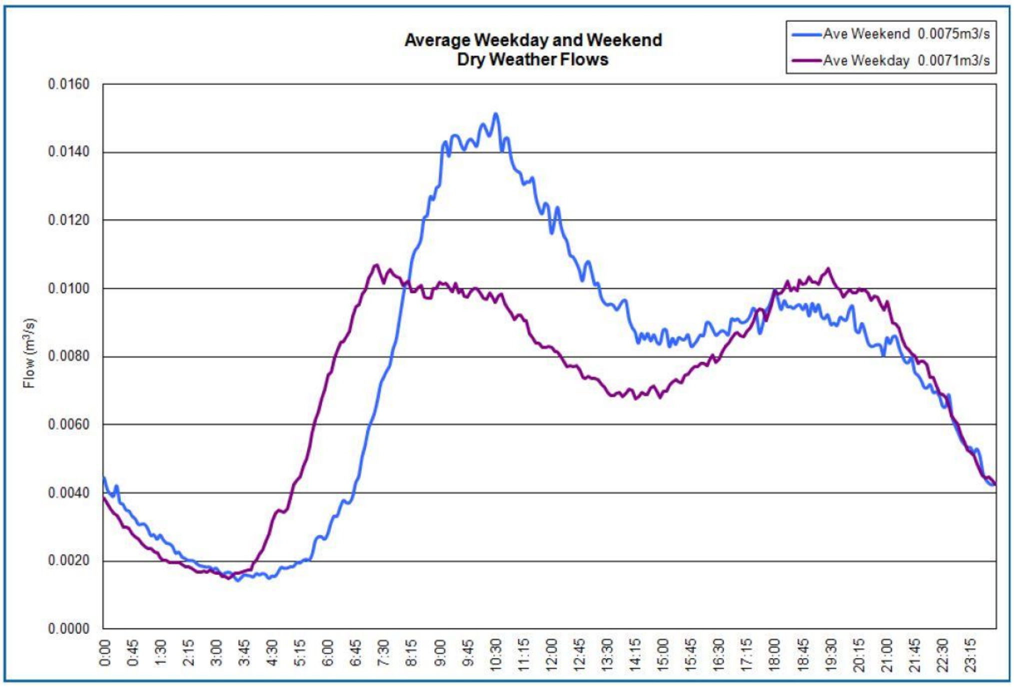

Figure 7 - Hydrograph showing varied flows on weekday/weekend (Carne 2015b)

Carne (2011) and Carne & Le (2015a) suggest parameters or Key Performance Indicators (KPI) that have been used in previous I/I analysis projects. The parameters suggested by Carne (2011) that should be determined when quantifying and analysing I/I are:

- GWI

$$GWI_1 = ADWF_{measured} \,/\, Population_{theoretical} \tag{2.8}$$

$$GWI_2 = ADWF_{measured} \,/\, Water\ Consumption_{measured} \tag{2.9}$$

- RDII

$$RDII_1 = Volume\ of\ RDII_{measured} \,/\, Rainfall\ Volume_{measured} \tag{2.10}$$

$$SWI_1 = PWWF_{measured} \,/\, ADWF \tag{2.11}$$

The guideline values for GWI_1 are between 130L/p/d and 220L/p/d, values below this indicate potential exfiltration and values above this indicate significant GWI. This may be irrelevant due to the areas under consideration that have transient populations.

The GWI_2 values are more likely to be relevant as they are related to water consumption which is directly affected by population in areas with transient populations. The normal expected range for this is 0.7 - 0.9.

$RDII_1$ values for systems in good condition are in the range 2-5%, however, there is evidence that systems can have values greater than 20% which indicate elevated levels of wet weather response. The threshold for undertaking a rehabilitation program to minimise I/I is 8%.

Historical design practice adopted SWI_1 values of 5.0, however, some studies have encountered values as high as 30. Because there is less sources for inflow & infiltration within a pressure sewer system, the values expected for both $RDII_1$ and SWI_1 parameters should be lower than those typically found in gravity sewer systems.

2.7 Operational Costs of Sewerage Systems

As detailed in Section 2.4.2, the economic effects of I/I can be analysed through the operational, maintenance, investigation and capital costs that are incurred to Local Water Utilities (LWUs) a result of I/I within a sewerage system.

As part of this research, the operational costs (including maintenance costs) associated with pressure sewer systems will be investigated to provide background information relevant to justifying the requirements for undertaking an I/I rehabilitation strategy. Quantifying the potential savings in capital and operating costs associated with sizing collection, transfer, and treatment infrastructure to cater for PWWF events will not be undertaken as part of this research.

LWU's in NSW are benchmarked against other providers, a requirement under the National Water Initiative. Various social, environmental, and economic performance indicators are reported on annually to provide valuable data which determines the current position and assesses the future water supply and sewerage needs for these areas.

NSW Department of Planning and Environment (DPIE) provides an online performance monitoring data dashboard that compares various service indicators for LWU's in regional NSW. The operating costs for sewerage systems (c/kL) for all LWU's in the NSW South Region in the 2020-21 Financial Year are shown in Figure 8. Eurobodalla's operational cost (c/kL) was approximately 35% greater than the weighted median for the South Region. NSW DPIE (2022) detailed that the Eurobodalla's operating costs cost per kL of sewage treated was 288.57 cents which were is 38% greater than Shoalhaven and 30% less than Bega Valley which are the two costal shires which neighbour the Eurobodalla LGA.

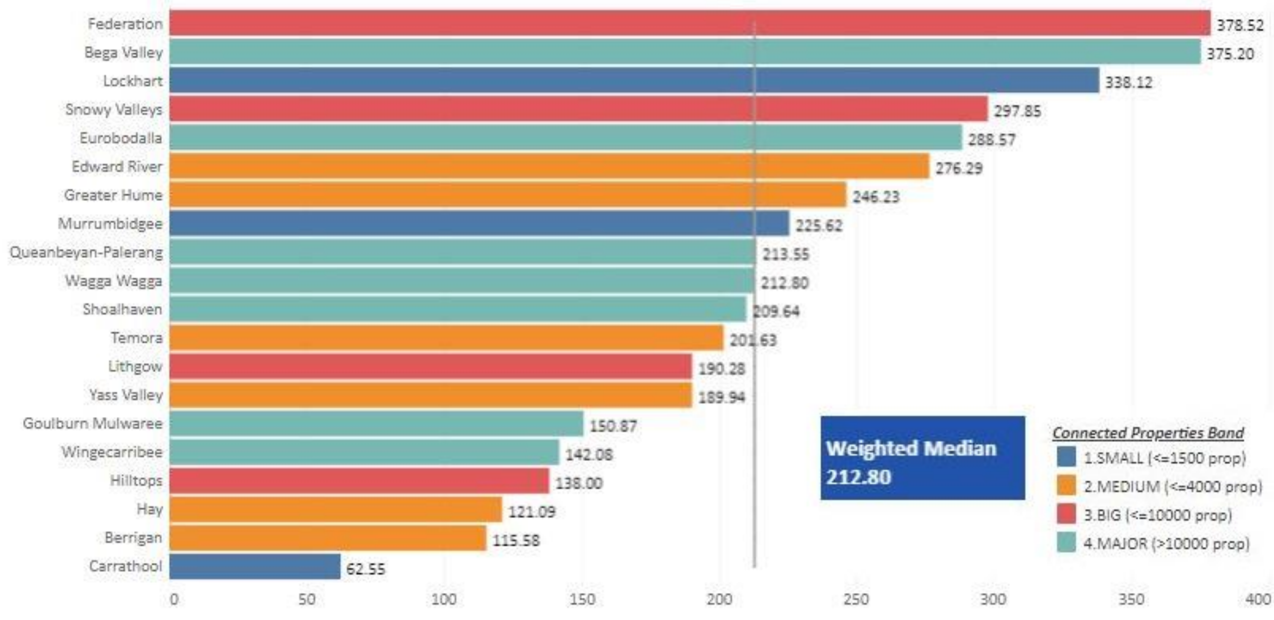

Figure 8 - Operating costs for sewerage systems NSW South Region (c/kL) (NSW DPIE 2022)

The operating costs per property for LWU's in the NSW South region were also obtained from NSW DPIE's (2022) benchmarking. The costs in terms of $/property are detailed in Figure 9. Eurobodalla's operational and maintenance cost per property is $674.66.

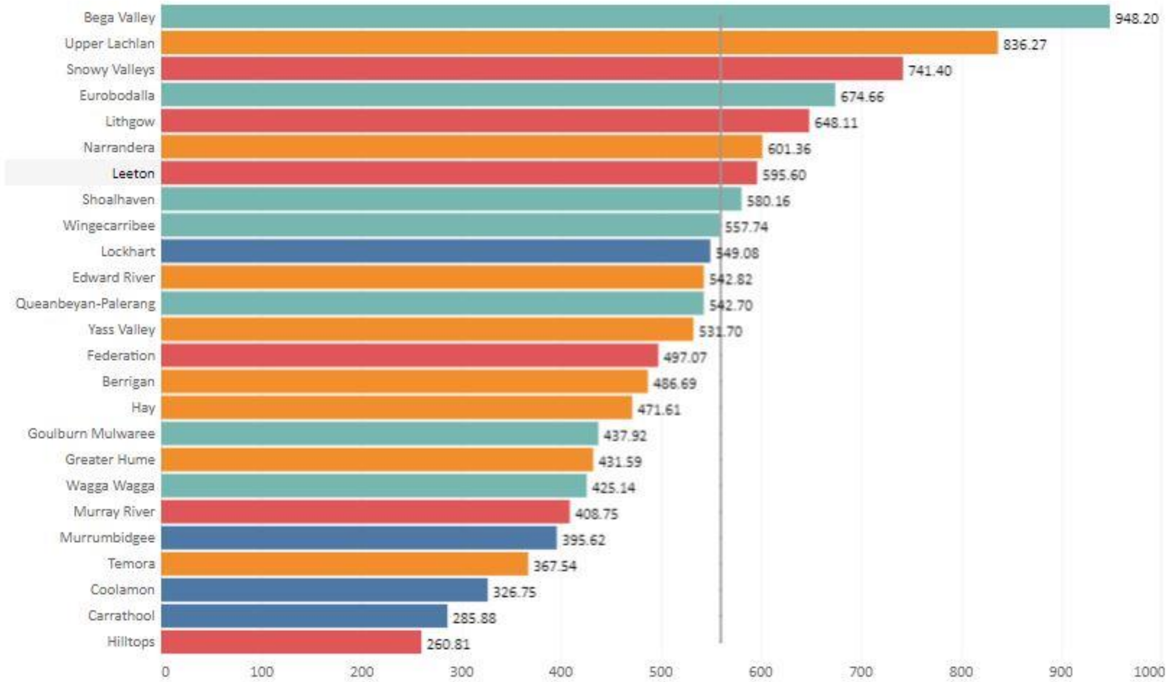

Figure 9 - Operating costs for sewerage systems NSW South Region ($/prop) (NSW DPIE 2022)

Unfortunately, the NSW DPIE data does not include any performance monitoring or benchmarking for pressure sewer systems, this would be a useful measure that would be beneficial to LWU's to draw comparisons in costs associated with PSS's.

In Haarhoff and van der Linde's (2009) sewer system cost comparison for Point Wells, an operational cost of $156 per property/year was adopted for both pressure sewer and gravity sewer servicing options for a system to service 245 residential dwellings in a brownfield site. The parameters of this PSS are comparable with the pressure sewer systems in the Eurobodalla Shire, however, Eurobodalla's operational costs per property are significantly higher than those at Point Wells.

GHD (2018) undertook a review of low pressure sewer options and costs for Gladstone Regional Council, where they reviewed the capital and operational costs associated with the existing PSS which has an ultimate total of 99 connections. GHD adopted an annual Operational Expenditure (OPEX) cost of $635.27 per property for the 2017/18 FY, which assumed each property would have two callouts and one vac-truck pump out per year. GHD did not include pump and control box replacements as an OPEX cost, they included it in their Capital Expenditure (CAPEX) costs for the system. The costs associated with the replacement of a pump and control box was $4,479 per property for the 2017/18FY. GHD noted that there is uncertainty around the life span of the pump and control box and modelled Net Present Value (NPV) scenarios for a 10 year & 20 year pump and control box replacement program. The annual OPEX costs including pump and control box replacement for 2017/18 FY equated to $859.22 and $1,083.17 for 10 and 20 year service lives, respectively.

2.8 Summary

The literature review revealed that there has been little research undertaken within Australia relevant to quantifying I/I in PSS, highlighting the knowledge gap in this area and justifying the need for this research project.

Each LWU has its own method of designing sewer systems to cater for wet weather events, the literature review evaluated the key differences of each method. One of the common themes throughout the literature review was that the preferred method for designing sewers incorporates historical data or models from relevant catchments rather than assuming a specified factor for anticipated I/I in the system. The review also identified that a sizeable portion of I/I in a gravity sewer system is through private laterals, which are the only sources of I/I in a PSS.

Summaries of the methods of calculating the various flow components from pressure sewer design guidelines and gravity sewer design guidelines have been provided to assist in comparison of these values to those obtained as part of the I/I analysis of the Potato Point PSS.

The literature review identified the major contributing sources of I/I in a pressure sewer system, and identified the economic, environmental & public health, and regulatory issues that I/I can cause. The defects are more likely to be present in areas where PSS is being retrofitted to replace existing OSMS systems, as the age and condition of existing private sewer laterals is unknown. The regulatory issues associated with the rectification of defects in a PSS are a challenge for all service providers. Proportioning the responsibilities of the service provider and property owner can be difficult.

The best method of quantifying I/I is to follow the methods outlined by Carne (2011) and Carne & Le (2015a) in the I/I management guidelines. These methods have been developed specifically for gravity systems with guideline parameter values for GWI and RDII specified. There is no evidence of these values being applicable to pressure sewer, which supports the requirement for development of suitable values or factors for I/I in PSS's.

Operational costs for sewerage systems have been investigated and unit costs for the total operational costs associated with sewerage systems have been articulated using benchmarking from LWU's in NSW. Costs associated with operation and maintenance of sewer systems in the Eurobodalla is quite high when compared to other service providers in the NSW South Region. The benchmarking does have a gap for operational costs associated with pressure sewer, which supports the requirement to establish actual operational costs for PSS's in future research.

GHD (2018) reviewed OPEX costs associated with low pressure sewer systems for the 1770 village, which has similar design parameters to the Potato Point village. The OPEX costs adopted for the NPV calculations were comparable to the per property operating costs determined for the Eurobodalla by NSW DPIE (2022).

3 Methodology

3.1 Data Collection & Preliminary Analysis

3.1.1 Catchment Selection

The literature review did not highlight any previous research that has been undertaken on pressure sewer systems where I/I is causing operational issues. Implementation of PSS's in sewered areas that are experiencing I/I issues has even been considered as a solution to reduce the I/I in some instances.

Given that the recently constructed PSS at Potato Point experienced a significant I/I response to rain events shortly after the system was commissioned in February 2022, it was contemplated that this system would be suitable for quantification of I/I within a PSS. Although the sample size of rainfall events and climatic conditions since the system was commissioned is relatively small, the results from the analysis may provide rationale to undertake further investigation related to the sources of I/I within the system and remediate the I/I issues appropriately.

The sewage flows from all 151 properties within the Potato Point PSS are measured prior to discharging into a local SPS located on the western side of the village. The SPS is required to collect and store sewage from the PSS before it is pumped by a progressive cavity pump through a small diameter High Density Polyethylene (HDPE) sewer rising main to the Bodalla STP where it is treated before being discharged to the environment.

The Potato Point Reservoir only supplies customers located within the residential area of the Potato Point village. All properties with a water connection are also connected to the PSS, which means that all flows within the water supply and sewerage systems are measured appropriately. There may be some water losses from unauthorised consumption, customer metering inaccuracies and leakage.

Figure 10 shows the location of the rainfall and flow measurement sites relevant to the Potato Point PSS.

Figure 10 – Locality map of rainfall and flow measurement sites for relevant to the Potato Point PSS

3.1.2 Data Collection

The literature review examined several methods of calculating the various components of flow relevant to quantification of I/I. Each method utilises different sets of data, some of which are not relevant to I/I within PSS. It was determined that the data required to undertake the analysis of I/I includes water consumption data, rainfall data, and SPS flow data.

ESC utilises a Supervisory Control and Data Acquisition (SCADA) system to monitor and control its mechanical and electrical water and wastewater equipment. The SCADA system provides an interface that allows straightforward extraction of data into Microsoft Excel .xlsx files that can be analysed in further detail using the Microsoft Excel Spreadsheet software program. An example of the home screen for the Potato Point SPS site in ESC's SCADA system is provided as Figure 11.

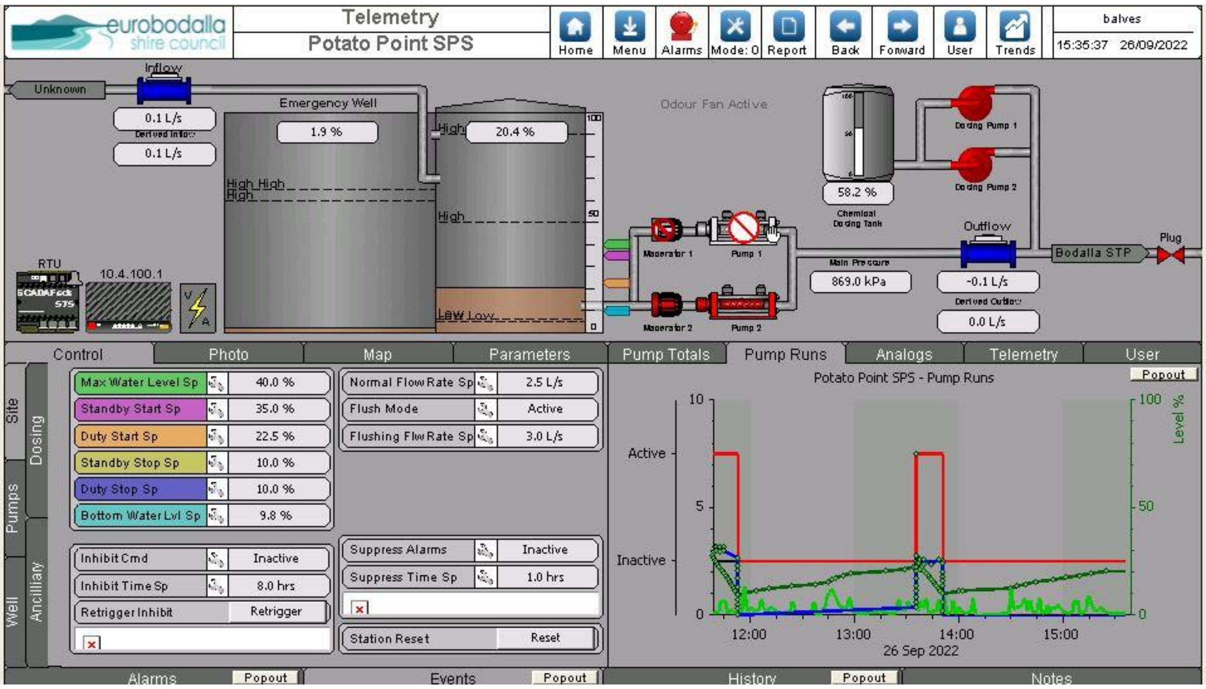

Figure 11 - Potato Point SPS interface from ESC's SCADA system

The following sets of data were acquired for use in the development of the customised hydraulic model and to fulfil the objectives of this research:

<u>Bureau of Meteorology (BOM)</u>

- 2016 Design Rainfalls for the Potato Point village
- Daily observed rainfall data from various stations

<u>ESC SCADA system</u>

- Daily and hourly observed rainfall data from Bodalla STP Weather Station
- Daily and hourly flow total data from Potato Point SPS inlet & outlet flow meters
- Daily flow total data from Potato Point reservoir outlet flow meter

Each set of data was analysed individually before using the data in the development of the hydraulic model. It was checked for reliability, accuracy, and completeness prior to use, with any errors or anomalies noted.

3.1.3 Preliminary Analysis - Rainfall

There are no ESC or BOM weather stations within the Potato Point village, however, there are several stations within proximity. Rainfall data was obtained from the following sources:

- BOM's (2022b) 'Climate Data Online' tool – Daily rainfall (mm) data observed at site:
    - 069122 – Dalmeny (Binalong St) – located 8km South of Potato Point
    - 069036 – Bodalla Post Office – located 7.8km West of Potato Point
- ESC's SCADA system - Hourly and Daily rainfall (mm)
    - Bodalla STP weather station – located 6.4km West of Potato Point

A summary of the daily rainfall from each site is shown in Figure 12 and detailed daily rainfall data is provided in Appendix C.

Preliminary analysis of the daily rainfall data at each site shows that the daily totals are comparable. The rainfall at the Dalmeny site was 124.8mm less than Bodalla STP, with over 80mm of this difference attributable to the period between the 7th and 12th of April 2022. All other periods of rainfall were consistent in terms of total rainfall measured. BOM's daily data was based on resetting at 9am each day, whereas the ESC SCADA Bodalla STP data resets at 12am.

For further analysis, the data from ESC's SCADA Bodalla STP data was used as it provides the benefit of providing hourly flow data as well as having a data reset time which matches the data reset time for the daily flows. This makes it an ideal data set for use in the customised hydraulic model.

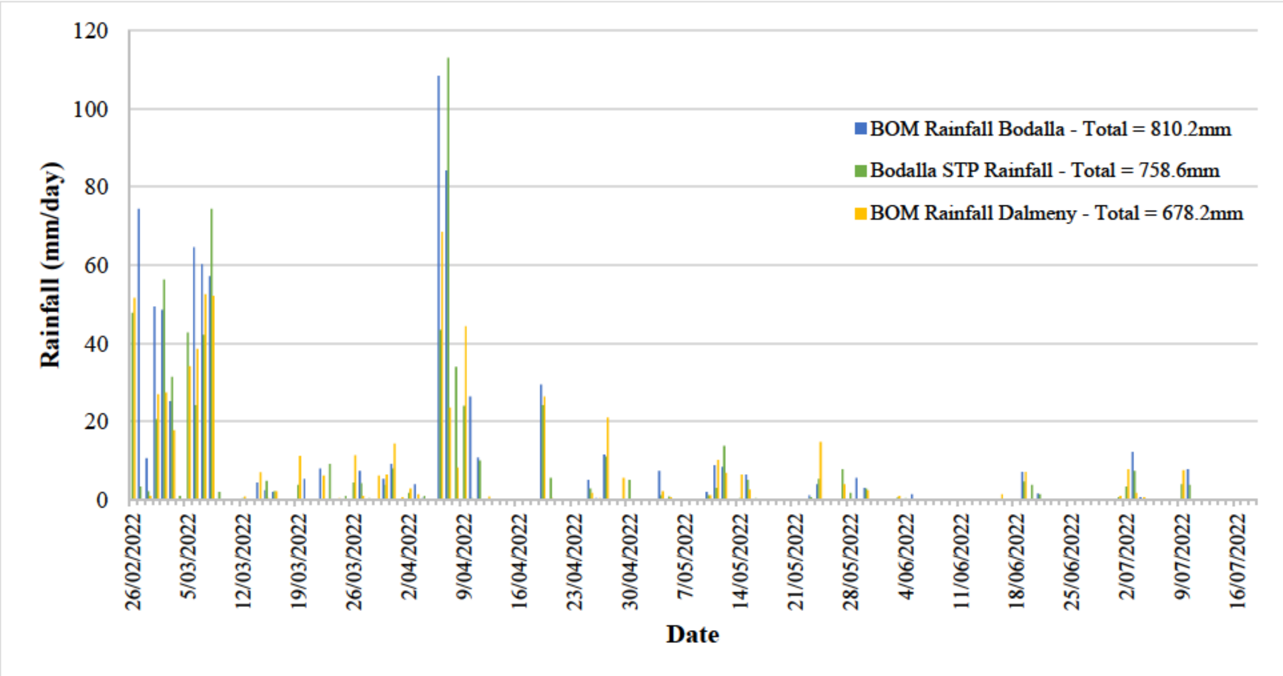

Figure 12 - Daily rainfall observed at each site

3.1.4 Preliminary Analysis - Reservoir Flows

Daily water consumption for the Potato Point Village was assumed to be the daily flows from the Potato Point reservoir, which is measured by the outlet flow meter. A summary of the daily flows is provided in Figure 13 and details of the daily reservoir flow data is provided in Appendix D.

Analysis of the raw data from the reservoir outlet flow meter showed that there was an increase of approximately 40% in water use during the school holiday period between 8th April and 25th April, the increase was from 37.17kL to 52.18kL daily.

It was anticipated that the weekend water consumption would increase because of the village experiencing a seasonal population. However, the analysis of water consumption data showed that there is only a 5.9% difference in average daily water use between Sundays and Wednesdays which were the highest and lowest days for average consumption, respectively. Although there is only a small difference in flows between weekdays and weekends, this does not guarantee the diurnal flow pattern is the same, as the patterns of time in which water is consumed may vary.

Only one anomaly was identified in the Potato Point Reservoir outlet flow meter data, which was a daily reading on 19th July 2022 of 107.52kL. This is approximately three times the average flow during the period being analysed. Further investigation into the unusually high water use on this date did not provide any justification for the high readings, as there were no operational issues reported. The daily flow data for the Reservoir Outlet Flow meter on the 19th of July 2022 was excluded from further analysis.

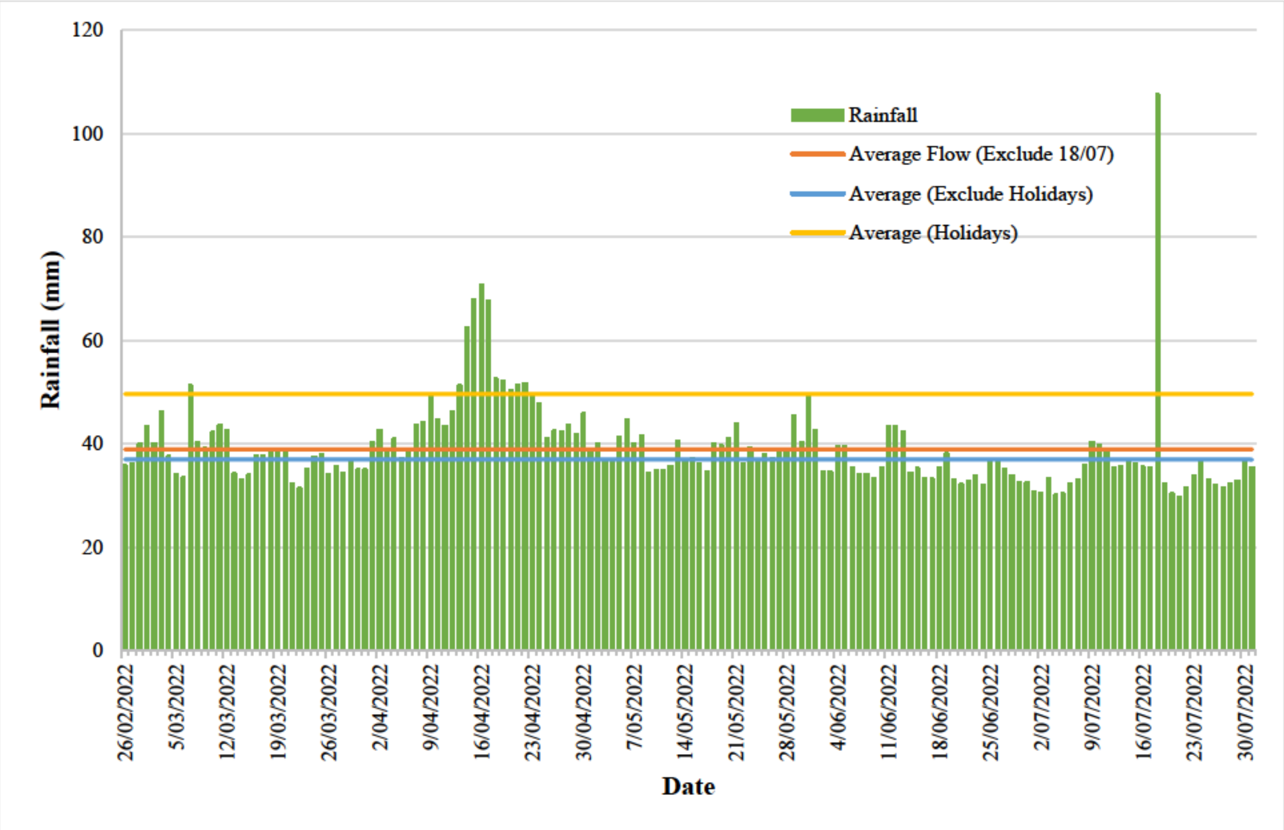

Figure 13 - Daily outlet flow data from Potato Point Reservoir

3.1.5 Preliminary Analysis – Daily SPS Flows

Flow meter data for the Potato Point PSS was extracted from ESC's SCADA system, two sets of data were obtained:

- Potato Point SPS inlet flow meter – hourly & daily totals (kL)
- Potato Point SPS outlet flow meter – hourly & daily totals (kL)

A graph which summarises the daily SPS flows is shown in Figure 14. Detailed daily flow data is provided in Appendix D.

Potato Point SPS inlet flow meter became operational on 18th November 2021, however, the daily flow totals from this date until the 25th of February 2022 are not correct, as the daily flow totals during this period are consistently < 1kL. The data between 6th June 2022 and 5th July 2022 was excluded from further analysis, as no readings were observed by the SPS inlet flow meter during this period.

The SPS outlet flow meter measured totals were consistently greater than the SPS inlet flow meter totals by between 1 and 5kL. This discrepancy is expected as there are contributions to the total daily volume by the SPS wet well washers and any manual washdown by ESC operational staff. Daily flow totals reset at 12am each day, which may mean a portion of the flows for a particular day is not captured in the outflow readings until the following period.

The SPS inlet flow meter data for the period between 26th February 2022 and 31st July 2022 was determined to be suitable for use in the customised hydraulic model

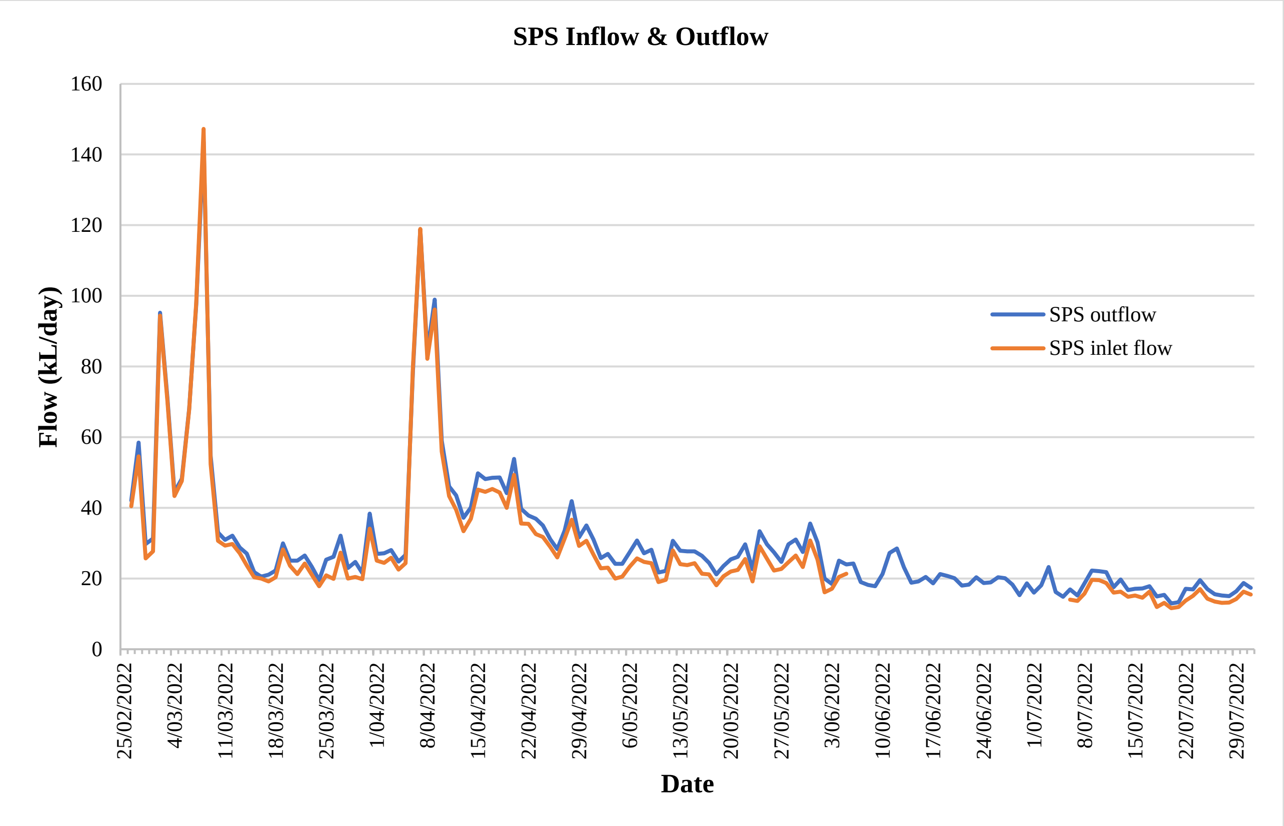

Figure 14 – Potato Point SPS inlet flow and outflow comparison

3.1.6 Preliminary Analysis – Hourly SPS Inlet Flows

A preliminary analysis of the measured hourly flow data from the SPS inlet was undertaken to determine whether it was suitable for use in the model. Several sample sets from dry weather periods were examined to ensure that they followed a diurnal flow pattern, which was confirmed to be the case in all sample sets. An example of a sample set of data where a diurnal flow pattern is followed is shown in Figure 15.

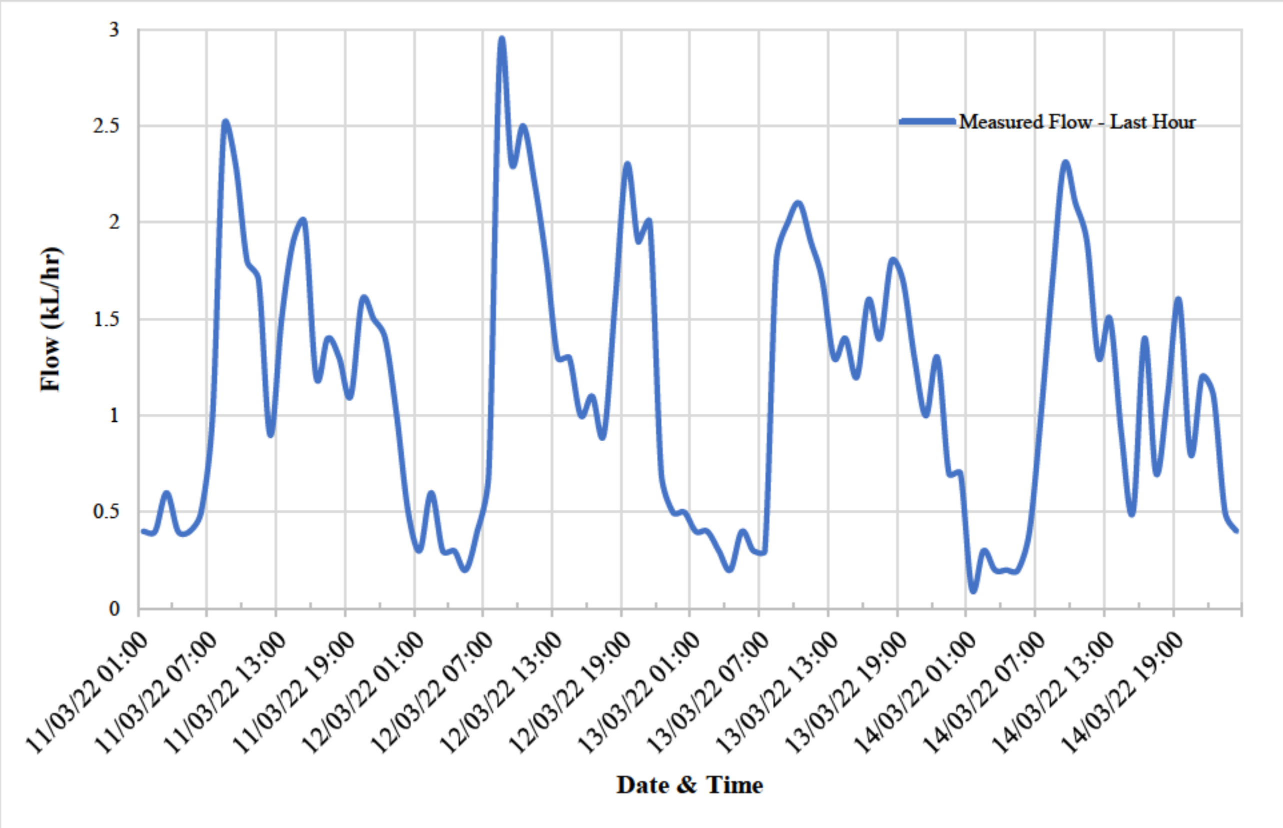

Figure 15 – Measured hourly flow 11/3/22 – 14/3/22

One limitation of the measured hourly flow data is that the measurements were only accurate to the nearest 0.1kL, which did not match the daily flow totals which were accurate to 0.01kL. There was some slight discrepancies where the hourly flow totals for a daily period did not match the flow measurements from the daily flow readings. These inaccuracies were only minor, with all flows confirmed to be within ± 2% of the comparable flows, an example of these discrepancies is shown in Table 3.

	3/5/22	4/5/22	5/5/22	6/5/22	7/5/22	8/5/22	9/5/22	10/5/22
Sum of Hourly flow for day (kL)	22.9	20.2	20.5	23.4	25.7	24.8	24.4	19
Daily flow (kL)	23.06	19.98	20.52	23.4	25.73	24.7	24.37	19.01

Table 3 – Discrepancies between hourly and daily flow totals between 3/5/22 – 10/5/22

3.1.7 Relationship between SPS Inlet Flows, Reservoir Outlet Flows and Rainfall

Establishing a relationship between rainfall and SPS inlet flow is an essential component of the analysis of I/I. If there is no obvious relationship between rainfall and flows, then there is likely no issues related to I/I.

Figure 16 shows the proportional relationship between rainfall and SPS inflow for the Potato Point PSS. The two periods of most significant rainfall during March and April show that there is an initial inflow response where the flow increases sharply after significant rainfall events of >10mm, and a delayed infiltration response where the SPS flows gradually reduce back to normal.

The relationship between reservoir outlet flows and SPS inlet flows is also proportional, however, the proportion of SPS inlet flows to reservoir flows decreases after a prolonged period with no significant rainfall. This is evidence that the antecedent catchment wetness affects the immediate inflow response and subsequent infiltration response following a rainfall event. Therefore, when determining the appropriate DWF during a wet weather event, the timing, duration, and intensity of previous rainfall should be considered whilst quantifying the RDII response.

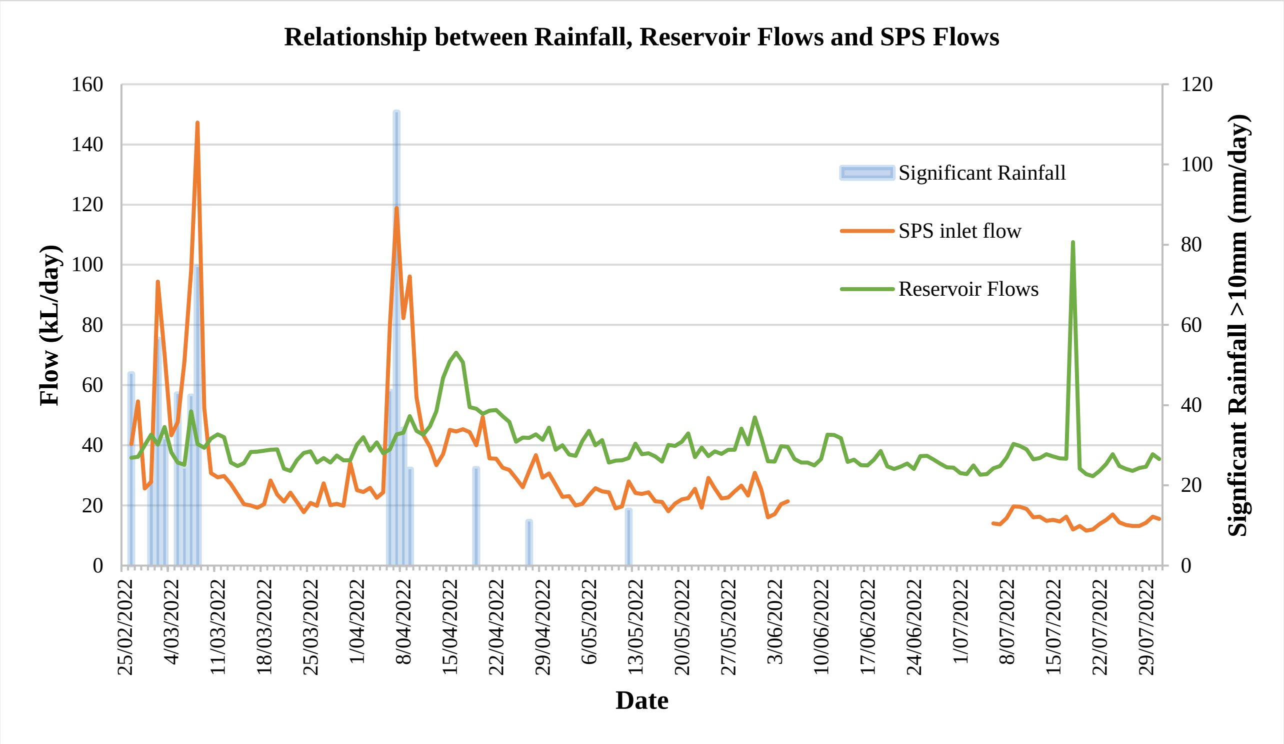

Figure 16 – Relationship between rainfall, reservoir outflow and SPS inlet flow

3.1.8 Data Exclusion

The following dates should be excluded from further analysis as there is errors or anomalies in the data:

- All days prior to the 26th of February 2022
- 6th June 2022 – 5th July 2022 (both dates inclusive)
- 18th July 2022

This provides a total of 125 days for further analysis between the 26th of February 2022 and 31st July 2022.

3.2 Dry Weather Data Analysis

3.2.1 Dry Weather Days

To establish the DWF for any given period, the flows during dry weather need to be analysed. To be considered a dry day, the following criteria must be met:

- total rainfall for day must be less than 1.5mm
- total rainfall in preceding 3 days must be less than 3mm

For this analysis, a dry period is defined as a period of 4 or more consecutive dry days.

3.2.2 Dry Weather Flow

As part of an RDII analysis, it is important to establish a suitable predicted Dry Weather Flow (DWF) hydrograph so that RDII volumes can be quantified. The establishment of DWF hydrographs was completed for two types of days, categorised as follows:

- Dry days that occur on weekdays
- Dry days that occur on weekends/holidays (including school & public holidays)

The DWF hydrographs for each dry period were developed by determining the average SPS inlet flow for each of the 24 hourly increments of a day for the duration of the respective dry period.

In accordance with the method which Carne (2011) determined DWF, both dry weather sanitary flow and GWI are included in the value for DWF.

3.2.3 Proportional DWF Hydrograph

To further enhance the suitability of the DWF hydrograph for use in quantifying the RDII response, it was recognised that a mean DWF hydrograph should be developed for both weekday and weekend/holidays to simplify the inputs of the model whilst still providing a good representation of the residential diurnal flow pattern. A limitation of this was that it is likely that measured flow values would be higher and lower than the values from the mean DWF hydrograph during periods where water consumption is higher and lower than the average daily flow, respectively.

To address this limitation, it was devised that a proportional DWF hydrograph should be developed that represents the hourly flows as a proportion of average hourly flow experienced, rather than a fixed volume. The hourly flow proportion for each of the 24 hourly increments period was calculated for both the weekday and weekend/holiday hydrographs. The average of the flow proportions from all dry periods was used to develop proportional DWF hydrographs for both weekdays and weekend/holidays.

3.2.4 PDWF

PDWF generally occurs in the mid-morning peak in accordance with the diurnal flow pattern. The PDWF for each dry period was determined by identifying the highest measured hourly flow from each period. The peaking factor for the PDWF from each dry period is calculated using equation (3.1), and comparisons are drawn between the calculated factors and those from the various sewer design guidelines.

$$Peaking\ Factor \quad = \quad \frac{PDWF}{ADWF} \tag{3.1}$$

The peaking factor from the proportional DWF hydrographs is determined using equation (3.2). The value of this peaking factor is expected to be lower than the peaking factors determined from the measured flows, as it is deduced from the maximum of the average hourly flow rather than the maximum of measured hourly flow.

$$Peaking\ Factor \ = \frac{Max.\ Flow\ Proportion\ (\%)}{ADWF\ Flow\ Proportion\ \ (\%)} \tag{3.2}$$

3.2.5 GWI

An estimation of GWI was determined by analysing the minimum night-time flows as recommended by Carne (2011). The hours used for the estimation are in accordance with the hours used by the Queensland Department of Energy and Water Supply (2014), which are the hours between midnight and 4:00am.

Because DWF flows include GWI flows, the adoption of a factor for GWI is not necessary for the RDII model. An analysis of the GWI flows was still undertaken to compare the values between each period so the values could be used to evaluate the GWI values compared to the values described by Carne (2011).

3.2.6 Return to Sewer Factor

The relationship between water consumption and sewage flows during each dry period was also analysed to derive a RSF for each dry period. Carne (2011) refers to this as the GWI_2 value however it is referred to as RSF hereafter. The RSF is calculated using equation (3.3)

$$RSF = \frac{Sewage\ Inflows}{Water\ Consumption} \tag{3.3}$$

3.2.7 Establishing DWF

DWF for any given period is different based on varying daily water consumption and differing RSF's for various times of the year. For the model to be as accurate as possible, determination of a suitable DWF should consider these factors. It was hypothesised that equation (3.4) would provide a better representation of predicted DWF than the methods used by the various sewer design guidelines, as it incorporates daily water consumption values as a variable, which are likely to impact daily inlet flows to the SPS.

$$DWF = Daily\ Reservoir\ Flow\ \times Hourly\ Flow\ Proportion\ \times RSF \tag{3.4}$$

3.3 Wet Weather Analysis

3.3.1 AEP Events

Intensity Frequency Duration (IFD) Tables and Charts for the Bodalla STP weather station were obtained from BOM's 2016 Design Rainfall Data System (BOM, 2022c). The AEP data for the 63.2%, 50%, 20% and 10% events for all periods greater than 1 hour and the measured hourly rainfall data from Bodalla STP Weather Station was entered into Microsoft Excel so that the AEP for rain events during the analysis period could be determined. Details of the IFD Design Rainfalls and Very Frequent Design Rainfalls are provided in Appendix E.

Periods of rain that exceed the 63.2% AEP (1 in 1 year ARI) event for 1 hour or greater were identified in Excel and were used for quantifying the RDII response in the wet weather model. The entire duration of these wet weather periods was analysed.

3.3.2 PWWF

PWWF is an important parameter to understand the impact of RDII during rainfall events. PWWF for this analysis is defined by determining the highest hourly flow total into the SPS for each of the wet weather periods being analysed. This is in accordance with the method used by Carne (2011).

3.3.3 RDII

RDII volume is equal to the measured flow minus the DWF determined for any given period. When analysing flow hydrographs, RDII volume is equal to the area between the measured flow and DWF.

3.4 Customised Hydraulic Model Development

3.4.1 Model Objective

Once the data was verified to ensure it is reliable, accurate, and complete, it was then used in the development of the customised hydraulic model.

The objective of the development of the model is effectively quantify the RDII response to a rainfall event for events of varying duration and intensity. If the development of the model is successful it should provide outputs which assist in determining how significant the I/I issues are in the system, and if they need to be addressed. The technique used for quantification of I/I was comparable to the method used in the I/I management guidelines by Carne (2011) and Carne & Le (2015a), albeit with some slight differences in determining the DWF.

3.4.2 Excel Processing

Microsoft Excel was used to analyse all forms of data obtained and to create the customised hydraulic model. A major benefit of using an Excel based model was that it provided a simple user interface that was compatible with all forms of input data obtained. It also allows for production of graphs which are a great tool to visually demonstrate the effects rainfall is having on flows into the SPS.

3.4.3 Daily DWF Model

The accuracy and reliability of the daily DWF was improved during the development of the model through calibration, validation, and optimisation. Three different iterations were modelled to confirm that DWF was suitable for use in the wet weather model. The required inputs and assumptions made for each of the three iterations are as follows:

Iteration 1

- Assume daily DWF is equal to the average daily DWF from all days in dry periods 1 – 6.
- Reservoir flows ignored
- RSF ignored

Iteration 2

- Determine daily DWF for each day using equation (3.4)
- Daily reservoir flow is the measured reservoir outlet flow from the respective day
- RSF is assumed to be the average of the RSF values from all dry periods

Iteration 3

- Determine daily DWF for each day using equation (3.4)
- Daily reservoir flow is the measured reservoir outlet flow from the respective day
- RSF is equal to the RSF calculated for the respective period

Predicted daily DWF for each iteration was compared to the measured daily flows so the accuracy and reliability of each iteration could be determined, to ensure that DWF values were suitable for use in the customised hydraulic model.

3.4.4 Hourly DWF Model

An excel model was developed to model the hourly flows in accordance with the assumptions made for iteration 3 of the daily DWF calculation. The following data was required for input into the model:

- Hourly SPS inlet flow data
- Daily Flow – Potato Point reservoir outlet flow meter
- Hourly DWF flow proportion for weekdays and weekend/holidays
- Return to Sewer Factor for dry periods

Given that a pressure sewer unit does not pump sewage immediately after receiving it, it is unlikely that the hourly DWF model provides a diurnal pattern without errors. However, given that the RSF used in the model was derived based on the total water consumption and sewage flows for each dry period, the total of the hourly predicted DWF's should match the measured flows for the respective dry period. Confirmation that this is the case validates the hourly DWF model is providing appropriate outputs.

3.4.5 RDII Quantification Model

The RDII quantification model incorporates the hourly DWF model as the means of establishing appropriate DWF values. Hourly rainfall was also used as an input in the model to assist in illustrating how the hourly SPS flows increase as a response to rainfall.

The RDII volume for each hour is calculated by subtracting the hourly DWF from the measured flow. Any situations where measured flow is less than DWF should be investigated further to determine why this is the case.

The RDII analysis focuses on the period from when rainfall commences, and sewage flows increase above normal DWF flow until flows return to normal DWF. Ideally, there should be no negative values for RDII during the wet weather period, however, minor negative RDII values are acceptable as they are unavoidable without a perfect model. The sum of the RDII volume is produced as an output of the model, which is used for discussion of results.

Other outputs from the model which need to be considered when discussing results include measured inlet flow, reservoir flows, RSF, predicted DWF, total rainfall, PDWF, and PWWF.

3.4.6 RDII Analysis

Initially, the entire wet weather period and the following dry period is analysed to gain an understanding of how rainfall impacts the sewage flows. Each wet weather period is then split into segments for detailed analysis based on when the rain is falling during each period, so that the RDII response can be evaluated based on the intensity, duration, and volume of rainfall, as well as increasing levels of antecedent catchment wetness.

3.4.7 Limitations and Assumptions

Limited flow data is available as the Potato Point inlet flow meter only became operational in February 2022. This is a limitation of the research as ideally several years of data would have been available for a range of climatic conditions to improve the accuracy, consistency, and reliability of the DWF flows. A longer analysis period would have provided more rain events of varying duration and intensity where the RDII response could be quantified. Haarhoff & van der Linde (2009) demonstrated that even with limited flow monitoring data, analysis of a PSS can still provide results which provide insight to how a system is performing relative to the expected volumes of I/I.

An assumption made to enable the development of a suitable DWF model for a rain event was the RSF for a wet weather period was selected as the RSF from the dry period which succeeded the wet weather period being analysed. Adoption of a RSF in this manner may mean that the predicted hourly flows return to normal quite quickly following a rainfall event, which may result in an underestimation of the infiltration component that occurs due to an increase in antecedent catchment wetness.

3.5 Comparison with Guidelines

The outputs from the RDII quantification model are compared to the design factors identified in the various pressure sewer design guidelines from Australia during the literature review. The relevant flow components from each method were calculated, using the design parameters from the Potato Point system. The outputs from the model are also compared to the KPI's from the I/I management guidelines reviewed in the literature review. The results were not compared to the gravity sewer design guidelines as part of this comparison.

Outputs from wet weather periods were compared and the event with the greatest magnitude of rainfall response was used for the comparisons with the pressure sewer design guidelines.

3.6 Operational Costs Analysis

The electricity costs associated with collecting and transporting sewage between private properties and the Potato Point SPS are borne by the property owner, however, Council is responsible for all other operation and maintenance costs.

For simplicity in the cost analysis due to time constraints, the OPEX costs adopted for the Potato Point PSS are adopted as Eurobodalla's operational costs of 288.57 c/kL for the 2020-21FY (NSW DPIE, 2022).

To determine the operational costs associated with the I/I, an analysis of the predicted volumes of I/I was undertaken for an average year which considered the outputs from the RDII model. The mean rainfall for Bodalla of 974.8mm from Table 4 below was be adopted. I/I volumes for a mean year are multiplied by the operational cost of 288.57c/kL to determine the annual costs associated with the I/I.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	96.6	106.9	112.2	81.7	75.1	83.9	54.5	54.8	59.8	78.2	80.2	87.3	974.8
Lowest	2.5	2.6	1.3	0.0	0.0	0.0	0.0	0.2	0.0	4.2	1.2	3.8	412.5
5th percentile	11.8	8.7	8.9	2.8	3.7	3.5	1.4	2.5	4.7	10.5	7.6	14.7	577.8
10th percentile	16.8	16.2	18.2	8.4	8.6	6.3	4.1	4.6	9.9	17.8	16.7	19.7	626.4
Median	74.8	64.6	71.4	46.2	47.0	45.0	28.3	25.0	43.5	53.7	68.1	68.2	927.1
90th percentile	211.2	212.8	249.3	216.1	210.9	192.3	152.8	149.4	133.9	151.7	157.3	204.6	1397.0
95th percentile	274.0	337.1	346.4	236.3	230.2	284.6	206.1	193.6	175.5	188.6	205.6	227.8	1673.9
Highest	550.8	811.3	605.4	557.0	776.9	555.4	281.5	377.9	456.9	756.6	396.4	354.5	1892.6

Table 4 - Bodalla Post Office 069036 monthly rainfall statistics (BOM, 2022b)

An analysis of the CAPEX and OPEX costs associated with design and construction of appropriately sized sewerage collection, transfer, and treatment infrastructure was excluded from the analysis. The focus of the cost analysis is to determine the economic impacts of I/I, based on using the existing infrastructure for collection, transfer, and treatment.

4 Results and Discussion

4.1 Dry Weather Analysis

4.1.1 Dry Weather Days

The dry weather criteria provided a total of 48 dry days out of a total of 127. Of the 48 dry days, there were 6 periods of 4 or more consecutive dry days which are analysed in further detail. These periods are:

- 11th March – 14th March (Period 1)
- 14th April – 18th April (Period 2)
- 3rd May – 10th May (Period 3)
- 18th May – 23rd May (Period 4)
- 2nd June – 5th June (Period 5)
- 13th July – 20th July (Period 6)

The number of dry days and duration of dry periods were less than anticipated, which may have been influenced by the La Niña event that influenced the east coast of Australia between 23rd November 2021 and 21st June 2022 (BOM 2022d).

4.1.2 DWF Hydrographs

The mean DWF flow hydrographs for each period was determined for weekdays and weekends/holidays. Examples of the weekday DWF hydrographs is shown in Figure 17 below. Whilst a diurnal flow pattern was observed for all periods, there was a significant difference in the peak daily flows and subsequently the total flows from each dry period. Details of the hourly flows during dry weather are provided in Appendix F.

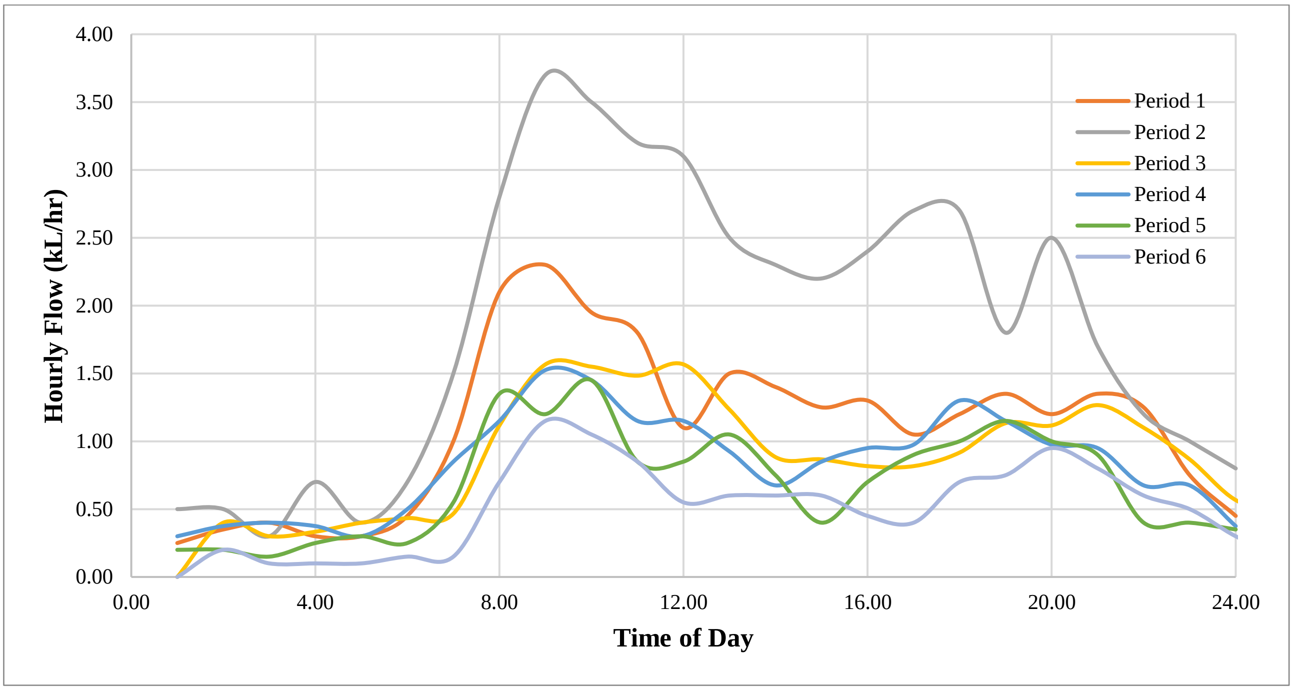

Figure 17 – Mean weekday DWF hydrographs from each dry period

4.1.3 Proportional DWF

Proportional DWF hydrograph for weekdays and weekend/holidays were developed by taking the average of the flow proportions from all dry periods. Details of the average hourly flow from each period are provided in Appendix F.

The proportional DWF hydrographs developed indicate a suitable diurnal flow pattern. These hydrographs are provided in Figure 18. The weekends/holidays hydrograph shows that the peak flows which occur mid-morning are of greater magnitude and occur approximately one hour later than the peak flows on weekdays. This is comparable to the pattern detailed by Carne (2018) in Figure 7, however the peaks observed by Carne were approximately 3 hours apart.

The proportional DWF hydrographs were also compared to the residential diurnal sewer demand factors produced by Hunter Water (2018) which are detailed in Table 1. The night-time GWI flows from this design guideline were equal to a much smaller proportion of the flows. This shows that the Potato Point PSS may have I/I issues due to the increased proportions of GWI. The diurnal pattern observed in the Hunter Water hydrograph was comparable to weekday and weekend/holiday DWF hydrographs for Potato Point, albeit with a greater magnitude of morning peak. The peak morning and afternoon flows occurred between 1 and 2 hours prior to those observed in the Potato Point PSS.

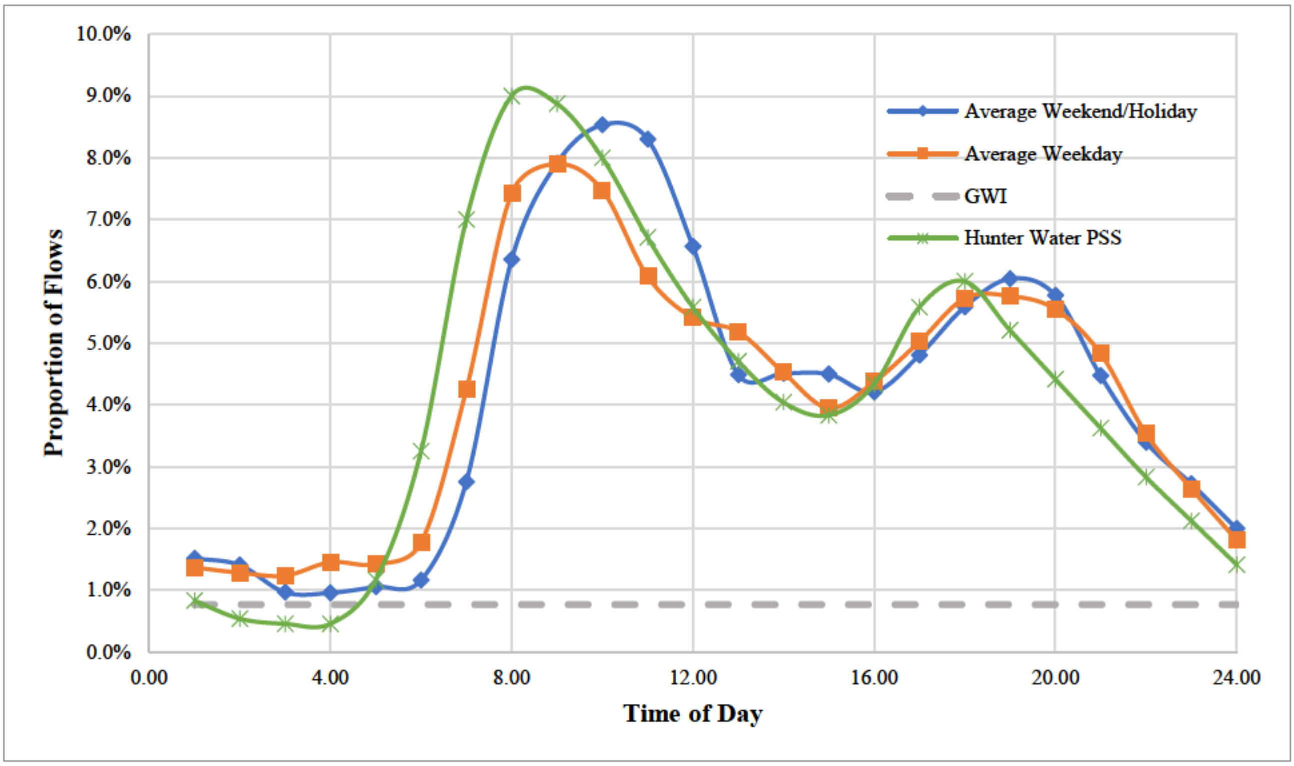

Figure 18 – Average daily DWF hydrographs proportional to hourly flows

4.1.4 PDWF

PDWF values and peaking factors were determined for each of the 6 dry periods using equation (3.1), and for proportional DWF flows using equation (3.2). The details of the PDWF analysis are provided in Table 5.

Period	DWF (kL/hr)	PDWF (kL/hr)	Peaking Factor	Date/Time
Period 1	1.14	2.9	2.54	12/03/2022 8:00
Period 2	1.80	4.2	2.33	16/04/2022 9:00
Period 3	0.94	2.5	2.65	7/05/2022 10:00
Period 4	0.89	2.3	2.59	22/05/2022 10:00
Period 5	0.78	2.2	2.82	5/06/2022 10:00
Period 6	0.61	2.3	3.77	17/07/2022 9:00
Averages	1.03	2.73	2.78	

Table 5 - Summary of DWF, PDWF values and peaking factors for each dry period

The PDWF has significant variations, however the peaking factor is quite consistent except for Period 6. Periods 1-5 all have a peaking factor between 2.33 and 2.82 which shows consistency between the flows from each period. These peaking factors are in accordance with expected values from the design guidelines.

The PDWF peaking factor for the proportional DWF was also derived, with details as follows:

- Average Proportional PDWF factor for weekdays = 1.90 × DWF (8am – 9am)
- Average Proportional PDWF factor for weekends/holidays = 2.05 × DWF (9am – 10am)

4.1.5 GWI

To determine a GWI which reflects the minimum night-time flow percentages recommended by Carne (2011), values between 50% and 80% were analysed. An optimum value of 60% of the minimum night-time flows was adopted for GWI.

The factor of 60% provided an average daily GWI percentage of 18.49% of the daily flows which is equal to 0.77% when converted to an hourly percentage. When adopting this value, the percentage of morning flows for all periods between 12am and 4am are in accordance with the values advised by Carne & Le (2015) except for the average flows between 3am and 4am which were 80.3%. Details for the GWI proportions are provided in Table 6 and Table 7.

Weekday Average Hourly Flow Proportions			
Hour	Average	GWI	% AM Flows
1.00	1.37%	0.77%	56.2%
2.00	1.29%	0.77%	59.9%
3.00	1.24%	0.77%	62.2%
4.00	1.46%	0.77%	52.9%
Average	1.34%	0.77%	57.83%

Table 6 - Weekday GWI and % of morning flows

Weekend/Holiday Average Hourly Flow Proportions			
Hour	Average	GWI	% AM Flows
1.00	1.52%	0.77%	50.7%
2.00	1.41%	0.77%	54.7%
3.00	0.97%	0.77%	79.6%
4.00	0.96%	0.77%	80.3%
Average	1.21%	0.77%	66.33%

Table 7 - Weekend/Holiday GWI and % of morning flows

4.1.6 Return to Sewer Factor

The RSF for each dry period was determined using equation (3.3) so that appropriate RSF values could be used in the RDII quantification model. The RSF for each dry period varies significantly, which is likely because of varying antecedent catchment wetness for the Potato Point village for the dry periods. For initial analysis of the wet weather period, the RSF used was equal to the RSF from the dry period which succeeded each wet weather period. The RSF for each dry period is shown in Table 8.

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Averages
DWF Hourly (kL/hr)	1.14	1.80	0.94	0.89	0.78	0.61	1.03
DWF Daily (kL/d)	27.38	43.30	22.61	21.30	18.73	14.66	24.66
Ave. Res Flows (kL/d)	38.41	64.24	38.81	40.04	37.10	34.67	42.21
RSF %	71.3%	67.4%	58.3%	53.2%	50.5%	42.3%	57.1%

Table 8 – Return to Sewer Factor details

4.2 Wet Weather Analysis

4.2.1 AEP Events

Two events were found to have exceeded 63.2% AEP event for any of the IFD durations from the IFD table provided in Appendix E. These events were analysed further with the RDII quantification model. Details of these rainfall events are:

Event 1

- Period between 26th February – 9th March
- Total Rainfall = 348.4mm
- Greatest 1 hour rainfall = 16.2mm
- Greatest 24 hour rainfall = 93.2mm
- Exceeded the 63.2% AEP Event for 48 hour period
- Exceeded 50% AEP Event for all IFD Periods ≥72 hours
- Within 4mm of exceeding 20% AEP Event for 168 hour period of 290mm

Event 2

- Rain Period 6th April – 11th April
- Total Rainfall = 224.8mm
- Greatest 1 hour rainfall = 21.4mm
- Greatest 24 hour rainfall = 141mm
- Exceeded the 63.2% AEP Event for 1 hour, 6 hour and 9 hour periods
- Exceeded the 50% AEP Event for all IFD periods ≥ 9 hours

4.3 Customised Hydraulic Model Development

4.3.1 Daily DWF Model

Detailed flow data and results from the calibration, validation, and optimisation of the daily DWF is provided in Appendix G. Iteration 3 provided the most accurate and reliable values for daily DWF during the dry period. Figure 19 shows the relationship between the measured flows and the predicted DWF for each dry weather day.

Iteration 1 was the least accurate of the three modelling techniques used. This technique fails to provide suitable DWF volumes on days which are much greater or lower than the mean DWF. This technique only estimates the DWF to within 25% of the measured flow, 53% of the time which is not ideal for use in the hourly DWF model.

When using the technique detailed in Iteration 2, the accuracy of the daily DWF model improves to being within 25% of the measured flow 74% of the time. Whilst this is an improvement, it would still result in issues when using this technique in the RDII model, as there is potential for a greater number of RDII values that are negative which may cast doubt over the reliability of the RDII model.

When applying the technique from Iteration 3 which uses equation (3.4) to determine the daily DWF, the predicted flow is within 10% of the measured flow 76% of the time and within 25% of the measured flow 100% of the time. This is a much better representation of the DWF and is therefore suitable for use in the RDII quantification model.

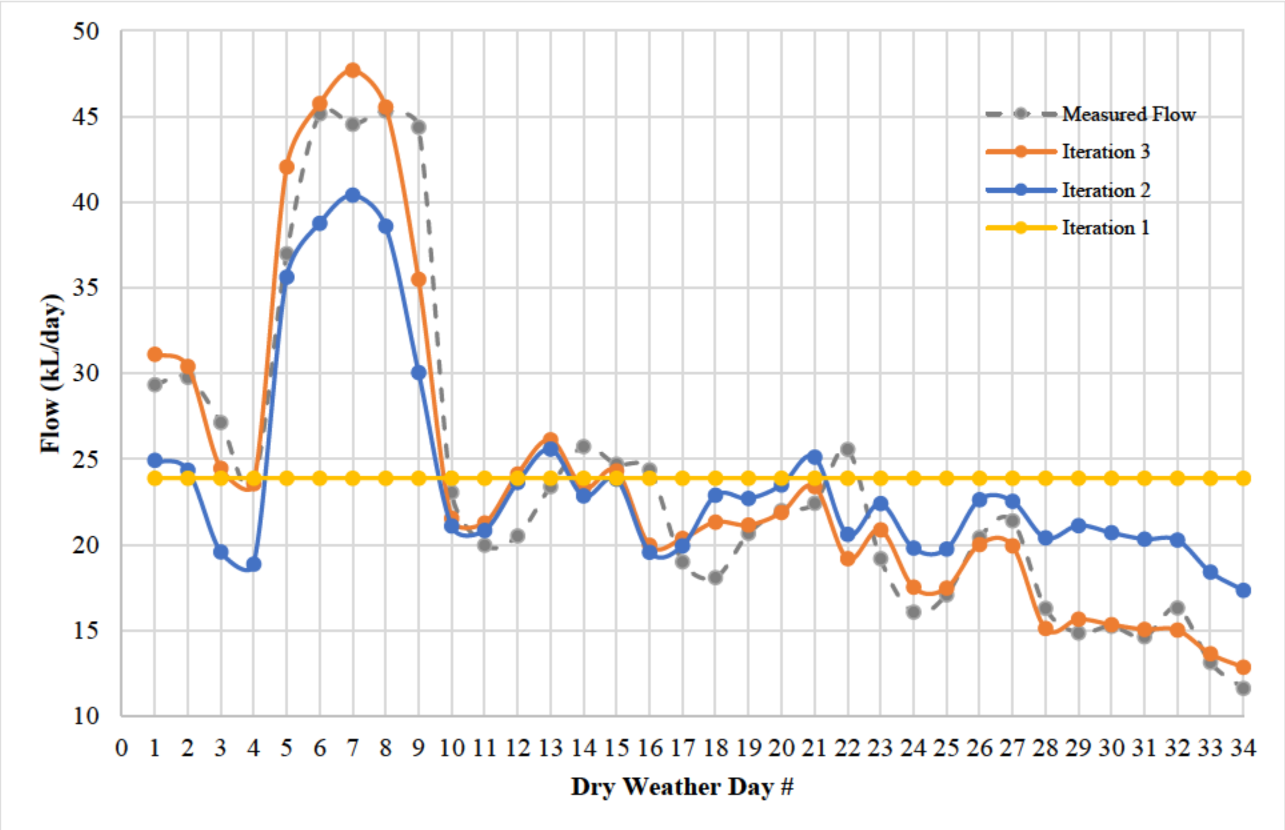

Figure 19 – Graph comparing the daily DWF from each iteration

4.3.2 Hourly DWF Model

The predicted dry weather flows were confirmed to be the same as the total of measured flow for period 3. Figure 20 and Figure 21 show the predicted hourly DWF flows compared with the measured hourly flows from the Potato Point SPS inlet flow meter for Dry Period 1 and 3, respectively.

The hydrograph demonstrates that the hourly DWF model has good DWF prediction capabilities with suitable diurnal flow patterns. Details of the hourly DWF model for Period 3 is provided in Appendix H.

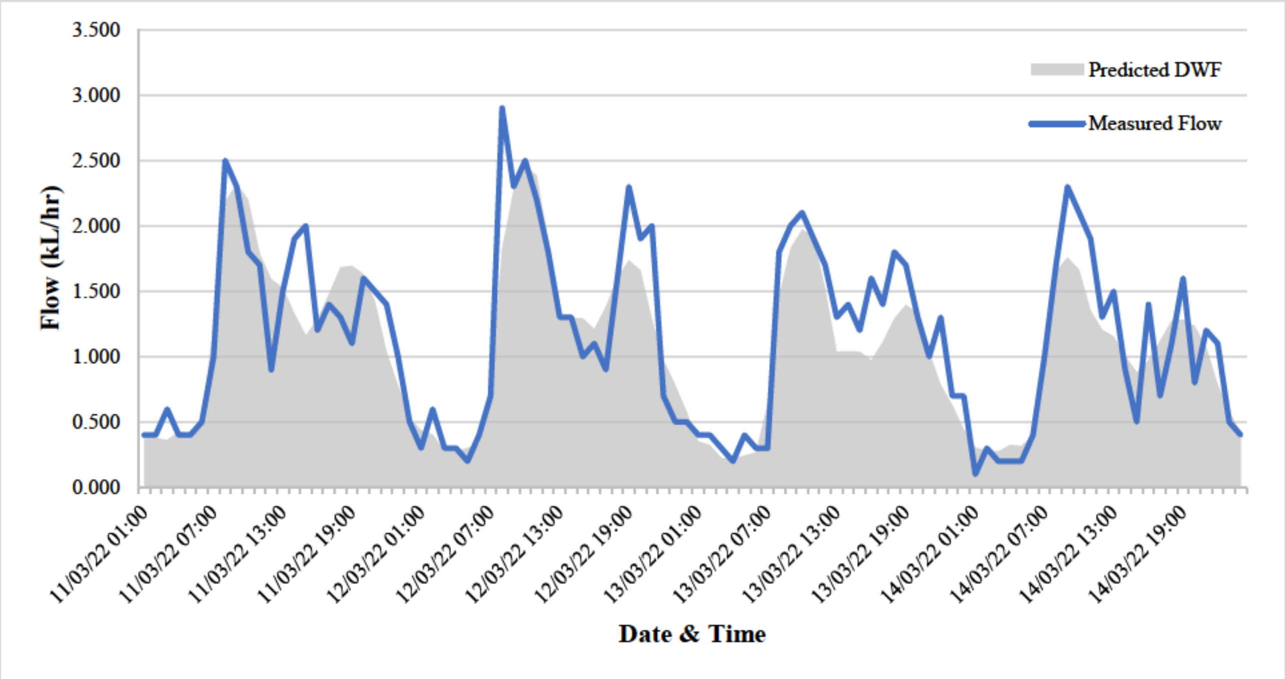

Figure 20 - Period 1 hourly DWF model validation

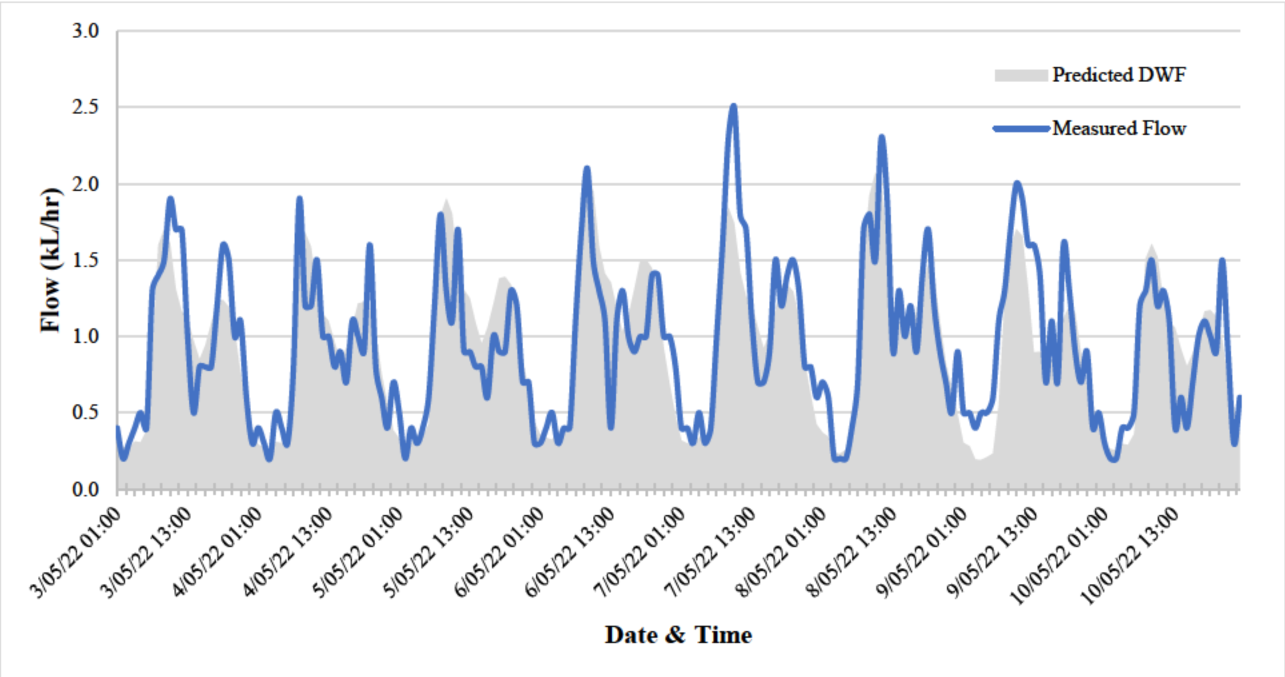

Figure 21 – Period 3 hourly DWF model validation

4.4 RDII Quantification

4.4.1 Wet Weather Period 1 (WWP1) Preliminary RDII Analysis

The first analysis focuses on the period between 26/2/2022 and 14/3/22. The hourly rainfall and flows were imported into the RDII quantification model, and the DWF for each hourly period was established using the technique from Iteration 3 which determines DWF using equation (3.4). Details of the hourly flows for the wet weather period are provided in Appendix F.

A RSF of 71.3% was adopted which was the RSF value for dry period 1, which is at the end of this analysis period. The daily reservoir flows were obtained from Appendix D and were also imported into the model.

The RDII volume is equal to the area between the measured flow and DWF, any situations where measured flow is less than DWF should be investigated further to determine why this is the case. There were several negative values of RDII identified prior to the rain commencing and after the flows returned to normal for the rainfall during the 24 hour period from 9am 26/2/22. It was concluded that a reduced RSF factor should be adopted for this period so that predicted DWF was closer to measured flow, the RSF for the period from 9am 26/2/22 – 9pm 1/3/22 was changed to 55% accordingly, and the DWF became a better match. The RSF after this period was retained as 71.3%. A hydrograph which incorporates the revised RSF values is shown in Figure 22. Examples of the RDII model used for the preliminary analysis for both wet weather periods is provided in Appendix H.

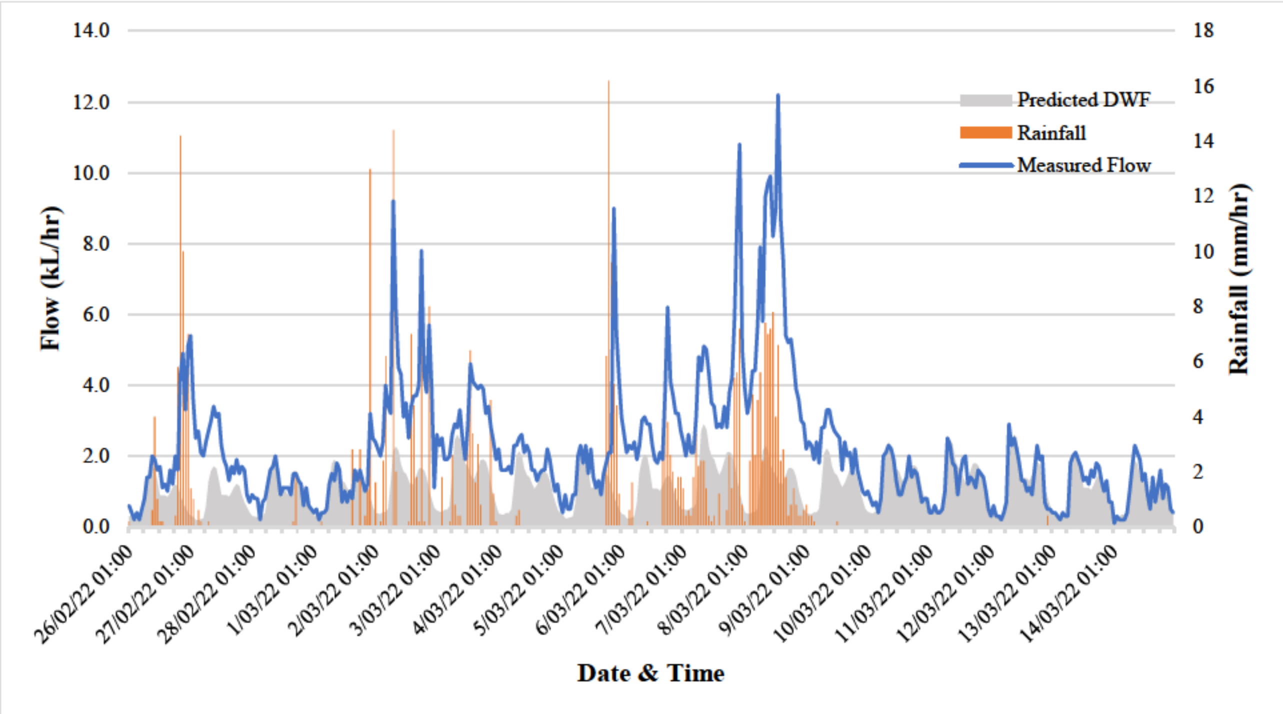

Figure 22 – Period 1 hydrograph

4.4.2 WWP1 Detailed RDII Analysis

A more detailed analysis was also undertaken for the periods where there is significant RDII. There are three distinguishable periods of rainfall within WWP1 where measured flows return to DWF prior to the next period of rainfall occurring. An example of the detailed analysis model is provided in Appendix H. The detailed analysis was completed for three segments, with dates and RSF details as follows:

- Segment 1 - 8am 26/2/22 – 8am 28/2/22 (RSF 55%) – Hydrograph shown as Figure 23
- Segment 2 – 9pm 1/3/22 – 5pm 5/3/22 (RSF 71.3%) – Hydrograph shown as Figure 24
- Segment 3 – 5pm 5/3/22 – 8am 10/3/22 (RSF 71.3%) – Hydrograph show as Figure 25

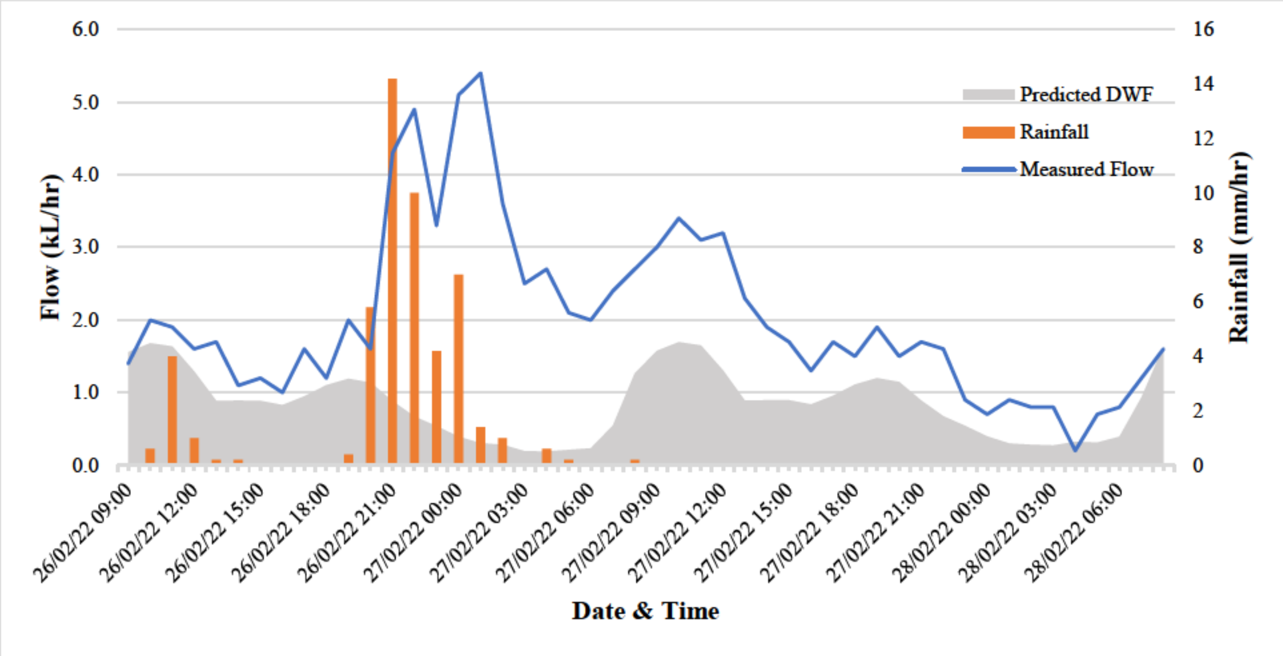

Figure 23 – Period 1 Segment 1 hydrograph

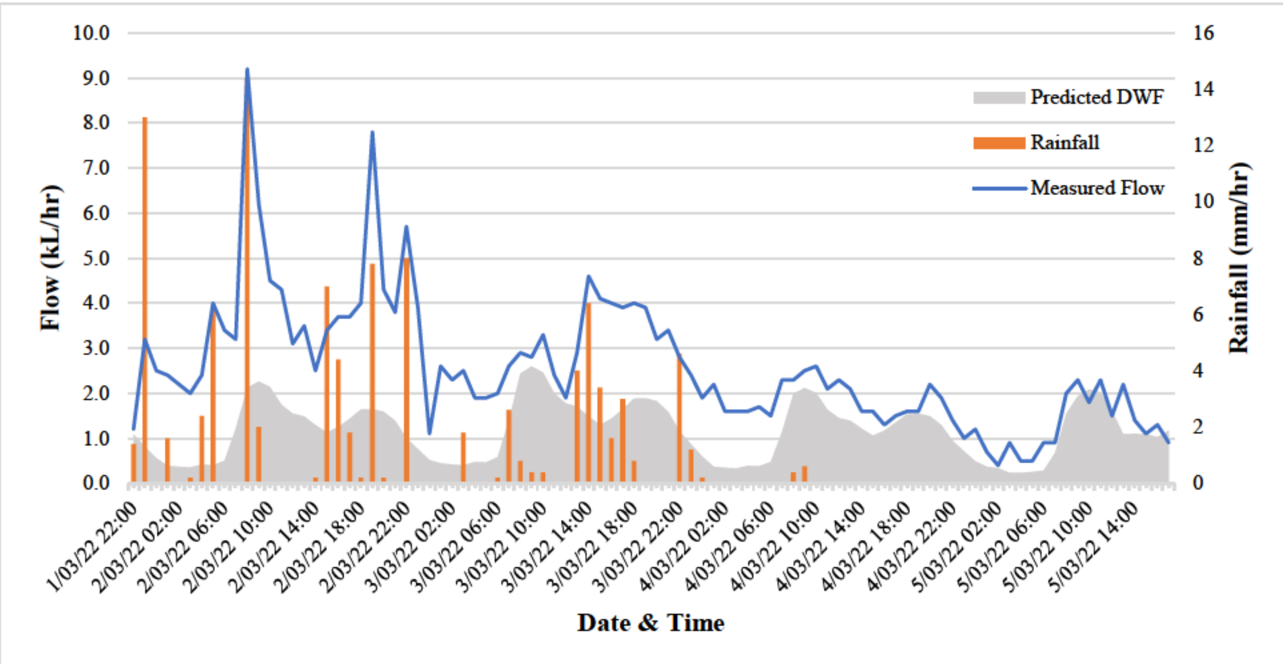

Figure 24 – Period 1 Segment 2 hydrograph

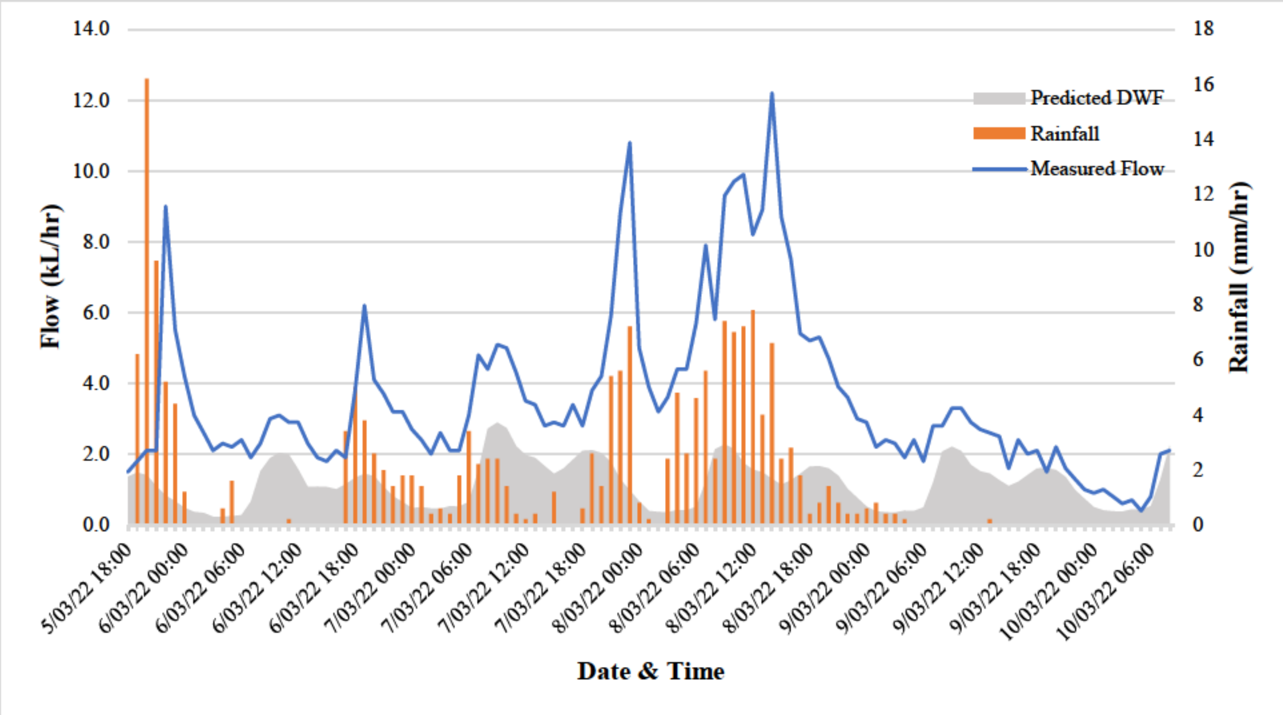

Figure 25 – Period 1 Segment 3 hydrograph

4.4.3 Wet Weather Period 2 (WWP2) Preliminary RDII Analysis

The second analysis of I/I was for the period for the period between 5/4/2022 and 18/4/22, the last 4 days of this analysis are the same as from dry period 2. A RSF of 67.4% was adopted throughout the wet weather period which was confirmed to be appropriate by analysing the RDII values. A hydrograph for the entire period is provided in Figure 26.

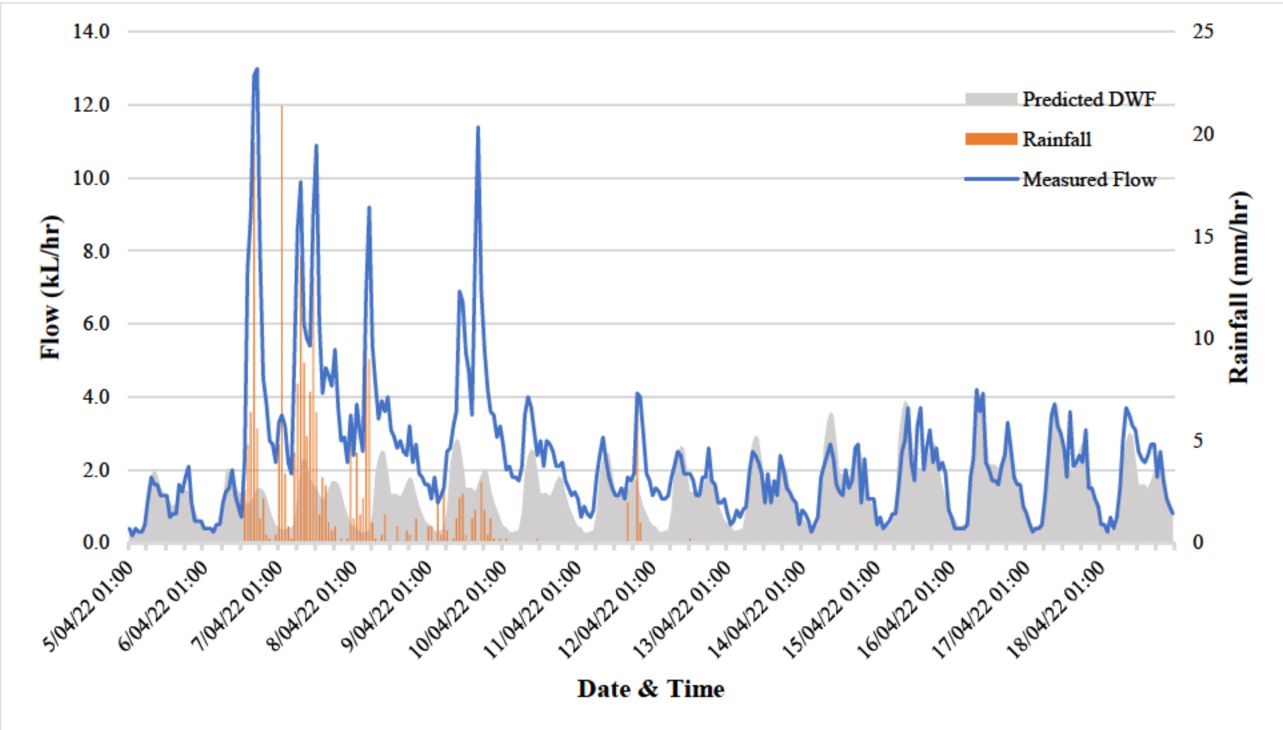

Figure 26 - Period 2 hydrograph

4.4.4 WWP2 Detailed RDII Analysis

The detailed RDII analysis only focuses on times where flows are greater than what would have been anticipated during dry weather. Two blocks of rainfall of were identified for further RDII analysis from Period 2, with dates and RSF details as follows:

- Segment 1 – 2pm 6/4/22 – 10am 11/4/22 (RSF 67.4%) Hydrograph shown as Figure 27
- Segment 2 – 4pm 11/4/22 – 9am 12/4/22 (RSF 67.4%) Hydrograph shown as Figure 28

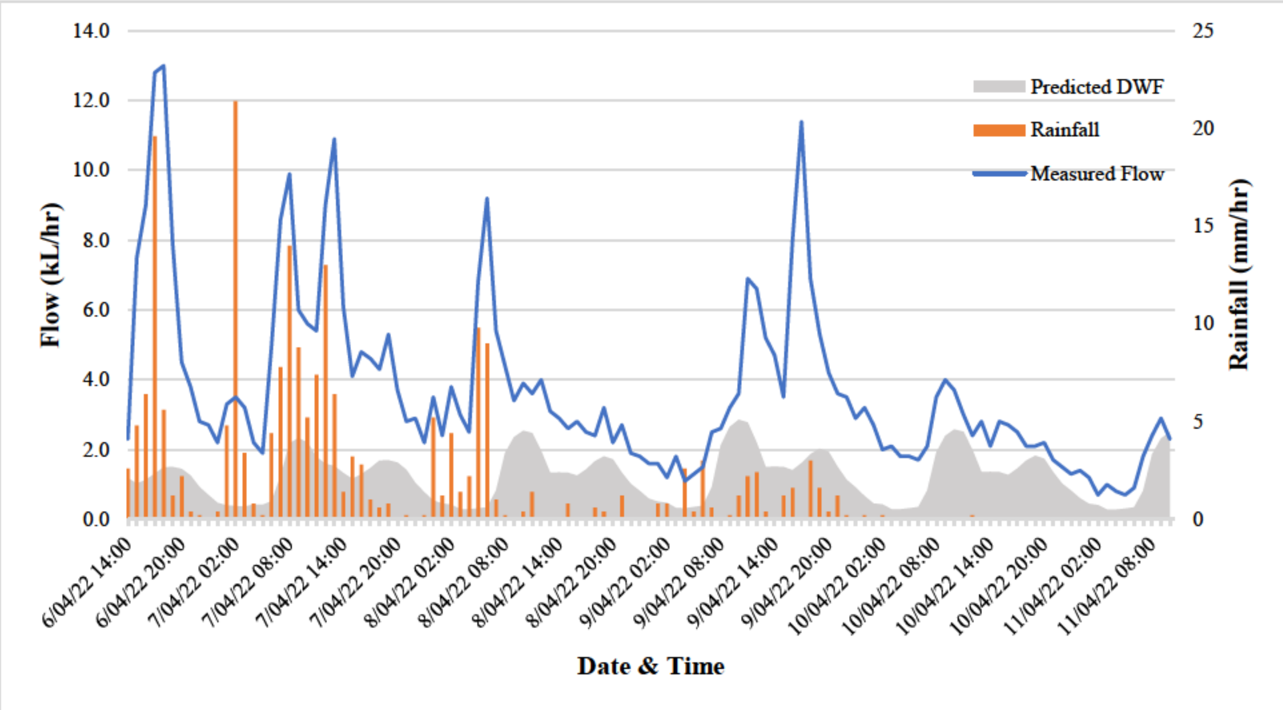

Figure 27 – Period 2 Segment 1 hydrograph

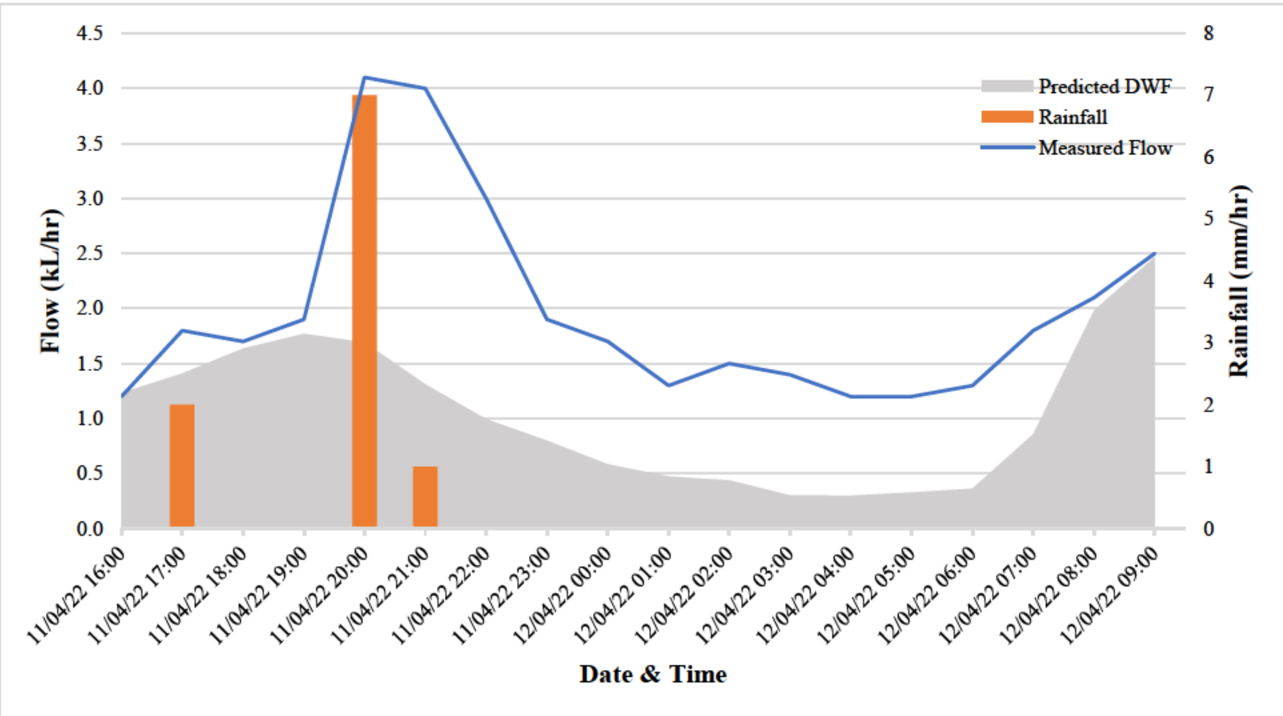

Figure 28 – Period 2 Segment 2 hydrograph

4.4.5 Discussion

The preliminary analysis of the two wet weather periods analysed produced comparable outputs, these are provided in Table 9. WWP2 had less total rainfall but had higher IFD rainfall intensities which corresponded to a lower probability AEP being exceeded. The more intense rainfall resulted in a higher PWWF than the peak from WWP1. The values determined for ratio of rainfall to RDII were within 5% of each other, which demonstrates that the RDII response is quite consistent based on the two wet weather periods analysed.

Peak measured flows occurred simultaneously with periods of high intensity rainfall, there was little lag time between rain falling and flows being measured, which demonstrates the inflow response to a rain event is significant and immediate. For both WWP1 and WWP2, flow volumes returned to DWF rates approximately 30 hours after the rainfall had concluded for each wet weather period.

RDII Model Outputs Summary – Preliminary Analysis		
Output	**Period 1**	**Period 2**
ADWF (kL/hr)	1.12	1.45
PDWF (kL/hr)	2.89	4.07
Average Daily Res Flow (kL)	39.64	51.46
Time (hrs)	408	336
Rainfall (mm)	348.8	225.00
SPS inlet flow (kL)	909.5	790.50
RDII (kL)	453.74	304.92
Rainfall: RDII (mm: kL)	1.30	1.36
PWWF (kL/hr)	10.92	13.00

Table 9 – RDII model outputs from preliminary analysis

The detailed analysis of the wet weather periods provided additional insight of the RDII response to rainfall events. For WWP1, the Rainfall to RDII ratio was the lowest for Segment 1 and highest for Segment 3 which suggests that as the catchment becomes saturated, a greater proportion of rain enters the sewer system. The outputs from Period 2 confirmed this, albeit with a relatively minor rain event for Segment 2.

RDII Model Outputs Summary - Detailed Analysis					
	Period 1			**Period 2**	
	Segment 1	Segment 2	Segment 3	Segment 1	Segment 2
ADWF (kL/hr)	1.12			1.45	
PDWF (kL/hr)	2.89			4.07	
RSF	55.0%	71.3%	71.3%	67.4%	67.4%
Segment Time (hrs)	48	92	111	117	18
Normalised flow time (hrs)	24	32	28	32	12
Rainfall (mm)	51	103.2	185.6	214.80	10.00
SPS inlet flow (kL)	97.7	236.3	400.1	436.40	35.60
RDII (kL)	56.86	128.35	269.48	291.58	16.65
Rainfall: RDII (mm: kL)	1.11	1.24	1.45	1.36	1.67
PWWF (kL/hr)	5.4	9.2	12.2	13.00	4.10

Table 10 – RDII model outputs from detailed analysis

4.5 Comparison with guidelines

4.5.1 Pressure Sewer Design Guidelines Calculations

The relevant flow components from the pressure sewer design guidelines reviewed during the literature review have been calculated based on the design parameters from the Potato Point PSS. The methods used to calculate each flow component are provided in section 2.2 of the literature review. The following assumptions have been made for calculation of the various flow components:

- Number of properties connected (ET) = 151
- EP/ET = 3 (Hunter Water), 3.6 (Pressure System Solutions), 3.5 (WSAA, QLD, PWC)
- ADWF = 150L/d/EP (Hunter Water, Pressure System Solutions), 180 L/d/EP (WSAA), 150 L/d/EP - 275 L/d/EP (QLD), 300 L/d/EP (PWC)

<u>ADWF (Total)</u>

Using Equation (2.1)

- Hunter Water = 2.83 kL/hr (From Equation 2.1)
- Pressure System Solutions = 3.40 kL/hr (From Equation 2.1)
- PWC (2022) = 6.61 kL/hr (From Equation 2.1)
- QLD (historical) = 3.30 kL/hr - 6.06 kL/hr (From Equation 2.1)
- QLD (system performance) = 1.45 kL/hr

<u>PDWF</u>

- PWC (2022) = 23.12kL/hr (From Equation 2.2)
- QLD (2014) (historical) = 8.02 kL/hr – 14.73 kL/hr (From Equation 2.3)
- QLD (2014) (system performance) = 4.07 kL/hr

<u>PWWF</u>

- WSAA (2007) = 21.77 kL/hr (From Equation 2.4)
- Hunter Water (2018) = 21.69 kL/hr (From Equation 2.5)
- PWC (2018) = 46.24 kL/hr (From Equation 2.6)
- QLD (2014) (historical) = 9.90 – 18.18 kL/hr (From Equation 2.7)
- QLD (2014) (system performance) = 13.00 kL/hr

<u>Potato Point PSS RDII Quantification Model (Period 2)</u>

- ADWF = 1.45 kL/hr
- PDWF = 4.07 kL/hr
- PWWF = 13.00 kL/hr

4.5.2 I/I Management Guidelines Calculations

The KPI's from the I/I management guidelines reviewed during the literature review have been calculated based on the design parameters from the Potato Point PSS. The following assumptions have been made for the calculations:

- ADWF = 1.45 kL/hr = 34.8 kL/d
- Number of Lots (ET) = 151 3.5EP/ET
- Population (EP) = 528.5
- Catchment Area = 14 ha
- Rainfall = 225mm
- RDII Volume = 304.92 kL
- PWWF = 13 kL/hr

<u>KPI Values from Carne (2011)</u>

- $GWI_1 = 130\ L/EP/d - 220\ L/EP/d$
- $RSF\ (GWI_2) = 70 - 90\%$
- $RDII_1 = 2 - 5\%$
- $SWI_1 = 5.0$

<u>KPI Values - Potato Point PSS RDII Quantification Model</u>

- $GWI_1 = 65.85$ (From Equation 2.8)
- $RSF\ (GWI_2) = 67.4\%$ (From Equation 2.9)
- $RDII_1 = 0.97\%$ (From Equation 2.10)
- $SWI_1 = 8.97$ (From Equation 2.11)

4.5.3 Discussion

The Potato Point PSS is not performing in accordance with the hydraulic loadings assumed in Pressure Sewer Solutions (2016) concept design report for the system. Dry weather flows are less than 50% of the ADWF rates from the concept design report. This report noted that a wet weather response should not occur, however, if there is evidence of a significant RDII response then I/I should be investigated.

The GWI_1 value for the Potato Point PSS is significantly lower than the values suggested by Carne (2011), Carne suggests this may be indicative of exfiltration. The RSF values, are close to the range considered normal by Carne, which indicates there is no exfiltration.

$RDII_1$ is not relevant to the analysis of I/I in PSS, as the catchment area for rainfall is exceedingly difficult to determine as an entire catchment area does not contribute into individual PSU's. The value determined for SWI_1 is considered quite high, considering that design practice for gravity sewer system is to adopt an SWI_1 value of 5.0. This indicates there is underlying I/I issues in the Potato Point PSS.

4.6 Operational Costs

An OPEX cost of 288.57 c/kL was adopted to evaluate the economic impacts of infiltration and inflow in a pressure sewer system. An analysis of the operational costs for a mean rainfall year was undertaken. For this analysis, the following assumptions were made based on the results from the analysis of I/I:

- Rainfall = 974.8mm (mean)
- Rainfall (mm) to RDII (kL) ratio = 1.36 (highest from preliminary analysis)

This resulted in a mean result of 1325.7 kL of RDII annually, which costs $3,826 annually to collect, transfer, and treat based on an OPEX cost of 288.57 c/kL. This is a minor component of ESC's sewer operating expense of approximately $22 million dollars annually (ESC, 2021). Whilst the OPEX costs associated are not a significant economic concern, there is no suggestion that the high volumes of I/I do not need to be investigated. Further investigation into methods of identifying sources of I/I is still warranted to develop an appropriate strategy for identification and remediation of defects. The volumes of RDII entering the system may be reduced through remediation of defects, however the reductions that can be achieved are difficult to quantify.

5 Conclusions

5.1 Achievement of objectives

The aim and objectives of the project have been fulfilled by successfully quantifying I/I in the pressure sewer system at Potato Point. An extensive literature review was undertaken, and a customised hydraulic model was developed to effectively quantify the I/I within the Potato Point PSS.

Existing sewer design standards and I/I management guidelines were critically reviewed to provide details of how I/I flows impact the appropriate design of sewer infrastructure. There are several methods of determining the various flow components, which can result in vastly different values for each component. The literature review investigated sources of I/I, and detailed the economic, environmental & public health, and regulatory issues I/I can cause.

A major component of the research was developing a predictive model for DWF which was suitable for use in the hourly RDII quantification model. Various methods of determining DWF were implemented, with the DWF model becoming more reliable and accurate through an iterative process of calibration, validation, and optimisation. The final DWF model incorporated relative RSF and water consumption values, which provides a better DWF pattern where water consumptions vary significantly. The model is particularly relevant for determination of DWF and quantification of RDII in holiday villages with transient populations.

The customised hydraulic model provides outputs which accurately derive the DWF and RDII flows during wet weather periods of varying intensity. As a result, a better understanding of the inflow and infiltration within a low pressure sewer system during wet weather periods has been developed, which addresses the existing knowledge gap in the literature. The results of the research provide opportunity for further investigation of suitable design factors for retrofit of PSS in backlog sewerage areas, which include future systems within the Eurobodalla LGA.

The water consumption and subsequent sewage flows evident in the Potato Point village are significantly less than what was assumed during the design of the system. Further review of these values for future PSS schemes should be considered throughout the design process.

Whilst the costs associated with collecting, transferring, and treating the I/I flows are not a significant economic issue at present, over a prolonged period these costs do add up. The high volumes if I/I entering the system should still be investigated, as it is likely that a small number of properties are contributing to the majority of the I/I issues like in the case studies evaluated during the literature review.

5.2 Further Work

This section identifies potential future works which would further contribute to reducing the knowledge gap relevant to inflow and infiltration in pressure sewer systems within Australia.

Although the I/I within the system was quantified successfully for two wet-weather periods, there was no quantifiable parameters developed which are relevant to how antecedent catchment wetness affects volumes of GWI and RDII. Further research regarding how antecedent catchment wetness influences I/I into sewer systems would be beneficial and may be suitable as an input to the DWF models to further enhance the reliability and accuracy of DWF during wet weather periods.

The RDII quantification model demonstrated that there is significant I/I entering the pressure sewer system during rainfall events. The immediate and delayed responses indicate that there is defects that are contributing to both inflow and infiltration problems within the system. Further investigation into the source of the I/I would be beneficial to ESC, as it would reduce the operating costs associated with the system and could minimise the risk of uncontained sewer spills from the sewer infrastructure which is not designed to cater for the large volumes of I/I entering the Potato Point system. The wet weather capacity of the existing sewage collection, transfer and treatment infrastructure should be evaluated to determine the AEP events which would cause sewage spills into the environment.

Investigation into potential remediation methods which can resolve I/I issues, and potential cost sharing arrangements for rectification of defects should also be explored further.

Further analysis of the other pressure sewerage schemes within the Eurobodalla should also be considered. By analysing other systems, it would provide good benchmarking data for comparison of the performance of each system so that rectification of defects and issues could be prioritised appropriately. It would also provide additional supporting data which could extend the literature so that design factors in pressure sewer design guidelines and I/I management guidelines are more relevant to backlog sewerage areas.

Further investigation into the CAPEX and OPEX costs associated with designing and constructing pressure sewer infrastructure to cater for wet weather periods should be undertaken, as these costs can be significant over the asset life of sewer infrastructure.

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Appendices

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Appendix A – Project Specification

ENG4111/4112 Research Project

Project Specification

For: Billy Alves

Title: Analysis of Inflow and Infiltration in a Low-Pressure Sewer System

Major: Civil Engineering

Supervisors: Dr Vasantha Aravinthan

Enrolment: ENG4111 – EXT S1, 2022

ENG4112 – EXT S2, 2022

Project Aim: To quantify the Inflow and Infiltration (I/I) within a low-pressure sewer system and determine the operational costs associated with collecting and treating I/I

Programme: Version 1, 16th March 2022

1. Conduct an extensive literature review on the sewer design guidelines adopted in various states of Australia, specifically on the methods in which I/I values are determined and incorporated into sewer design.
2. Research the potential causes and effects of I/I in a low-pressure sewer system.
3. Devise a sewer flow monitoring programme identifying suitable catchments for analysis.
4. Gather baseline data relative to I/I within a low-pressure sewer system.
5. Analyse and evaluate the gathered data from step 4, to extract any correlation with catchment parameters and meteorological patterns such as rainfall and runoff.
6. Develop a customised hydraulic model for quantifying the I/I in an operational low-pressure sewer system using EXCEL and define the assumptions and limitations of the model.
7. Undertake calibration, validation, and optimisation of the customised model developed in step 6.
8. Compare the data from the model with the predicted values of I/I from various adopted sewer design guidelines from step 1.
9. Complete a life cycle cost analysis to determine the additional operational costs of collecting and treating I/I within a low-pressure sewer system.

If time and resource permit:

10. Analyse the cost and resource requirements of identifying and remediating defective sewer infrastructure within private properties.
11. Complete a cost-benefit analysis to determine if remediating private sewer infrastructure to reduce I/I is economically viable for Eurobodalla Shire Council to reduce operational costs associated with I/I.

Appendix B – Project Planning

Table B. 1: Resource Requirements

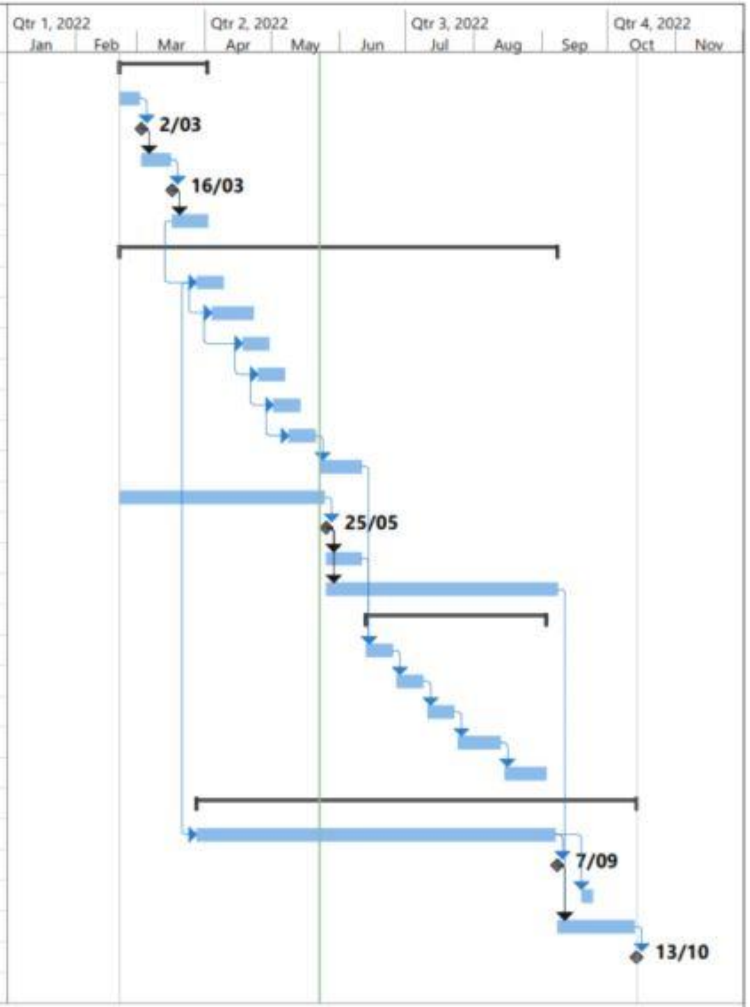
Item	Source	$	Purpose
Laptop	ESC	$0	Computer to undertake project work
Microsoft Excel	ESC	$0	To develop a hydraulic model
Microsoft Office programs (Word, PowerPoint, Project)	ESC	$0	Programs required to write up and present project work
Access to ESC GIS system	ESC	$0	Access to ESC's GIS system for downloading and viewing various GIS data including geological conditions and catchment area sizes
AutoCAD 2019	ESC	$0	For any CAD Drafting relevant to project
Bureau of Meteorology (BOM) Rainfall Data	BOM	< $200	Collection of rainfall data, for various time intervals
ARI Rainfall Data	BOM	$0	Determination of various ARI rainfall events
ESC Water Billing Data	ESC	$0	Collection of data related to water usage from water meters
ESC SCADA system	ESC	$0	Collection of data relevant to water and sewer infrastructure including data from the following: • Reservoir flow meters • SPS derived flows • SPS inlet & outlet flow meters • STP flow meters • PSS flow meters
ESC Water and Sewer infrastructure documentation	ESC	$0	Review of previous design documentation related to design of low-pressure sewer systems
Stationary & Printing	ESC	$0	General office work and calculations, Printing documents for perusal and making comments
Relevant Literature	USQ Library	$0	Undertaking detailed literature review of all relevant literature
WSAA Codes & Guidelines	WSAA	$0	Undertaking detailed literature review of Australian sewer design guidelines

Table B. 2: Risk Assessment

Risk	Initial Risk Assessment			Controls	Risk Assessment with Controls		
	Consequence	**Probability**	**Risk Level**		**Consequence**	**Probability**	**Risk Level**
Formal project approval not given by USQ or ESC	Major	Possible	High	Begin discussions with potential supervisors from USQ and ESC in late 2021. Ensure approval is obtained early.	Major	Unlikely	Medium
Computer problems – Loss of work	Major	Possible	High	Store project works on multiple cloud storage systems, backup work frequently	Minor	Unlikely	Low
Access to data required for modelling not obtained when required	Major	Unlikely	Moderate	Request data early and ensure permissions are granted prior to commencing project	Major	Rare	Low
Data not suitable for interpretation	Moderate	Possible	Moderate	Gather data for multiple catchments and verify with other SCADA readings	Minor	Unlikely	Low
Incomplete or incorrect modelling	Major	Possible	High	Ensure model validation is undertaken, double check and cross check works with manual calculations	Major	Unlikely	Medium
WHS risks associated with sitting at desk for extended periods of time	Moderate	Possible	Moderate	Take regular breaks and ensure deck is set up suitably ergonomically	Moderate	Unlikely	Low
Insufficient time allowed to proposed project	Moderate	Likely	High	Speak with supervisor on a regular basis. If scope is too broad, discuss refining it early on in project	Moderate	Unlikely	Low
Access to literature not suitable	Moderate	Unlikely	Low	Ensure project objectives are suitable by consulting with project supervisor	Moderate	Rare	Low
COVID-19 impacting ability to complete project	Moderate	Unlikely	Low	Ensure access to all literature, software and hardware is available via different methods	Moderate	Rare	Low
Outcomes of research are used in future study	Minor	Possible	Low	Include appropriate disclaimer to limit the reliance for future study	Minor	Rare	Low

Figure B. 1: Project Program

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Phase 1 – Preliminary Tasks**	**30 days**	**Mon 21/02/22**	**Fri 1/04/22**	
2	1A - Liaison with Potential Supervisors	7 days	Mon 21/02/22	Tue 1/03/22	
3	*1B - Formal Topic Allocation*	*1 day*	*Wed 2/03/22*	*Wed 2/03/22*	2
4	1C - Resource Identification	9 days	Thu 3/03/22	Tue 15/03/22	3
5	*1D - Project Specification*	*1 day*	*Wed 16/03/22*	*Wed 16/03/22*	4
6	1E - Incorporate Feedback & Revise Final Scope	12 days	Thu 17/03/22	Fri 1/04/22	5
7	**Phase 2 - Literature Review and Data Collection**	**143 days**	**Mon 21/02/22**	**Wed 7/09/22**	
8	2A - Investigate relevant background information	2 wks	Mon 28/03/22	Fri 8/04/22	6SS+7 days
9	2B - Review various sewer design guidelines	3 wks	Mon 4/04/22	Fri 22/04/22	8SS+1 wk
10	2C - Investigate sources and effects of I/I	2 wks	Mon 18/04/22	Fri 29/04/22	9SS+2 wks
11	2D - Review methods of quantifying I/I	2 wks	Mon 25/04/22	Fri 6/05/22	10SS+1 wk
12	2E - Research operational costs of sewers	2 wks	Mon 2/05/22	Fri 13/05/22	11SS+1 wk
13	2F - Determine suitable catchments for analysis	2 wks	Mon 9/05/22	Fri 20/05/22	12SS+1 wk
14	2G - Gather relative data	3 wks	Mon 23/05/22	Fri 10/06/22	13
15	2H - Prepare progress report	13.4 wks	Mon 21/02/22	Tue 24/05/22	
16	*2I - Submit progress report*	*1 day*	*Wed 25/05/22*	*Wed 25/05/22*	15
17	2J - Incorporate feedback into report	12 days	Thu 26/05/22	Fri 10/06/22	16
18	2K - Continued Literature Review	15 wks	Thu 26/05/22	Wed 7/09/22	16
19	**Phase 3 - Data Analysis and Model Development**	**60 days**	**Mon 13/06/22**	**Fri 2/09/22**	
20	3A - Analyse and evaluate gathered data	2 wks	Mon 13/06/22	Fri 24/06/22	14,17
21	3B - Develop a customised model using EXCEL	2 wks	Mon 27/06/22	Fri 8/07/22	20
22	3C - Calibrate, validate, and optimise the model	2 wks	Mon 11/07/22	Fri 22/07/22	21
23	3D - Compare I/I values with design values	3 wks	Mon 25/07/22	Fri 12/08/22	22
24	3E - Complete life cycle cost analysis	3 wks	Mon 15/08/22	Fri 2/09/22	23
25	**Phase 4 - Dissertation and Presentation**	**144 days**	**Mon 28/03/22**	**Thu 13/10/22**	
26	4A - Prepare draft dissertation	23.4 wks	Mon 28/03/22	Tue 6/09/22	8SS
27	*4B - Submit draft dissertation*	*1 day*	*Wed 7/09/22*	*Wed 7/09/22*	26
28	*4C - Present results, analysis and implications*	*1 wk*	*Mon 19/09/22*	*Fri 23/09/22*	26
29	4D - Prepare final dissertation	5 wks	Thu 8/09/22	Wed 12/10/22	27,18
30	*4E - Submit final dissertation*	*1 day*	*Thu 13/10/22*	*Thu 13/10/22*	29
31	*Milestone tasks shown in italics*				



Project: Project plan
Date: Mon 23/05/22

Task		Inactive Task		Manual Summary Rollup		External Milestone	
Split		Inactive Milestone		Manual Summary		Deadline	
Milestone		Inactive Summary		Start-only		Progress	
Summary		Manual Task		Finish-only		Manual Progress	
Project Summary		Duration-only		External Tasks			

Appendix C – Rainfall Data

Table C. 1: Daily Rainfall – Bodalla STP Weather Station

Daily Rainfall (mm) - Bodalla STP Weather Station						
2022	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1st		20.6	0.2	0	0	0.6
2nd		56.4	1.8	0	0	3.4
3rd		31.4	0.2	0	0.6	7.4
4th		1	1	1.2	0.4	0.2
5th		42.8	0	0.8	0	0
6th		24.2	43.4	0.2	0	0
7th		42.2	113	0	0	0
8th		74.4	34	0	0	0
9th		2	24	0	0.2	4
10th		0	0.4	1.2	0	3.8
11th		0	10	3	0	0
12th		0.4	0.2	13.8	0	0
13th		0	0	0	0	0
14th		0	0	0.4	0	0
15th		4.8	0	5	0	0
16th		2.2	0	0.4	0	0
17th		0.2	0	0	0.2	0
18th		0.2	0	0	0	0
19th		3.8	24.2	0	4.6	0
20th		0	5.6	0	3.8	1.2
21st		0	0	0	1.4	7
22nd		0	0	0	0.2	2.2
23rd		9.2	0	0.6	0	0.4
24th		0	0	5.4	0	0.2
25th		1	2.8	0.2	0	0
26th	47.8	4.4	0.2	0	0	2.6
27th	3.4	4.2	11	7.8	0	0
28th	2.2	0.4	0	1.8	0	0.8
29th		0	0.2	0.2	0	0.2
30th		3.8	5	2.8	0	0
31st		8		0.2		0
Sub Totals	**53.4**	**337.6**	**277.2**	**45**	**11.4**	**34**
Total						**758.6**

Table C. 2: Daily Rainfall – BOM 069036 Bodalla Post Office

Daily Rainfall (mm) - BOM 069036 Bodalla Post Office						
2022	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1st		49.4		0	0	
2nd		48.6		0	0	
3rd		25.2	4*	0		12.2*
4th		0	0.4	7.4		0.6
5th		0	0	0.2	1.4*	0
6th		64.6	108.4	0	0	0
7th		60.2	84.2	0	0	0
8th		57.2		0	0	
9th		0		0	0	
10th		0	26.4*	2	0	7.8*
11th		0	10.8	8.8	0	0
12th		0	0	8.4	0	0
13th		0	0		0	0.2
14th		4.4	0		0	0
15th		2.4	0	6.4*	0	0
16th		2	0	0	0	0
17th		0	0	0		0
18th		0	0	0		0
19th		0	29.4	0	7.2*	0
20th		5.4	0	0		1.4
21st		0	0	0	1.6*	9.2
22nd		8		0	0	
23rd		0		1.2	0	
24th		0.2		4	0	1.6*
25th		0	5*	0	0	0.8
26th		0	0.4	0	0	2.6
27th	74.4*	7.4	11.6		0	0
28th	10.6	0	0		0	1.4
29th		0	0	5.6*	0	0
30th		5.4	0	3	0	0
31st		9.2		0		0
Sub Total	**85**	**349.6**	**280.6**	**47**	**10.2**	**37.8**
Total						**810.2**
*Blanks in data indicate data being measured over a several day period where the period of measurement is equal to the number of blanks						

Table C. 3: Daily Rainfall – BOM 069122 Dalmeny (Binalong St)

Daily Rainfall (mm) - BOM 069122 Dalmeny (Binalong St)						
2022	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1st		27	0.6	0	0	1
2nd		27.4	2.8	0	0	7.8
3rd		17.8	1.4	0	1	1.8
4th		0.2	0	2.2	0	0.6
5th		34.2	0	0.6	0	0
6th		38.6	68.6	0	0	0
7th		52.6	23.6	0	0	0
8th		52.2	8.2	0.2	0	0
9th		0	44.4	0	0	7.6
10th		0	0	1.2	0	0
11th		0		10.2	0	0
12th		0.8	0.8*	6.8	0	0
13th		0	0	0	0	0
14th		7	0.2	6.4	0	0
15th		0.4	0	2.6	0	0
16th		2.2	0	0	1.4	0
17th		0	0	0	0	0
18th		0	0	0	0	0
19th		11.2	26.4	0	7.2	0
20th		0	0.4	0	0.2	7.6
21st		0	0	0	0	8.2
22nd		6.2	0	0	0	2
23rd		0	0	0	0	0
24th		0.4	0	14.8	0	0
25th		0	1.8	0	0	1.6
26th	51.6	11.4	0.4	0	0	1
27th		1	21	4	0	0
28th	1*	0	0	0	0	1.4
29th		6.2	5.6	0	0	0
30th		6.4	0	2.4	0	0
31st		14.4		0		0
Sub Totals	**69.2**	**317.6**	**206.2**	**51.4**	**9.8**	**40.6**
Total						**678.2**
*Blanks in data indicate data being measured over a several day period where the period of measurement is equal to the number of blanks						

Table C. 4: Bodalla Post Office 069036 – Rainfall Statistics

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	96.6	106.9	112.2	81.7	75.1	83.9	54.5	54.8	59.8	78.2	80.2	87.3	974.8
Lowest	2.5	2.6	1.3	0.0	0.0	0.0	0.0	0.2	0.0	4.2	1.2	3.8	412.5
5th percentile	11.8	8.7	8.9	2.8	3.7	3.5	1.4	2.5	4.7	10.5	7.6	14.7	577.8
10th percentile	16.8	16.2	18.2	8.4	8.6	6.3	4.1	4.6	9.9	17.8	16.7	19.7	626.4
Median	74.8	64.6	71.4	46.2	47.0	45.0	28.3	25.0	43.5	53.7	68.1	68.2	927.1
90th percentile	211.2	212.8	249.3	216.1	210.9	192.3	152.8	149.4	133.9	151.7	157.3	204.6	1397.0
95th percentile	274.0	337.1	346.4	236.3	230.2	284.6	206.1	193.6	175.5	188.6	205.6	227.8	1673.9
Highest	550.8	811.3	605.4	557.0	776.9	555.4	281.5	377.9	456.9	756.6	396.4	354.5	1892.6

Table C. 5: Wet Weather Period 1 Hourly Rainfall Totals Bodalla STP (1 of 2)

Wet Weather Period 1									
	Hourly Rainfall Totals (mm)								
Hour	26/2/22	27/2/22	28/2/22	1/3/22	2/3/22	3/3/22	4/3/22	5/3/22	6/3/22
1.00	0.2	1.4	0	0	1.6	0	0	0	0
2.00	0	1	0	0	0	0	0	0	0
3.00	0	0	0	0	0.2	1.8	0	0	0
4.00	0	0.6	0	0.2	2.4	0	0	0	0.6
5.00	0	0.2	0	0	6.2	0	0	0	1.6
6.00	0	0	0	0	0	0.2	0	0	0
7.00	0	0	0	0	0	2.6	0	0	0
8.00	0	0.2	0	0	14.4	0.8	0.4	0	0
9.00	0	0	0	0	2	0.4	0.6	0	0
10.00	0.6	0	0	0	0	0.4	0	0	0
11.00	4	0	0	0	0	0	0	0	0.2
12.00	1	0	0	0	0	0	0	0	0
13.00	0.2	0	0	0	0	4	0	0	0
14.00	0.2	0	0	0	0.2	6.4	0	0	0
15.00	0	0	0	0	7	3.4	0	0	0
16.00	0	0	0	2.8	4.4	1.6	0	0	0
17.00	0	0	0.2	0	1.8	3	0	0	3.4
18.00	0	0	2	0	0.2	0.8	0	0	5
19.00	0.4	0	0	2.8	7.8	0	0	6.2	3.8
20.00	5.8	0	0	0	0.2	0	0	16.2	2.6
21.00	14.2	0	0	0.4	0	0	0	9.6	2
22.00	10	0	0	1.4	8	4.6	0	5.2	1.4
23.00	4.2	0	0	13	0	1.2	0	4.4	1.8
24.00	7	0	0	0	0	0.2	0	1.2	1.8
Total	47.8	3.4	2.2	20.6	56.4	31.4	1	42.8	24.2

Table C. 6: Wet Weather Period 1 Hourly Rainfall Totals Bodalla STP (2 of 2)

Wet Weather Period 1								
	Hourly Rainfall Totals (mm)							
Hour/Day	7/3/22	8/3/22	9/3/22	10/3/22	11/3/22	12/3/22	13/3/22	14/3/22
1.00	1.4	0.2	0.8	0	0	0	0	0
2.00	0.4	0	0.4	0	0	0	0	0
3.00	0.6	2.4	0.4	0	0	0	0	0
4.00	0.4	4.8	0.2	0	0	0	0	0
5.00	1.8	2.6	0	0	0	0	0	0
6.00	3.4	4.6	0	0	0	0	0	0
7.00	2.2	5.6	0	0	0	0	0	0
8.00	2.4	2.4	0	0	0	0	0	0
9.00	2.4	7.4	0	0	0	0	0	0
10.00	1.4	7	0	0	0	0	0	0
11.00	0.4	7.2	0	0	0	0	0	0
12.00	0.2	7.8	0	0	0	0	0	0
13.00	0.4	4	0.2	0	0	0	0	0
14.00	0	6.6	0	0	0	0	0	0
15.00	1.2	2.4	0	0	0	0	0	0
16.00	0	2.8	0	0	0	0	0	0
17.00	0	1.8	0	0	0	0	0	0
18.00	0.6	0.4	0	0	0	0	0	0
19.00	2.6	0.8	0	0	0	0	0	0
20.00	1.4	1.4	0	0	0	0	0	0
21.00	5.4	0.8	0	0	0	0	0	0
22.00	5.6	0.4	0	0	0	0	0	0
23.00	7.2	0.4	0	0	0	0.4	0	0
24.00	0.8	0.6	0	0	0	0	0	0
Total	42.2	74.4	2	0	0	0.4	0	0

Table C. 7: Wet Weather Period 2 Hourly Rainfall Totals Bodalla STP (1 of 2)

Wet Weather Period 2							
	Hourly Rainfall Totals (mm)						
Hour	5/4/22	6/4/22	7/4/22	8/4/22	9/4/22	10/4/22	11/4/22
1.00	0	0	4.8	1.2	0.8	0	0
2.00	0	0	21.4	4.4	0.8	0.2	0
3.00	0	0	3.4	1.4	0	0	0
4.00	0	0	0.8	2.2	2.6	0	0
5.00	0	0	0.2	9.8	0.4	0	0
6.00	0	0	4.4	9	3	0	0
7.00	0	0	7.8	1	0.6	0	0
8.00	0	0	14	0.2	0	0	0
9.00	0	0	8.8	0	0.2	0	0
10.00	0	0	5.2	0.4	1.2	0	0
11.00	0	0	7.4	1.4	2.2	0	0
12.00	0	0	13	0	2.4	0.2	0
13.00	0	0	6.4	0	0.4	0	0
14.00	0	2.6	1.4	0	0	0	0
15.00	0	4.8	3.2	0.8	1.2	0	0
16.00	0	6.4	2.8	0	1.6	0	0
17.00	0	19.6	1	0	0	0	2
18.00	0	5.6	0.6	0.6	3	0	0
19.00	0	1.2	0.8	0.4	1.6	0	0
20.00	0	2.2	0	0	0.4	0	7
21.00	0	0.4	0.2	1.2	1.2	0	1
22.00	0	0.2	0	0	0.2	0	0
23.00	0	0	0.2	0	0	0	0
24.00	0	0.4	5.2	0	0.2	0	0
Total	0	43.4	113	34	24	0.4	10

Table C. 8: Wet Weather Period 2 Hourly Rainfall Totals Bodalla STP (2 of 2)

Wet Weather Period 2							
	Hourly Rainfall Totals (mm)						
Hour/Day	12/4/22	13/4/22	14/4/22	15/4/22	16/4/22	17/4/22	18/4/22
1.00	0	0	0	0	0	0	0
2.00	0	0	0	0	0	0	0
3.00	0	0	0	0	0	0	0
4.00	0	0	0	0	0	0	0
5.00	0	0	0	0	0	0	0
6.00	0	0	0	0	0	0	0
7.00	0	0	0	0	0	0	0
8.00	0	0	0	0	0	0	0
9.00	0	0	0	0	0	0	0
10.00	0	0	0	0	0	0	0
11.00	0	0	0	0	0	0	0
12.00	0	0	0	0	0	0	0
13.00	0.2	0	0	0	0	0	0
14.00	0	0	0	0	0	0	0
15.00	0	0	0	0	0	0	0
16.00	0	0	0	0	0	0	0
17.00	0	0	0	0	0	0	0
18.00	0	0	0	0	0	0	0
19.00	0	0	0	0	0	0	0
20.00	0	0	0	0	0	0	0
21.00	0	0	0	0	0	0	0
22.00	0	0	0	0	0	0	0
23.00	0	0	0	0	0	0	0
24.00	0	0	0	0	0	0	0
Total	0.2	0	0	0	0	0	0

Appendix D – Daily Flow Summary

Table D. 1: Potato Point Reservoir - Daily Outlet Flows

Potato Point Reservoir - Daily Outlet Flows (kL)						
2022	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1st		43.51	25.11	38.53	42.58	30.72
2nd		40.18	24.41	40.01	34.69	30.46
3rd		46.11	25.87	36.94	34.6	33.32
4th		37.66	22.51	36.47	39.63	30.16
5th		34.24	24.36	41.39	39.47	30.41
6th		33.51	79.92	44.8	35.44	32.34
7th		51.32	118.91	40.01	34.21	33.12
8th		40.38	82.23	41.71	34.24	35.93
9th		39.18	96.13	34.26	33.24	40.38
10th		42.26	55.94	34.92	35.42	39.79
11th		43.64	43.39	34.98	43.46	38.66
12th		42.65	39.49	35.7	43.38	35.34
13th		34.3	33.37	40.56	42.29	35.72
14th		33.04	36.98	37.04	34.5	36.99
15th		34.04	45.15	37.33	35.26	36.25
16th		37.74	44.54	36.24	33.44	35.6
17th		37.84	45.31	34.52	33.25	35.51
18th		38.19	44.36	40.08	35.25	107.52
19th		38.49	40.03	39.76	38.12	32.24
20th		38.63	49.33	41.13	33	30.38
21st		32.23	35.6	43.99	32.16	29.71
22nd		31.45	35.5	36.08	32.86	31.5
23rd		35.06	32.56	39.22	33.92	33.83
24th		37.45	31.8	36.39	32.11	37.07
25th		37.99	29	38.01	36.42	33.08
26th	35.83	34.2	26.02	37.15	36.51	32.08
27th	36.14	35.73	31.33	38.48	35.16	31.5
28th	40.01	34.27	36.67	38.48	33.87	32.4
29th		36.59	29.26	45.57	32.62	32.88
30th		35.03	30.68	40.33	32.57	37.01
31st		35.03		49.23		35.46
Sub Totals	**111.98**	**1171.94**	**1295.76**	**1209.31**	**1073.67**	**1127.36**
Total						**5990.02**

Table D. 2: Potato Point SPS - Daily Inlet Flows

Potato Point SPS - Daily Inflow (kL)						
2022	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1st		27.74	25.11	26.77	25.32	
2nd		94.38	24.41	22.88	16.07	
3rd		70.23	25.87	23.06	17.08	
4th		43.34	22.51	19.98	20.42	
5th		47.63	24.36	20.52	21.39	
6th		67.76	79.92	23.4		14.06
7th		98.04	118.91	25.73		13.68
8th		147.26	82.23	24.7		15.78
9th		52.37	96.13	24.37		19.62
10th		30.72	55.94	19.01		19.59
11th		29.33	43.39	19.69		18.77
12th		29.76	39.49	27.99		16.05
13th		27.14	33.37	24.1		16.29
14th		23.68	36.98	23.83		14.86
15th		20.38	45.15	24.32		15.24
16th		20.02	44.54	21.36		14.62
17th		19.19	45.31	21.18		16.31
18th		20.4	44.36	18.09		11.95
19th		28.27	40.03	20.66		13.13
20th		23.6	49.33	21.99		11.62
21st		21.27	35.6	22.42		11.96
22nd		24.26	35.5	25.56		13.8
23rd		21.07	32.56	19.19		15.16
24th		17.79	31.8	29.19		17.05
25th		20.87	29	25.59		14.3
26th	40.45	19.92	26.02	22.3		13.49
27th	54.61	27.32	31.33	22.69		13.16
28th	25.67	20.04	36.67	24.65		13.18
29th		20.48	29.26	26.57		14.23
30th		19.83	30.68	23.28		16.26
31st		34.11		30.82		15.48
Sub Totals	**120.73**	**1168.2**	**1295.76**	**725.89**	**100.28**	**389.64**
Total						**3800.5**

Table D. 3: Potato Point SPS - Daily Outflow

Potato Point SPS - Daily Outflow (kL)						
2022	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1st		31.33	26.99	31.03	30.28	16.04
2nd		95.19	27.14	25.78	20.03	18.12
3rd		71.13	28.07	26.94	18.48	23.24
4th		44.48	24.85	24.19	25.1	16.23
5th		48.25	26.69	24.16	23.95	14.81
6th		68.06	78.64	27.45	24.25	16.93
7th		97.43	118.9	30.77	19.01	15.24
8th		143.59	84.05	27.14	18.18	18.66
9th		54.77	98.99	28.12	17.85	22.31
10th		33.04	59.02	21.74	21.27	22.06
11th		30.92	46.05	22.18	27.26	21.83
12th		32.16	43.53	30.66	28.55	17.59
13th		28.81	37.17	27.88	23.2	19.74
14th		27.04	40.07	27.68	18.85	16.79
15th		21.8	49.78	27.68	19.23	17.11
16th		20.59	48.13	26.43	20.48	17.23
17th		21.1	48.52	24.48	18.66	17.85
18th		22.25	48.64	21.15	21.3	14.91
19th		29.98	44.15	23.54	20.7	15.36
20th		25.1	53.85	25.44	20.08	12.95
21st		25.09	39.78	26.13	18.06	13.32
22nd		26.51	37.81	29.68	18.32	17.1
23rd		23.37	36.97	22.66	20.41	16.96
24th		19.52	35	33.41	18.71	19.53
25th		25.34	31.15	29.71	18.93	17.06
26th	42.1	26.19	28.33	27.42	20.35	15.56
27th	58.46	32.15	33.6	24.69	20.13	15.2
28th	29.8	22.96	41.92	29.72	18.27	15.02
29th		24.74	31.72	31.01	15.27	16.36
30th		21.55	35.07	27.51	18.66	18.78
31st		38.42		35.57		17.41
Sub Totals	**130.36**	**1232.86**	**1384.58**	**841.95**	**623.82**	**537.3**
Total						**4750.87**

Appendix E – Design Rainfall Details: Bodalla STP

Table E. 1: IFD Design Rainfall Bodalla STP Weather Station

	Annual Exceedance Probability (AEP)						
Duration	63.2%	50%#	20%*	10%	5%	2%	1%
1 min	1.89	2.17	3.07	3.71	4.36	5.25	5.97
2 min	3.15	3.66	5.28	6.41	7.54	8.97	10.1
3 min	4.35	5.03	7.21	8.74	10.3	12.3	13.8
4 min	5.41	6.23	8.88	10.7	12.6	15.1	17.1
5 min	6.33	7.27	10.3	12.5	14.7	17.6	19.9
10 min	9.67	11.0	15.6	18.8	22.1	26.7	30.4
15 min	11.8	13.5	19.1	23.0	27.0	32.7	37.3
20 min	13.5	15.4	21.7	26.3	30.9	37.4	42.6
25 min	14.8	17.0	24.0	29.0	34.1	41.2	46.9
30 min	16.0	18.3	25.9	31.3	36.9	44.5	50.6
45 min	18.8	21.6	30.7	37.2	43.7	52.6	59.7
1 hour	21.1	24.3	34.7	42.0	49.4	59.3	67.0
1.5 hour	25.1	29.0	41.5	50.2	58.9	70.4	79.3
2 hour	28.5	33.0	47.4	57.3	67.1	80.0	90.0
3 hour	34.7	40.2	57.7	69.6	81.4	96.9	109
4.5 hour	42.9	49.6	71.0	85.6	99.9	119	134
6 hour	50.0	57.9	82.7	99.6	116	139	156
9 hour	62.4	72.1	103	124	145	174	197
12 hour	72.8	84.0	120	145	169	205	233
18 hour	89.4	103	147	179	211	257	294
24 hour	102	118	169	206	244	300	346
30 hour	112	129	187	228	272	336	389
36 hour	120	138	201	247	295	367	427
48 hour	131	152	223	276	333	416	487
72 hour	145	169	251	314	382	481	566
96 hour	152	178	267	336	411	519	610
120 hour	157	184	277	350	428	540	634
144 hour	161	189	284	358	438	551	646
168 hour	165	193	290	364	444	556	649

Figure E. 1: IFD Chart Bodalla STP Weather Station

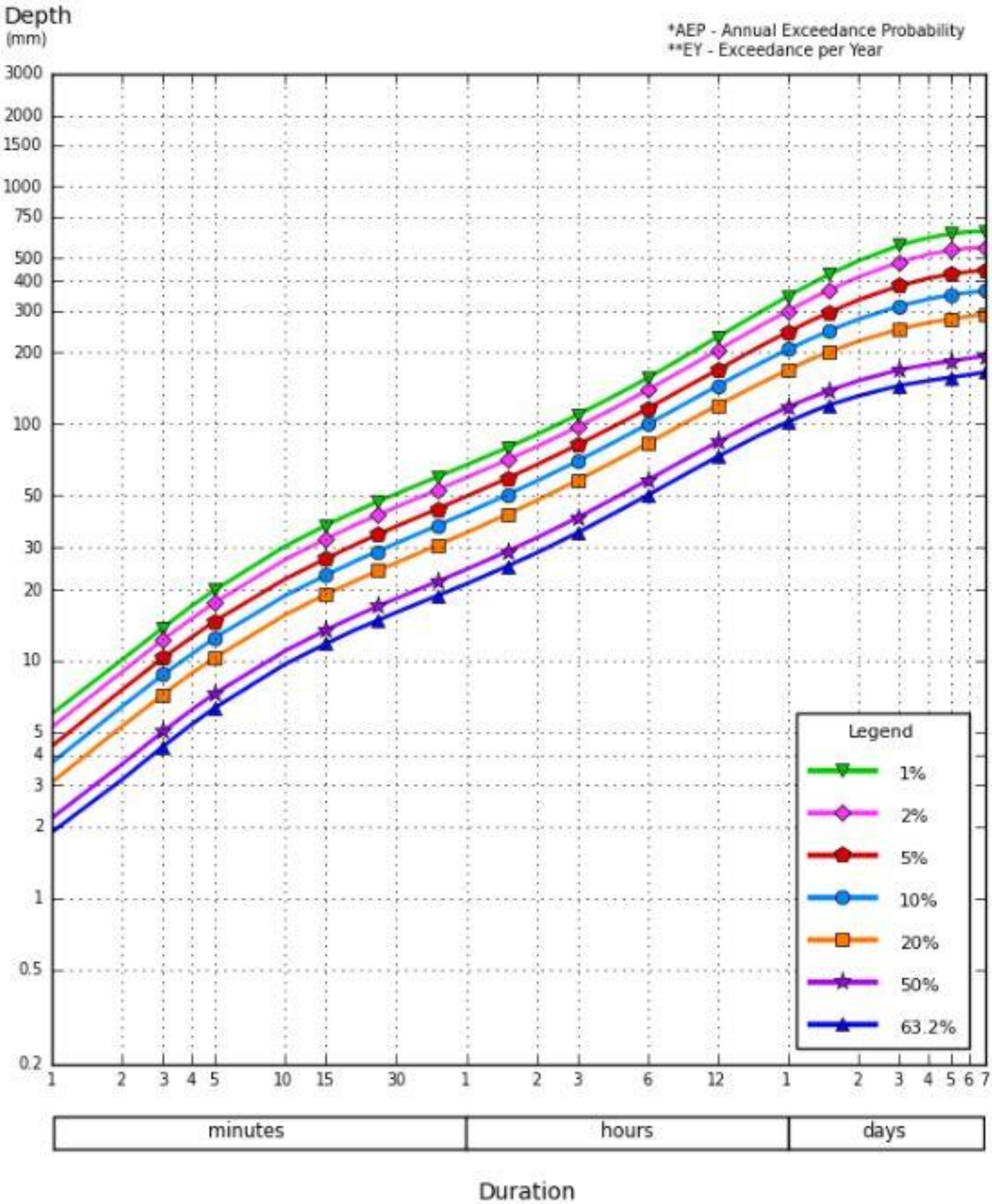


Table E. 2: Very Frequent Design Rainfall Depth – Bodalla STP

	Exceedance per Year (EY)							
Duration	12EY	6EY	4EY	3EY	2EY	1EY	0.5EY#	0.2EY*
1 min	0.717	0.838	1.05	1.22	1.45	1.89	2.41	3.13
2 min	1.23	1.44	1.80	2.07	2.46	3.15	4.06	5.38
3 min	1.67	1.96	2.47	2.84	3.38	4.35	5.58	7.36
4 min	2.05	2.41	3.05	3.51	4.19	5.41	6.91	9.06
5 min	2.38	2.81	3.55	4.10	4.90	6.33	8.08	10.5
10 min	3.59	4.22	5.36	6.20	7.43	9.67	12.3	15.9
15 min	4.41	5.18	6.56	7.58	9.09	11.8	15.0	19.4
20 min	5.04	5.91	7.47	8.63	10.3	13.5	17.1	22.2
25 min	5.56	6.51	8.22	9.49	11.4	14.8	18.8	24.5
30 min	6.01	7.03	8.87	10.2	12.2	16.0	20.3	26.4
45 min	7.12	8.32	10.5	12.1	14.4	18.8	24.0	31.3
1 hour	8.01	9.36	11.8	13.5	16.2	21.1	27.0	35.4
1.5 hour	9.48	11.1	13.9	16.0	19.2	25.1	32.2	42.3
2 hour	10.7	12.5	15.8	18.2	21.8	28.5	36.7	48.3
3 hour	12.8	15.0	19.0	22.0	26.4	34.7	44.7	58.8
4.5 hour	15.3	18.0	23.0	26.8	32.4	42.9	55.1	72.4
6 hour	17.4	20.6	26.5	30.9	37.5	50.0	64.3	84.3
9 hour	20.9	24.9	32.3	37.9	46.4	62.4	80.0	105
12 hour	23.7	28.3	37.0	43.6	53.7	72.8	93.2	122
18 hour	27.9	33.6	44.4	52.6	65.2	89.4	114	150
24 hour	30.9	37.6	49.9	59.4	73.8	102	131	172
30 hour	33.3	40.6	54.1	64.6	80.6	112	143	190
36 hour	35.1	42.9	57.4	68.7	85.9	120	154	205
48 hour	37.6	46.3	62.3	74.6	93.7	131	169	227
72 hour	40.4	50.0	67.8	81.6	103	145	187	256
96 hour	41.7	51.8	70.6	85.3	108	152	197	272
120 hour	42.3	52.6	72.3	87.5	111	157	204	283
144 hour	42.5	52.9	73.4	89.2	113	161	209	290
168 hour	42.6	53.0	74.2	90.5	116	165	214	295

Appendix F – Hourly Flow Details

Table F. 1: Potato Point SPS – Dry Period 1 Measured Hourly SPS Inlet Flow

Period 1 - Hourly Flow (kL/hr)						
	Daily Totals				Averages	
Hour	11/3/22	12/3/22	13/3/22	14/3/22	Weekday	Weekend
1.00	0.4	0.3	0.4	0.1	0.25	0.35
2.00	0.4	0.6	0.4	0.3	0.35	0.50
3.00	0.6	0.3	0.3	0.2	0.40	0.30
4.00	0.4	0.3	0.2	0.2	0.30	0.25
5.00	0.4	0.2	0.4	0.2	0.30	0.30
6.00	0.5	0.4	0.3	0.4	0.45	0.35
7.00	1	0.7	0.3	1	1.00	0.50
8.00	2.5	2.9	1.8	1.7	2.10	2.35
9.00	2.3	2.3	2	2.3	2.30	2.15
10.00	1.8	2.5	2.1	2.1	1.95	2.30
11.00	1.7	2.2	1.9	1.9	1.80	2.05
12.00	0.9	1.8	1.7	1.3	1.10	1.75
13.00	1.5	1.3	1.3	1.5	1.50	1.30
14.00	1.9	1.3	1.4	0.9	1.40	1.35
15.00	2	1	1.2	0.5	1.25	1.10
16.00	1.2	1.1	1.6	1.4	1.30	1.35
17.00	1.4	0.9	1.4	0.7	1.05	1.15
18.00	1.3	1.6	1.8	1.1	1.20	1.70
19.00	1.1	2.3	1.7	1.6	1.35	2.00
20.00	1.6	1.9	1.3	0.8	1.20	1.60
21.00	1.5	2	1	1.2	1.35	1.50
22.00	1.4	0.7	1.3	1.1	1.25	1.00
23.00	1	0.5	0.7	0.5	0.75	0.60
24.00	0.5	0.5	0.7	0.4	0.45	0.60
Total	29.3	29.6	27.2	23.4	26.35	28.4

Table F. 2: Potato Point SPS – Dry Period 2 Measured Hourly SPS Inlet Flow

Period 2 - Hourly Flow (kL/hr)							
	Daily Totals					Averages	
Hour	14/4/22	15/4/22	16/4/22	17/4/22	18/4/22	Weekday	Weekend
1.00	0.9	0.5	0.7	0.8	0.5	0.50	0.73
2.00	0.8	0.7	0.4	0.5	0.5	0.50	0.60
3.00	0.6	0.4	0.4	0.3	0.3	0.30	0.43
4.00	0.3	0.5	0.4	0.4	0.7	0.70	0.40
5.00	0.5	0.6	0.4	0.4	0.4	0.40	0.48
6.00	0.7	0.8	0.5	0.5	0.7	0.70	0.63
7.00	1.8	0.8	1.8	1.3	1.5	1.50	1.43
8.00	2.1	1.6	2.3	2.4	2.8	2.80	2.10
9.00	2.4	2.5	4.2	3.5	3.7	3.70	3.15
10.00	2.7	2.8	3.6	3.8	3.5	3.50	3.23
11.00	2.3	3.7	4.1	3.2	3.2	3.20	3.33
12.00	1.6	2.2	2.2	3	3.1	3.10	2.25
13.00	1.4	1.7	2	2.6	2.5	2.50	1.93
14.00	1.3	3.2	1.7	1.8	2.3	2.30	2.00
15.00	2	3.7	1.7	3.6	2.2	2.20	2.75
16.00	1.5	2	1.6	2.1	2.4	2.40	1.80
17.00	1.7	2.6	2.1	2.2	2.7	2.70	2.15
18.00	2.6	3.1	2.4	2.4	2.7	2.70	2.63
19.00	2.7	2.2	3.3	2.2	1.8	1.80	2.60
20.00	1.1	2.6	2.6	3.1	2.5	2.50	2.35
21.00	2.3	2	1.8	1.5	1.7	1.70	1.90
22.00	1.2	2.2	1.6	1.5	1.2	1.20	1.63
23.00	1.2	1.9	1.6	1.2	1	1.00	1.48
24.00	1.2	0.9	1	1	0.8	0.80	1.03
Total	36.9	45.2	44.4	45.3	44.7	44.7	42.95

Table F. 3: Potato Point SPS – Dry Period 3 Measured Hourly SPS Inlet Flow

Period 3 - Hourly Flow (kL/hr)										
	Daily Totals								Averages	
Hour	3/5/22	4/5/22	5/5/22	6/5/22	7/5/22	8/5/22	9/5/22	10/5/22	Weekday	Weekend
1.00	0.4	0.4	0.5	0.3	0.4	0.7	0.5	0.3	0.40	0.55
2.00	0.2	0.3	0.2	0.4	0.4	0.6	0.5	0.2	0.30	0.50
3.00	0.3	0.2	0.4	0.5	0.3	0.2	0.4	0.2	0.33	0.25
4.00	0.4	0.5	0.3	0.3	0.5	0.2	0.5	0.4	0.40	0.35
5.00	0.5	0.4	0.4	0.4	0.3	0.2	0.5	0.4	0.43	0.25
6.00	0.4	0.3	0.6	0.4	0.4	0.4	0.6	0.5	0.47	0.40
7.00	1.3	0.8	1.2	1.1	1	0.7	1.1	1.2	1.12	0.85
8.00	1.4	1.9	1.8	1.7	1.6	1.7	1.3	1.3	1.57	1.65
9.00	1.5	1.2	1.3	2.1	2.3	1.8	1.7	1.5	1.55	2.05
10.00	1.9	1.2	1.1	1.5	2.5	1.5	2	1.2	1.48	2.00
11.00	1.7	1.5	1.7	1.3	1.8	2.3	1.9	1.3	1.57	2.05
12.00	1.7	1	0.9	1.1	1.7	1.9	1.6	1.1	1.23	1.80
13.00	1	1	0.9	0.4	1.1	0.9	1.6	0.4	0.88	1.00
14.00	0.5	0.8	0.8	1.1	0.7	1.3	1.4	0.6	0.87	1.00
15.00	0.8	0.9	0.8	1.3	0.7	1	0.7	0.4	0.82	0.85
16.00	0.8	0.7	0.6	1	0.9	1.2	1.1	0.7	0.82	1.05
17.00	0.8	1.1	1	0.9	1.5	0.9	0.7	1	0.92	1.20
18.00	1.2	1	0.9	1	1.2	1.4	1.6	1.1	1.13	1.30
19.00	1.6	0.9	0.9	1	1.4	1.7	1.3	1	1.12	1.55
20.00	1.5	1.6	1.3	1.4	1.5	1.2	0.9	0.9	1.27	1.35
21.00	1	0.8	1.2	1.4	1.3	0.9	0.7	1.5	1.10	1.10
22.00	1.1	0.6	0.7	1	0.8	0.7	0.9	0.9	0.87	0.75
23.00	0.6	0.4	0.7	1	0.8	0.5	0.4	0.3	0.57	0.65
24.00	0.3	0.7	0.3	0.8	0.6	0.9	0.5	0.6	0.48	0.75
Total	22.9	20.2	20.5	23.4	25.7	24.8	24.4	19	21.68	25.25

Table F. 4: Potato Point SPS – Dry Period 4 Measured Hourly SPS Inlet Flow

Period 4 - Hourly Flow (kL/hr)								
	Daily Totals						Averages	
Hour	18/5/22	19/5/22	20/5/22	21/5/22	22/5/22	23/5/22	Weekday	Weekend
1.00	0.3	0.3	0.3	0.5	0.6	0.3	0.30	0.55
2.00	0.3	0.4	0.4	0.4	0.3	0.4	0.38	0.35
3.00	0.3	0.4	0.5	0.2	0.3	0.4	0.40	0.25
4.00	0.4	0.3	0.5	0.3	0.4	0.3	0.38	0.35
5.00	0.3	0.2	0.3	0.3	0.4	0.4	0.30	0.35
6.00	0.5	0.5	0.4	0.2	0.1	0.6	0.50	0.15
7.00	1.1	1.1	0.5	0.7	0.8	0.7	0.85	0.75
8.00	1.1	1.2	1.3	1.4	1.4	1	1.15	1.40
9.00	1.3	1.3	1.7	1.6	1.5	1.8	1.53	1.55
10.00	1.3	1.3	2.2	1.8	2.3	1	1.45	2.05
11.00	1	1.1	1.3	1.9	2.3	1.2	1.15	2.10
12.00	0.9	1.2	1.6	1.1	1.8	0.9	1.15	1.45
13.00	0.9	0.7	1.4	1.1	1	0.7	0.93	1.05
14.00	0.5	0.7	0.9	1.1	1.2	0.6	0.68	1.15
15.00	1	0.6	0.7	0.9	1	1.1	0.85	0.95
16.00	0.8	1.1	0.9	0.7	1.6	1	0.95	1.15
17.00	0.9	1.1	1.1	1.3	1.4	0.8	0.98	1.35
18.00	1.3	1.6	1.1	1.5	1.2	1.2	1.30	1.35
19.00	1	1.5	0.9	1.5	1.8	1.2	1.15	1.65
20.00	0.7	1.3	1.1	1.2	0.7	0.8	0.98	0.95
21.00	0.6	1	1.1	0.7	1.5	1.1	0.95	1.10
22.00	0.6	0.6	0.7	0.8	0.9	0.8	0.68	0.85
23.00	0.7	0.6	0.8	0.7	0.7	0.5	0.68	0.85
24.00	0.3	0.5	0.4	0.3	0.5	0.3	0.38	0.40
Total	18.1	20.6	22.1	22.2	25.7	19.1	20	24.1

Table F. 5: Potato Point SPS – Dry Period 5 Measured Hourly SPS Inlet Flow

Period 5 - Hourly Flow (kL/hr)						
	Daily Totals				Averages	
Hour	2/6/22	3/6/22	4/6/22	5/6/22	Weekday	Weekend
1.00	0.1	0.3	0.3	0.1	0.20	0.20
2.00	0.2	0.2	0.2	0.2	0.20	0.20
3.00	0.2	0.1	0.1	0.3	0.15	0.20
4.00	0.2	0.3	0.2	0.1	0.25	0.15
5.00	0.3	0.3	0.2	0.2	0.30	0.20
6.00	0.2	0.3	0.3	0.2	0.25	0.25
7.00	0.6	0.5	0.5	0.5	0.55	0.50
8.00	1.4	1.3	1.5	0.8	1.35	1.15
9.00	1.1	1.3	1.2	1.8	1.20	1.50
10.00	1.6	1.3	1.7	2.2	1.45	1.95
11.00	0.9	0.8	2.1	1.7	0.85	1.90
12.00	0.9	0.8	1.4	2	0.85	1.70
13.00	1.1	1	1.1	0.9	1.05	1.00
14.00	0.7	0.8	0.9	1.1	0.75	1.00
15.00	0.4	0.4	0.8	1.4	0.40	1.10
16.00	0.5	0.9	0.8	1.1	0.70	0.95
17.00	0.7	1.1	1.1	0.9	0.90	1.00
18.00	0.7	1.3	1.1	1.2	1.00	1.15
19.00	1.1	1.2	1	1.2	1.15	1.10
20.00	1.1	0.9	1.4	1.1	1.00	1.25
21.00	1	0.8	0.9	0.8	0.90	0.85
22.00	0.4	0.4	0.7	0.7	0.40	0.70
23.00	0.4	0.4	0.7	0.4	0.40	0.55
24.00	0.3	0.4	0.3	0.3	0.35	0.30
Total	16.1	17.1	20.5	21.2	16.6	20.85

Table F. 6: Potato Point SPS – Dry Period 6 Measured Hourly SPS Inlet Flow

Period 6 - Hourly Flow (kL/hr)										
	Daily Totals								**Averages**	
Hour/Day	13/7/22	14/7/22	15/7/22	16/7/22	17/7/22	18/7/22	19/7/22	20/7/22	Weekday	Weekend
1.00	0.2	0.1	0.1	0	0.2	Res Flow Errors	0.4	0	0.20	0.12
2.00	0	0	0.1	0.3	0.3		0.2	0	0.10	0.14
3.00	0.2	0	0.1	0	0.3		0	0.2	0.10	0.12
4.00	0.1	0	0.1	0	0.1		0	0.2	0.10	0.06
5.00	0.1	0.2	0.1	0.2	0		0.1	0.2	0.15	0.12
6.00	0.1	0.2	0.2	0.1	0.1		0.2	0.1	0.15	0.14
7.00	0.6	0.5	0.3	0.4	0.2		0.9	0.5	0.70	0.40
8.00	1.2	1	1.3	1	1		1	1.3	1.15	1.10
9.00	1.1	1.5	1.7	1.8	2.3		1	1.1	1.05	1.68
10.00	1.8	1.7	1.4	1.1	1.6		1.4	0.3	0.85	1.52
11.00	1.7	1.5	0.9	1.2	1.6		0.7	0.4	0.55	1.38
12.00	1	0.8	1.3	0.8	1.3		0.6	0.6	0.60	1.04
13.00	0.6	0.6	0.8	0.9	0.8		0.5	0.7	0.60	0.74
14.00	0.6	0.7	0.3	1	0.6		0.5	0.7	0.60	0.64
15.00	0.7	0.5	0.3	0.9	0.8		0.6	0.3	0.45	0.64
16.00	0.4	0.4	0.4	0.4	0.6		0.5	0.3	0.40	0.44
17.00	0.6	0.7	0.7	0.7	0.9		0.5	0.9	0.70	0.72
18.00	0.7	1	1	0.5	0.8		0.9	0.6	0.75	0.80
19.00	0.8	0.9	0.7	0.5	0.9		0.7	1.2	0.95	0.76
20.00	2	1	1.3	1	1.1		0.9	0.7	0.80	1.28
21.00	0.7	0.7	0.8	0.6	0.4		0.7	0.5	0.60	0.64
22.00	0.5	0.5	0.7	0.5	0.3		0.5	0.5	0.50	0.50
23.00	0.4	0.3	0.5	0.2	0.2		0.4	0.2	0.30	0.32
24.00	0.2	0.2	0.3	0.3	0.1		0.1	0.2	0.15	0.22
Total	16.3	15	15.4	14.4	16.5		13.3	11.7	12.5	15.52

Table F. 7: Potato Point SPS – Average and DWF Measured Hourly SPS Inlet Flow

All Periods - Hourly Flow (kL/hr)				
	Averages		**ADWF**	
Hour	Weekday	Weekend	Weekday	Weekend
1.00	0.31	0.36	0.98	0.93
2.00	0.30	0.33	0.98	0.93
3.00	0.28	0.22	0.98	0.93
4.00	0.35	0.22	0.98	0.93
5.00	0.31	0.24	0.98	0.93
6.00	0.42	0.27	0.98	0.93
7.00	0.95	0.63	0.98	0.93
8.00	1.69	1.39	0.98	0.93
9.00	1.89	1.73	0.98	0.93
10.00	1.78	1.86	0.98	0.93
11.00	1.52	1.83	0.98	0.93
12.00	1.34	1.43	0.98	0.93
13.00	1.24	1.00	0.98	0.93
14.00	1.10	1.02	0.98	0.93
15.00	0.99	1.06	0.98	0.93
16.00	1.09	0.96	0.98	0.93
17.00	1.21	1.08	0.98	0.93
18.00	1.35	1.28	0.98	0.93
19.00	1.25	1.38	0.98	0.93
20.00	1.29	1.25	0.98	0.93
21.00	1.10	1.01	0.98	0.93
22.00	0.82	0.78	0.98	0.93
23.00	0.62	0.64	0.98	0.93
24.00	0.43	0.47	0.98	0.93
Total	23.64	22.44	23.64	22.44

Table F. 8: DWF Weekday Hourly Flow Proportions

Weekday Flow - Hourly Flow Proportions								
Hour	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Average	HW (2018)
1.00	0.95%	1.12%	1.85%	1.50%	1.20%	1.60%	1.37%	0.83%
2.00	1.33%	1.12%	1.38%	1.88%	1.20%	0.80%	1.29%	0.54%
3.00	1.52%	0.67%	1.54%	2.00%	0.90%	0.80%	1.24%	0.46%
4.00	1.14%	1.57%	1.85%	1.88%	1.51%	0.80%	1.46%	0.46%
5.00	1.14%	0.89%	2.00%	1.50%	1.81%	1.20%	1.42%	1.17%
6.00	1.71%	1.57%	2.15%	2.50%	1.51%	1.20%	1.77%	3.25%
7.00	3.80%	3.36%	5.15%	4.25%	3.31%	5.60%	4.24%	7.00%
8.00	7.97%	6.26%	7.23%	5.75%	8.13%	9.20%	7.42%	9.00%
9.00	8.73%	8.28%	7.15%	7.63%	7.23%	8.40%	7.90%	8.88%
10.00	7.40%	7.83%	6.84%	7.25%	8.73%	6.80%	7.48%	8.00%
11.00	6.83%	7.16%	7.23%	5.75%	5.12%	4.40%	6.08%	6.71%
12.00	4.17%	6.94%	5.69%	5.75%	5.12%	4.80%	5.41%	5.58%
13.00	5.69%	5.59%	4.07%	4.63%	6.33%	4.80%	5.19%	4.71%
14.00	5.31%	5.15%	4.00%	3.38%	4.52%	4.80%	4.52%	4.04%
15.00	4.74%	4.92%	3.77%	4.25%	2.41%	3.60%	3.95%	3.83%
16.00	4.93%	5.37%	3.77%	4.75%	4.22%	3.20%	4.37%	4.33%
17.00	3.98%	6.04%	4.23%	4.88%	5.42%	5.60%	5.02%	5.58%
18.00	4.55%	6.04%	5.23%	6.50%	6.02%	6.00%	5.72%	6.00%
19.00	5.12%	4.03%	5.15%	5.75%	6.93%	7.60%	5.76%	5.21%
20.00	4.55%	5.59%	5.84%	4.88%	6.02%	6.40%	5.55%	4.42%
21.00	5.12%	3.80%	5.07%	4.75%	5.42%	4.80%	4.83%	3.63%
22.00	4.74%	2.68%	4.00%	3.38%	2.41%	4.00%	3.54%	2.83%
23.00	2.85%	2.24%	2.61%	3.38%	2.41%	2.40%	2.65%	2.13%
24.00	1.71%	1.79%	2.21%	1.88%	2.11%	1.20%	1.82%	1.42%
totals	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Table F. 9: DWF Weekend/Holiday Hourly Flow Proportions

Weekend/Holiday Flow - Hourly Flow Proportions								
Hour	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Average	HW (2018)
1.00	1.23%	1.69%	2.18%	2.28%	0.96%	0.77%	1.52%	0.83%
2.00	1.76%	1.40%	1.98%	1.45%	0.96%	0.90%	1.41%	0.54%
3.00	1.06%	0.99%	0.99%	1.04%	0.96%	0.77%	0.97%	0.46%
4.00	0.88%	0.93%	1.39%	1.45%	0.72%	0.39%	0.96%	0.46%
5.00	1.06%	1.11%	0.99%	1.45%	0.96%	0.77%	1.06%	1.17%
6.00	1.23%	1.46%	1.58%	0.62%	1.20%	0.90%	1.17%	3.25%
7.00	1.76%	3.32%	3.37%	3.11%	2.40%	2.58%	2.76%	7.00%
8.00	8.27%	4.89%	6.53%	5.81%	5.52%	7.09%	6.35%	9.00%
9.00	7.57%	7.33%	8.12%	6.43%	7.19%	10.82%	7.91%	8.88%
10.00	8.10%	7.51%	7.92%	8.51%	9.35%	9.79%	8.53%	8.00%
11.00	7.22%	7.74%	8.12%	8.71%	9.11%	8.89%	8.30%	6.71%
12.00	6.16%	5.24%	7.13%	6.02%	8.15%	6.70%	6.57%	5.58%
13.00	4.58%	4.48%	3.96%	4.36%	4.80%	4.77%	4.49%	4.71%
14.00	4.75%	4.66%	3.96%	4.77%	4.80%	4.12%	4.51%	4.04%
15.00	3.87%	6.40%	3.37%	3.94%	5.28%	4.12%	4.50%	3.83%
16.00	4.75%	4.19%	4.16%	4.77%	4.56%	2.84%	4.21%	4.33%
17.00	4.05%	5.01%	4.75%	5.60%	4.80%	4.64%	4.81%	5.58%
18.00	5.99%	6.11%	5.15%	5.60%	5.52%	5.15%	5.59%	6.00%
19.00	7.04%	6.05%	6.14%	6.85%	5.28%	4.90%	6.04%	5.21%
20.00	5.63%	5.47%	5.35%	3.94%	6.00%	8.25%	5.77%	4.42%
21.00	5.28%	4.42%	4.36%	4.56%	4.08%	4.12%	4.47%	3.63%
22.00	3.52%	3.78%	2.97%	3.53%	3.36%	3.22%	3.40%	2.83%
23.00	2.11%	3.43%	2.57%	3.53%	2.64%	2.06%	2.72%	2.13%
24.00	2.11%	2.39%	2.97%	1.66%	1.44%	1.42%	2.00%	1.42%
totals	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Table F. 10: Wet Weather Period 1 Measured Hourly SPS Inlet Flow (1 of 2)

Wet Weather Period 1									
	Hourly SPS Inflow Totals (kL)								
Hour	26/2/22	27/2/22	28/2/22	1/3/22	2/3/22	3/3/22	4/3/22	5/3/22	6/3/22
1.00	0.6	5.4	0.9	0.4	2.4	2.6	2.2	0.7	3.1
2.00	0.4	3.6	0.8	0.5	2.2	2.3	1.6	0.4	2.6
3.00	0.2	2.5	0.8	0.2	2	2.5	1.6	0.9	2.1
4.00	0.4	2.7	0.2	0.4	2.4	1.9	1.6	0.5	2.3
5.00	0.2	2.1	0.7	0.4	4	1.9	1.7	0.5	2.2
6.00	0.5	2	0.8	0.5	3.4	2	1.5	0.9	2.4
7.00	0.8	2.4	1.2	1.2	3.2	2.6	2.3	0.9	1.9
8.00	1.4	2.7	1.6	1.5	9.2	2.9	2.3	2	2.3
9.00	1.4	3	1.7	1.3	6.2	2.8	2.5	2.3	3
10.00	2	3.4	2	1.8	4.5	3.3	2.6	1.8	3.1
11.00	1.9	3.1	1.5	1.6	4.3	2.4	2.1	2.3	2.9
12.00	1.6	3.2	0.9	0.7	3.1	1.9	2.3	1.5	2.9
13.00	1.7	2.3	1.1	1	3.5	2.9	2.1	2.2	2.3
14.00	1.1	1.9	1.1	0.7	2.5	4.6	1.6	1.4	1.9
15.00	1.2	1.7	1.1	1	3.4	4.1	1.6	1.1	1.8
16.00	1	1.3	0.9	0.8	3.7	4	1.3	1.3	2.1
17.00	1.6	1.7	1.5	1.6	3.7	3.9	1.5	0.9	1.9
18.00	1.2	1.5	1.5	1.3	4	4	1.6	1.5	3.8
19.00	2	1.9	1.3	1.6	7.8	3.9	1.6	1.8	6.2
20.00	1.6	1.5	1.2	1.3	4.3	3.2	2.2	2.1	4.1
21.00	4.3	1.7	0.6	1	3.8	3.4	1.9	2.1	3.7
22.00	4.9	1.6	1.1	1.2	5.7	2.8	1.4	9	3.2
23.00	3.3	0.9	0.6	3.2	3.9	2.4	1	5.5	3.2
24.00	5.1	0.7	0.5	2.5	1.1	1.9	1.2	4.2	1.2
Total	40.4	54.8	25.6	27.7	94.3	70.2	43.3	47.8	66.2

Table F. 11: Wet Weather Period 1 Measured Hourly SPS Inlet Flow (2 of 2)

Wet Weather Period 1								
	Hourly SPS Inflow Totals (kL)							
Hour/Day	7/3/22	8/3/22	9/3/22	10/3/22	11/3/22	12/3/22	13/3/22	14/3/22
1.00	2.4	3.9	2.2	1	0.4	0.3	0.4	0.1
2.00	2	3.2	2.4	0.8	0.4	0.6	0.4	0.3
3.00	2.6	3.6	2.3	0.6	0.6	0.3	0.3	0.2
4.00	2.1	4.4	1.9	0.7	0.4	0.3	0.2	0.2
5.00	2.1	4.4	2.4	0.4	0.4	0.2	0.4	0.2
6.00	3.1	5.7	1.8	0.8	0.5	0.4	0.3	0.4
7.00	4.8	7.9	2.8	2	1	0.7	0.3	1
8.00	4.4	5.8	2.8	2.1	2.5	2.9	1.8	1.7
9.00	5.1	9.3	3.3	2.3	2.3	2.3	2	2.3
10.00	5	9.7	3.3	2.2	1.8	2.5	2.1	2.1
11.00	4.3	9.9	2.9	1.9	1.7	2.2	1.9	1.9
12.00	3.5	8.2	2.7	1.3	0.9	1.8	1.7	1.3
13.00	3.4	8.9	2.6	0.9	1.5	1.3	1.3	1.5
14.00	2.8	12.2	2.5	0.9	1.9	1.3	1.4	0.9
15.00	2.9	8.7	1.6	1.2	2	1	1.2	0.5
16.00	2.8	7.5	2.4	1.4	1.2	1.1	1.6	1.4
17.00	3.4	5.4	2	2	1.4	0.9	1.4	0.7
18.00	2.8	5.2	2.1	1.4	1.3	1.6	1.8	1.1
19.00	3.8	5.3	1.5	1.6	1.1	2.3	1.7	1.6
20.00	4.2	4.7	2.2	1.5	1.6	1.9	1.3	0.8
21.00	5.9	3.9	1.6	1.1	1.5	2	1	1.2
22.00	8.8	3.6	1.3	0.7	1.4	0.7	1.3	1.1
23.00	10.8	3	1	0.8	1	0.5	0.7	0.5
24.00	5	2.9	0.9	0.8	0.5	0.5	0.7	0.4
Total	98	147.3	52.5	30.4	29.3	29.6	27.2	23.4

Table F. 12: Wet Weather Period 2 Measured Hourly SPS Inlet Flow (1 of 2)

Wet Weather Period 2							
	Hourly SPS Inflow Totals (kL)						
Hour	5/4/22	6/4/22	7/4/22	8/4/22	9/4/22	10/4/22	11/4/22
1.00	0.4	0.4	3.3	2.4	1.6	2.7	1.2
2.00	0.2	0.4	3.5	3.8	1.2	2	0.7
3.00	0.4	0.4	3.2	3	1.8	2.1	1
4.00	0.3	0.3	2.2	2.5	1.1	1.8	0.8
5.00	0.3	0.5	1.9	6.8	1.3	1.8	0.7
6.00	0.5	0.5	5	9.2	1.5	1.7	0.9
7.00	1.2	1.1	8.6	5.4	2.5	2.1	1.8
8.00	1.8	1.4	9.9	4.4	2.6	3.5	2.4
9.00	1.6	1.5	6	3.4	3.2	4	2.9
10.00	1.6	2	5.6	3.9	3.6	3.7	2.3
11.00	1.3	1.3	5.4	3.6	6.9	3	1.8
12.00	1.3	1	9	4	6.6	2.4	1.5
13.00	1.3	0.7	10.9	3.1	5.2	2.8	1.3
14.00	0.7	2.3	6.1	2.9	4.7	2.1	1.3
15.00	0.8	7.5	4.1	2.6	3.5	2.8	1.5
16.00	0.8	9	4.8	2.8	8	2.7	1.2
17.00	1.6	12.8	4.6	2.5	11.4	2.5	1.8
18.00	1.4	13	4.3	2.4	6.9	2.1	1.7
19.00	1.8	7.9	5.3	3.2	5.3	2.1	1.9
20.00	2.1	4.5	3.7	2.2	4.2	2.2	4.1
21.00	1.1	3.8	2.8	2.7	3.6	1.7	4
22.00	0.6	2.8	2.9	1.9	3.5	1.5	3
23.00	0.6	2.7	2.2	1.8	2.9	1.3	1.9
24.00	0.6	2.2	3.5	1.6	3.2	1.4	1.7
Total	24.3	80	118.8	82.1	96.3	56	43.4

Table F. 13: Wet Weather Period 2 Measured Hourly SPS Inlet Flow (2 of 2)

Wet Weather Period 2							
	Hourly SPS Inflow Totals (kL)						
Hour/Day	12/4/22	13/4/22	14/4/22	15/4/22	16/4/22	17/4/22	18/4/22
1.00	1.3	0.8	0.9	0.5	0.7	0.8	0.5
2.00	1.5	0.5	0.8	0.7	0.4	0.5	0.5
3.00	1.4	0.6	0.6	0.4	0.4	0.3	0.3
4.00	1.2	0.9	0.3	0.5	0.4	0.4	0.7
5.00	1.2	0.7	0.5	0.6	0.4	0.4	0.4
6.00	1.3	0.9	0.7	0.8	0.5	0.5	0.7
7.00	1.8	1	1.8	0.8	1.8	1.3	1.5
8.00	2.1	1.9	2.1	1.6	2.3	2.4	2.8
9.00	2.5	2.5	2.4	2.5	4.2	3.5	3.7
10.00	2.4	2.4	2.7	2.8	3.6	3.8	3.5
11.00	1.9	2.2	2.3	3.7	4.1	3.2	3.2
12.00	1.9	1.9	1.6	2.2	2.2	3	3.1
13.00	1.9	1.1	1.4	1.7	2	2.6	2.5
14.00	1.7	1.9	1.3	3.2	1.7	1.8	2.3
15.00	1.3	1.1	2	3.7	1.7	3.6	2.2
16.00	1.3	1.7	1.5	2	1.6	2.1	2.4
17.00	1.8	1.3	1.7	2.6	2.1	2.2	2.7
18.00	1.8	2.4	2.6	3.1	2.4	2.4	2.7
19.00	2.6	2	2.7	2.2	3.3	2.2	1.8
20.00	1.7	1.5	1.1	2.6	2.6	3.1	2.5
21.00	1.6	1.4	2.3	2	1.8	1.5	1.7
22.00	1.1	1.2	1.2	2.2	1.6	1.5	1.2
23.00	1.1	1.1	1.2	1.9	1.6	1.2	1
24.00	1.2	0.5	1.2	0.9	1	1	0.8
Total	39.6	33.5	36.9	45.2	44.4	45.3	44.7

Appendix G – Dry Weather Iterative Model Details

Table G. 1: Iteration 1 Daily DWF Model Values

Details					Model			Accuracy				
Period	Day	Date	Day	SPS Inflow	Predict	Diff.	% Diff.	<5%	<10%	<20%	<25%	<50%
	1	11/03/22	Friday	29.33	23.88	- 5.45	19%			YES	YES	YES
	2	12/03/22	Saturday	29.76	23.88	- 5.88	20%			YES	YES	YES
	3	13/03/22	Sunday	27.14	23.88	- 3.26	12%			YES	YES	YES
1	4	14/03/22	Monday	23.68	23.88	0.20	-1%	YES	YES	YES	YES	YES
	5	14/04/22	Thursday	36.98	23.88	- 13.10	35%					YES
	6	15/04/22	Friday	45.15	23.88	- 21.27	47%					YES
	7	16/04/22	Saturday	44.54	23.88	- 20.66	46%					YES
	8	17/04/22	Sunday	45.31	23.88	- 21.43	47%					YES
2	9	18/04/22	Monday	44.36	23.88	- 20.48	46%					YES
	10	03/05/22	Tuesday	23.06	23.88	0.82	-4%	YES	YES	YES	YES	YES
	11	04/05/22	Wednesday	19.98	23.88	3.90	-20%			YES	YES	YES
	12	05/05/22	Thursday	20.52	23.88	3.36	-16%			YES	YES	YES
	13	06/05/22	Friday	23.4	23.88	0.48	-2%	YES	YES	YES	YES	YES
	14	07/05/22	Saturday	25.73	23.88	- 1.85	7%		YES	YES	YES	YES
	15	08/05/22	Sunday	24.7	23.88	- 0.82	3%	YES	YES	YES	YES	YES
	16	09/05/22	Monday	24.37	23.88	- 0.49	2%	YES	YES	YES	YES	YES
3	17	10/05/22	Tuesday	19.01	23.88	4.87	-26%					YES
	18	18/05/22	Wednesday	18.09	23.88	5.79	-32%					YES
	19	19/05/22	Thursday	20.66	23.88	3.22	-16%			YES	YES	YES
	20	20/05/22	Friday	21.99	23.88	1.89	-9%		YES	YES	YES	YES
	21	21/05/22	Saturday	22.42	23.88	1.46	-7%		YES	YES	YES	YES
	22	22/05/22	Sunday	25.56	23.88	- 1.68	7%		YES	YES	YES	YES
4	23	23/05/22	Monday	19.19	23.88	4.69	-24%				YES	YES
	24	02/06/22	Thursday	16.07	23.88	7.81	-49%					YES
	25	03/06/22	Friday	17.08	23.88	6.80	-40%					YES
	26	04/06/22	Saturday	20.42	23.88	3.46	-17%			YES	YES	YES
5	27	05/06/22	Sunday	21.39	23.88	2.49	-12%			YES	YES	YES
	28	13/07/22	Wednesday	16.29	23.88	7.59	-47%					YES
	29	14/07/22	Thursday	14.86	23.88	9.02	-61%					
	30	15/07/22	Friday	15.24	23.88	8.64	-57%					
6	31	16/07/22	Saturday	14.62	23.88	9.26	-63%					
	32	17/07/22	Sunday	16.31	23.88	7.57	-46%					YES
	33	19/07/22	Tuesday	13.13	23.88	10.75	-82%					
	34	20/07/22	Wednesday	11.62	23.88	12.26	-106%					
		TOTALS		**811.96**	**811.954**		**37%**	**15%**	**26%**	**50%**	**53%**	**85%**

Table G. 2: Iteration 2 Daily DWF Model Values

Details				Flows			Model			Accuracy				
Period	Day	Date	Day	Res. flow	RSF	SPS Inflow	Predict	Diff.	% Diff.	<5%	<10%	<20%	<25%	<50%
	1	11/03/22	Friday	43.64	57.1%	29.33	24.92	- 4.41	15%			YES	YES	YES
	2	12/03/22	Saturday	42.65	57.1%	29.76	24.35	- 5.41	18%			YES	YES	YES
	3	13/03/22	Sunday	34.3	57.1%	27.14	19.59	- 7.55	28%					YES
1	4	14/03/22	Monday	33.04	57.1%	23.68	18.87	- 4.81	20%				YES	YES
	5	14/04/22	Thursday	62.38	57.1%	36.98	35.62	- 1.36	4%	YES	YES	YES	YES	YES
	6	15/04/22	Friday	67.87	57.1%	45.15	38.75	- 6.40	14%			YES	YES	YES
	7	16/04/22	Saturday	70.75	57.1%	44.54	40.40	- 4.14	9%		YES	YES	YES	YES
	8	17/04/22	Sunday	67.57	57.1%	45.31	38.58	- 6.73	15%			YES	YES	YES
2	9	18/04/22	Monday	52.64	57.1%	44.36	30.06	-14.30	32%					YES
	10	03/05/22	Tuesday	36.94	57.1%	23.06	21.09	- 1.97	9%		YES	YES	YES	YES
	11	04/05/22	Wednesday	36.47	57.1%	19.98	20.82	0.84	-4%	YES	YES	YES	YES	YES
	12	05/05/22	Thursday	41.39	57.1%	20.52	23.63	3.11	-15%			YES	YES	YES
	13	06/05/22	Friday	44.8	57.1%	23.4	25.58	2.18	-9%		YES	YES	YES	YES
	14	07/05/22	Saturday	40.01	57.1%	25.73	22.85	- 2.88	11%			YES	YES	YES
	15	08/05/22	Sunday	41.71	57.1%	24.7	23.82	- 0.88	4%	YES	YES	YES	YES	YES
	16	09/05/22	Monday	34.26	57.1%	24.37	19.56	- 4.81	20%			YES	YES	YES
3	17	10/05/22	Tuesday	34.92	57.1%	19.01	19.94	0.93	-5%	YES	YES	YES	YES	YES
	18	18/05/22	Wednesday	40.08	57.1%	18.09	22.89	4.80	-27%					YES
	19	19/05/22	Thursday	39.76	57.1%	20.66	22.70	2.04	-10%		YES	YES	YES	YES
	20	20/05/22	Friday	41.13	57.1%	21.99	23.49	1.50	-7%		YES	YES	YES	YES
	21	21/05/22	Saturday	43.99	57.1%	22.42	25.12	2.70	-12%			YES	YES	YES
	22	22/05/22	Sunday	36.08	57.1%	25.56	20.60	- 4.96	19%			YES	YES	YES
4	23	23/05/22	Monday	39.22	57.1%	19.19	22.39	3.20	-17%			YES	YES	YES
	24	02/06/22	Thursday	34.69	57.1%	16.07	19.81	3.74	-23%				YES	YES
	25	03/06/22	Friday	34.6	57.1%	17.08	19.76	2.68	-16%			YES	YES	YES
	26	04/06/22	Saturday	39.63	57.1%	20.42	22.63	2.21	-11%			YES	YES	YES
5	27	05/06/22	Sunday	39.47	57.1%	21.39	22.54	1.15	-5%		YES	YES	YES	YES
	28	13/07/22	Wednesday	35.72	57.1%	16.29	20.40	4.11	-25%					YES
	29	14/07/22	Thursday	36.99	57.1%	14.86	21.12	6.26	-42%					YES
	30	15/07/22	Friday	36.25	57.1%	15.24	20.70	5.46	-36%					YES
6	31	16/07/22	Saturday	35.6	57.1%	14.62	20.33	5.71	-39%					YES
	32	17/07/22	Sunday	35.51	57.1%	16.31	20.28	3.97	-24%				YES	YES
	33	19/07/22	Tuesday	32.24	57.1%	13.13	18.41	5.28	-40%					YES
	34	20/07/22	Wednesday	30.38	57.1%	11.62	17.35	5.73	-49%					YES
		TOTALS		**1416.68**		**811.96**	**808.92**		**22%**	**12%**	**29%**	**65%**	**74%**	**100%**

Table G. 3: Iteration 3 Daily DWF Model Values

Details				Flows			Model			Accuracy				
Period	Day	Date	Day	Res. flow	RSF	SPS Inflow	ADWF	Diff.	% Diff.	<5%	<10%	<20%	<25%	<50%
	1	11/03/22	Friday	43.64	71.3%	29.33	31.12	1.79	-6%		YES	YES	YES	YES
	2	12/03/22	Saturday	42.65	71.3%	29.76	30.41	0.65	-2%	YES	YES	YES	YES	YES
	3	13/03/22	Sunday	34.3	71.3%	27.14	24.46	- 2.68	10%		YES	YES	YES	YES
1	4	14/03/22	Monday	33.04	71.3%	23.68	23.56	- 0.12	1%	YES	YES	YES	YES	YES
	5	14/04/22	Thursday	62.38	67.4%	36.98	42.04	5.06	-14%			YES	YES	YES
	6	15/04/22	Friday	67.87	67.4%	45.15	45.74	0.59	-1%	YES	YES	YES	YES	YES
	7	16/04/22	Saturday	70.75	67.4%	44.54	47.69	3.15	-7%		YES	YES	YES	YES
	8	17/04/22	Sunday	67.57	67.4%	45.31	45.54	0.23	-1%	YES	YES	YES	YES	YES
2	9	18/04/22	Monday	52.64	67.4%	44.36	35.48	- 8.88	20%				YES	YES
	10	03/05/22	Tuesday	36.94	58.3%	23.06	21.54	- 1.52	7%		YES	YES	YES	YES
	11	04/05/22	Wednesday	36.47	58.3%	19.98	21.26	1.28	-6%		YES	YES	YES	YES
	12	05/05/22	Thursday	41.39	58.3%	20.52	24.13	3.61	-18%			YES	YES	YES
	13	06/05/22	Friday	44.8	58.3%	23.4	26.12	2.72	-12%			YES	YES	YES
	14	07/05/22	Saturday	40.01	58.3%	25.73	23.33	- 2.40	9%		YES	YES	YES	YES
	15	08/05/22	Sunday	41.71	58.3%	24.7	24.32	- 0.38	2%	YES	YES	YES	YES	YES
	16	09/05/22	Monday	34.26	58.3%	24.37	19.97	- 4.40	18%			YES	YES	YES
3	17	10/05/22	Tuesday	34.92	58.3%	19.01	20.36	1.35	-7%		YES	YES	YES	YES
	18	18/05/22	Wednesday	40.08	53.2%	18.09	21.32	3.23	-18%			YES	YES	YES
	19	19/05/22	Thursday	39.76	53.2%	20.66	21.15	0.49	-2%	YES	YES	YES	YES	YES
	20	20/05/22	Friday	41.13	53.2%	21.99	21.88	- 0.11	0%	YES	YES	YES	YES	YES
	21	21/05/22	Saturday	43.99	53.2%	22.42	23.40	0.98	-4%	YES	YES	YES	YES	YES
	22	22/05/22	Sunday	36.08	53.2%	25.56	19.19	- 6.37	25%				YES	YES
4	23	23/05/22	Monday	39.22	53.2%	19.19	20.87	1.68	-9%		YES	YES	YES	YES
	24	02/06/22	Thursday	34.69	50.5%	16.07	17.52	1.45	-9%		YES	YES	YES	YES
	25	03/06/22	Friday	34.6	50.5%	17.08	17.47	0.39	-2%	YES	YES	YES	YES	YES
	26	04/06/22	Saturday	39.63	50.5%	20.42	20.01	- 0.41	2%	YES	YES	YES	YES	YES
5	27	05/06/22	Sunday	39.47	50.5%	21.39	19.93	- 1.46	7%		YES	YES	YES	YES
	28	13/07/22	Wednesday	35.72	42.3%	16.29	15.11	- 1.18	7%		YES	YES	YES	YES
	29	14/07/22	Thursday	36.99	42.3%	14.86	15.65	0.79	-5%		YES	YES	YES	YES
	30	15/07/22	Friday	36.25	42.3%	15.24	15.33	0.09	-1%	YES	YES	YES	YES	YES
6	31	16/07/22	Saturday	35.6	42.3%	14.62	15.06	0.44	-3%	YES	YES	YES	YES	YES
	32	17/07/22	Sunday	35.51	42.3%	16.31	15.02	- 1.29	8%		YES	YES	YES	YES
	33	19/07/22	Tuesday	32.24	42.3%	13.13	13.64	0.51	-4%	YES	YES	YES	YES	YES
	34	20/07/22	Wednesday	30.38	42.3%	11.62	12.85	1.23	-11%			YES	YES	YES
		TOTALS		**1416.68**		**811.96**	**812.47**		**10%**	**38%**	**76%**	**94%**	**100%**	**100%**

Appendix H – Customised Hydraulic Model Examples

Figure H. 1: Dry Period 3 Hourly DWF Model Example

							Return to Sewer Factor		58%
					Flow (kL)	Daily Res Flow	Proportion	ADWF + GWI	Actual RDII
Hour	Flows until	Day of Week	Date	Time	180.90	310.50	8.00	180.90	0.00
1.00	3/05/22 01:00	Tuesday	3/05/2022	1:00:00 AM	0.4	36.94	1.37%	0.29	0.11
2.00	3/05/22 02:00	Tuesday	3/05/2022	2:00:00 AM	0.2	36.94	1.29%	0.28	-0.08
3.00	3/05/22 03:00	Tuesday	3/05/2022	3:00:00 AM	0.3	36.94	1.24%	0.27	0.03
4.00	3/05/22 04:00	Tuesday	3/05/2022	4:00:00 AM	0.4	36.94	1.46%	0.31	0.09
5.00	3/05/22 05:00	Tuesday	3/05/2022	5:00:00 AM	0.5	36.94	1.42%	0.31	0.19
6.00	3/05/22 06:00	Tuesday	3/05/2022	6:00:00 AM	0.4	36.94	1.77%	0.38	0.02
7.00	3/05/22 07:00	Tuesday	3/05/2022	7:00:00 AM	1.3	36.94	4.24%	0.91	0.39
8.00	3/05/22 08:00	Tuesday	3/05/2022	8:00:00 AM	1.4	36.94	7.42%	1.60	-0.20
9.00	3/05/22 09:00	Tuesday	3/05/2022	9:00:00 AM	1.5	36.94	7.90%	1.70	-0.20
10.00	3/05/22 10:00	Tuesday	3/05/2022	10:00:00 AM	1.9	36.94	7.48%	1.61	0.29
11.00	3/05/22 11:00	Tuesday	3/05/2022	11:00:00 AM	1.7	36.94	6.08%	1.31	0.39
12.00	3/05/22 12:00	Tuesday	3/05/2022	12:00:00 PM	1.7	36.94	5.41%	1.16	0.54
13.00	3/05/22 13:00	Tuesday	3/05/2022	1:00:00 PM	1	36.94	5.19%	1.12	-0.12
14.00	3/05/22 14:00	Tuesday	3/05/2022	2:00:00 PM	0.5	36.94	4.52%	0.97	-0.47
15.00	3/05/22 15:00	Tuesday	3/05/2022	3:00:00 PM	0.8	36.94	3.95%	0.85	-0.05
16.00	3/05/22 16:00	Tuesday	3/05/2022	4:00:00 PM	0.8	36.94	4.37%	0.94	-0.14
17.00	3/05/22 17:00	Tuesday	3/05/2022	5:00:00 PM	0.8	36.94	5.02%	1.08	-0.28
18.00	3/05/22 18:00	Tuesday	3/05/2022	6:00:00 PM	1.2	36.94	5.72%	1.23	-0.03
19.00	3/05/22 19:00	Tuesday	3/05/2022	7:00:00 PM	1.6	36.94	5.76%	1.24	0.36
20.00	3/05/22 20:00	Tuesday	3/05/2022	8:00:00 PM	1.5	36.94	5.55%	1.19	0.31
21.00	3/05/22 21:00	Tuesday	3/05/2022	9:00:00 PM	1	36.94	4.83%	1.04	-0.04
22.00	3/05/22 22:00	Tuesday	3/05/2022	10:00:00 PM	1.1	36.94	3.54%	0.76	0.34
23.00	3/05/22 23:00	Tuesday	3/05/2022	11:00:00 PM	0.6	36.94	2.65%	0.57	0.03
24.00	4/05/22 00:00	Tuesday	4/05/2022	12:00:00 AM	0.3	36.94	1.82%	0.39	-0.09
1.00	4/05/22 01:00	Wednesday	4/05/2022	1:00:00 AM	0.4	36.47	1.37%	0.29	0.11
2.00	4/05/22 02:00	Wednesday	4/05/2022	2:00:00 AM	0.3	36.47	1.29%	0.27	0.03
3.00	4/05/22 03:00	Wednesday	4/05/2022	3:00:00 AM	0.2	36.47	1.24%	0.26	-0.06
4.00	4/05/22 04:00	Wednesday	4/05/2022	4:00:00 AM	0.5	36.47	1.46%	0.31	0.19
5.00	4/05/22 05:00	Wednesday	4/05/2022	5:00:00 AM	0.4	36.47	1.42%	0.30	0.10
6.00	4/05/22 06:00	Wednesday	4/05/2022	6:00:00 AM	0.3	36.47	1.77%	0.38	-0.08
7.00	4/05/22 07:00	Wednesday	4/05/2022	7:00:00 AM	0.8	36.47	4.24%	0.90	-0.10
8.00	4/05/22 08:00	Wednesday	4/05/2022	8:00:00 AM	1.9	36.47	7.42%	1.58	0.32
9.00	4/05/22 09:00	Wednesday	4/05/2022	9:00:00 AM	1.2	36.47	7.90%	1.68	-0.48
10.00	4/05/22 10:00	Wednesday	4/05/2022	10:00:00 AM	1.2	36.47	7.48%	1.59	-0.39
11.00	4/05/22 11:00	Wednesday	4/05/2022	11:00:00 AM	1.5	36.47	6.08%	1.29	0.21
12.00	4/05/22 12:00	Wednesday	4/05/2022	12:00:00 PM	1	36.47	5.41%	1.15	-0.15
13.00	4/05/22 13:00	Wednesday	4/05/2022	1:00:00 PM	1	36.47	5.19%	1.10	-0.10
14.00	4/05/22 14:00	Wednesday	4/05/2022	2:00:00 PM	0.8	36.47	4.52%	0.96	-0.16
15.00	4/05/22 15:00	Wednesday	4/05/2022	3:00:00 PM	0.9	36.47	3.95%	0.84	0.06
16.00	4/05/22 16:00	Wednesday	4/05/2022	4:00:00 PM	0.7	36.47	4.37%	0.93	-0.23
17.00	4/05/22 17:00	Wednesday	4/05/2022	5:00:00 PM	1.1	36.47	5.02%	1.07	0.03
18.00	4/05/22 18:00	Wednesday	4/05/2022	6:00:00 PM	1	36.47	5.72%	1.22	-0.22
19.00	4/05/22 19:00	Wednesday	4/05/2022	7:00:00 PM	0.9	36.47	5.76%	1.22	-0.32
20.00	4/05/22 20:00	Wednesday	4/05/2022	8:00:00 PM	1.6	36.47	5.55%	1.18	0.42
21.00	4/05/22 21:00	Wednesday	4/05/2022	9:00:00 PM	0.8	36.47	4.83%	1.03	-0.23

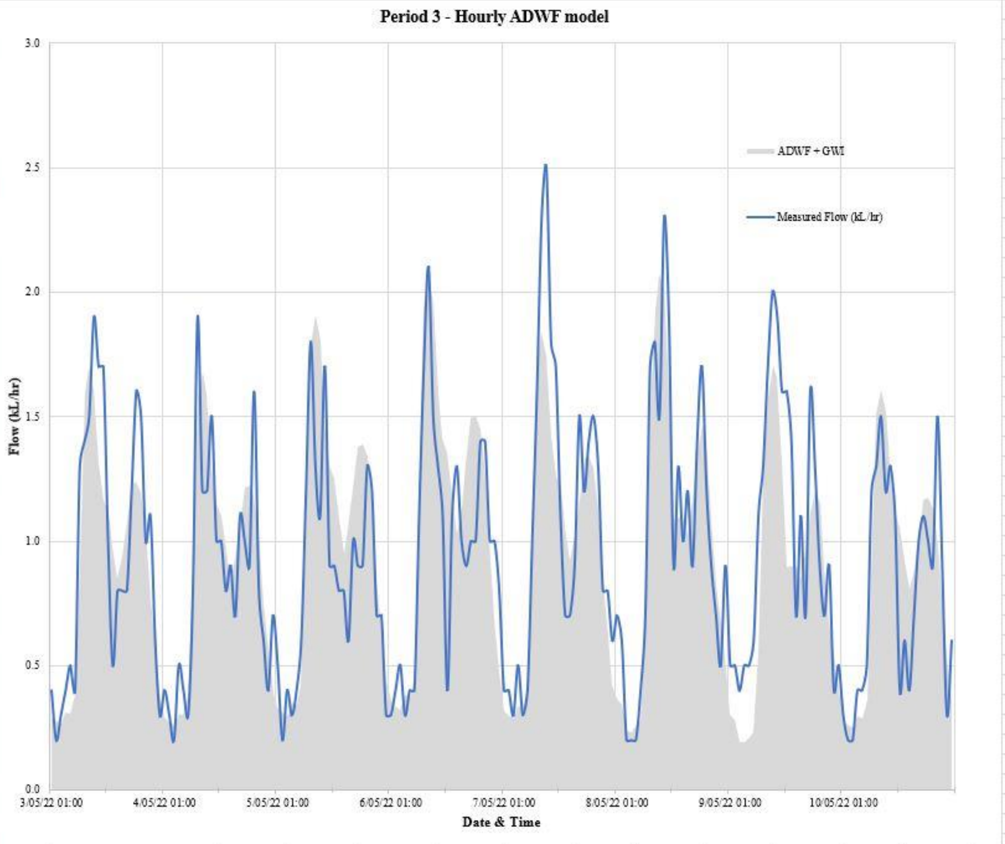


Figure H. 2: Wet Weather Period 1 Model Preliminary Analysis Example

					Flow (kL)	Rain (mm)	Daily Res Flow	Proportion	ADWF + GWI	Actual RDII	
Hour	Flows until	Day of Week	Date	Time	909.50	348.80	673.96	17.00	455.76	453.74	
1.00	26/02/22 01:00	Saturday	26/02/2022	1:00:00 AM	0.6	0.2	35.83	1.52%	0.299	0.301	
2.00	26/02/22 02:00	Saturday	26/02/2022	2:00:00 AM	0.4	0	35.83	1.41%	0.278	0.122	
3.00	26/02/22 03:00	Saturday	26/02/2022	3:00:00 AM	0.2	0	35.83	0.97%	0.191	0.009	
4.00	26/02/22 04:00	Saturday	26/02/2022	4:00:00 AM	0.4	0	35.83	0.96%	0.189	0.211	
5.00	26/02/22 05:00	Saturday	26/02/2022	5:00:00 AM	0.2	0	35.83	1.06%	0.208	-0.008	
6.00	26/02/22 06:00	Saturday	26/02/2022	6:00:00 AM	0.5	0	35.83	1.17%	0.230	0.270	
7.00	26/02/22 07:00	Saturday	26/02/2022	7:00:00 AM	0.8	0	35.83	2.76%	0.543	0.257	
8.00	26/02/22 08:00	Saturday	26/02/2022	8:00:00 AM	1.4	0	35.83	6.35%	1.252	0.148	
9.00	26/02/22 09:00	Saturday	26/02/2022	9:00:00 AM	1.4	0	35.83	7.91%	1.559	-0.159	seg 1
10.00	26/02/22 10:00	Saturday	26/02/2022	10:00:00 AM	2	0.6	35.83	8.53%	1.681	0.319	
11.00	26/02/22 11:00	Saturday	26/02/2022	11:00:00 AM	1.9	4	35.83	8.30%	1.636	0.264	
12.00	26/02/22 12:00	Saturday	26/02/2022	12:00:00 PM	1.6	1	35.83	6.57%	1.294	0.306	
13.00	26/02/22 13:00	Saturday	26/02/2022	1:00:00 PM	1.7	0.2	35.83	4.49%	0.885	0.815	
14.00	26/02/22 14:00	Saturday	26/02/2022	2:00:00 PM	1.1	0.2	35.83	4.51%	0.889	0.211	
15.00	26/02/22 15:00	Saturday	26/02/2022	3:00:00 PM	1.2	0	35.83	4.50%	0.886	0.314	
16.00	26/02/22 16:00	Saturday	26/02/2022	4:00:00 PM	1	0	35.83	4.21%	0.830	0.170	
17.00	26/02/22 17:00	Saturday	26/02/2022	5:00:00 PM	1.6	0	35.83	4.81%	0.947	0.653	
18.00	26/02/22 18:00	Saturday	26/02/2022	6:00:00 PM	1.2	0	35.83	5.59%	1.101	0.099	
19.00	26/02/22 19:00	Saturday	26/02/2022	7:00:00 PM	2	0.4	35.83	6.04%	1.191	0.809	
20.00	26/02/22 20:00	Saturday	26/02/2022	8:00:00 PM	1.6	5.8	35.83	5.77%	1.138	0.462	
21.00	26/02/22 21:00	Saturday	26/02/2022	9:00:00 PM	4.3	14.2	35.83	4.47%	0.881	3.419	
22.00	26/02/22 22:00	Saturday	26/02/2022	10:00:00 PM	4.9	10	35.83	3.40%	0.669	4.231	
23.00	26/02/22 23:00	Saturday	26/02/2022	11:00:00 PM	3.3	4.2	35.83	2.72%	0.537	2.763	
24.00	27/02/22 00:00	Saturday	27/02/2022	12:00:00 AM	5.1	7	35.83	2.00%	0.394	4.706	
1.00	27/02/22 01:00	Sunday	27/02/2022	1:00:00 AM	5.4	1.4	36.14	1.52%	0.302	5.098	
2.00	27/02/22 02:00	Sunday	27/02/2022	2:00:00 AM	3.6	1	36.14	1.41%	0.280	3.320	
3.00	27/02/22 03:00	Sunday	27/02/2022	3:00:00 AM	2.5	0	36.14	0.97%	0.192	2.308	
4.00	27/02/22 04:00	Sunday	27/02/2022	4:00:00 AM	2.7	0.6	36.14	0.96%	0.191	2.509	
5.00	27/02/22 05:00	Sunday	27/02/2022	5:00:00 AM	2.1	0.2	36.14	1.06%	0.210	1.890	
6.00	27/02/22 06:00	Sunday	27/02/2022	6:00:00 AM	2	0	36.14	1.17%	0.232	1.768	
7.00	27/02/22 07:00	Sunday	27/02/2022	7:00:00 AM	2.4	0	36.14	2.76%	0.548	1.852	
8.00	27/02/22 08:00	Sunday	27/02/2022	8:00:00 AM	2.7	0.2	36.14	6.35%	1.263	1.437	
9.00	27/02/22 09:00	Sunday	27/02/2022	9:00:00 AM	3	0	36.14	7.91%	1.573	1.427	
10.00	27/02/22 10:00	Sunday	27/02/2022	10:00:00 AM	3.4	0	36.14	8.53%	1.696	1.704	
11.00	27/02/22 11:00	Sunday	27/02/2022	11:00:00 AM	3.1	0	36.14	8.30%	1.650	1.450	
12.00	27/02/22 12:00	Sunday	27/02/2022	12:00:00 PM	3.2	0	36.14	6.57%	1.305	1.895	
13.00	27/02/22 13:00	Sunday	27/02/2022	1:00:00 PM	2.3	0	36.14	4.49%	0.893	1.407	
14.00	27/02/22 14:00	Sunday	27/02/2022	2:00:00 PM	1.9	0	36.14	4.51%	0.897	1.003	
15.00	27/02/22 15:00	Sunday	27/02/2022	3:00:00 PM	1.7	0	36.14	4.50%	0.894	0.806	
16.00	27/02/22 16:00	Sunday	27/02/2022	4:00:00 PM	1.3	0	36.14	4.21%	0.837	0.463	
17.00	27/02/22 17:00	Sunday	27/02/2022	5:00:00 PM	1.7	0	36.14	4.81%	0.956	0.744	
18.00	27/02/22 18:00	Sunday	27/02/2022	6:00:00 PM	1.5	0	36.14	5.59%	1.110	0.390	
19.00	27/02/22 19:00	Sunday	27/02/2022	7:00:00 PM	1.9	0	36.14	6.04%	1.201	0.699	
20.00	27/02/22 20:00	Sunday	27/02/2022	8:00:00 PM	1.5	0	36.14	5.77%	1.147	0.353	

RSF	71.3%
RSF	55.0%
Rain : I/I	1.30
ADWF	1.12
PDWF	2.89
PWWF	10.92

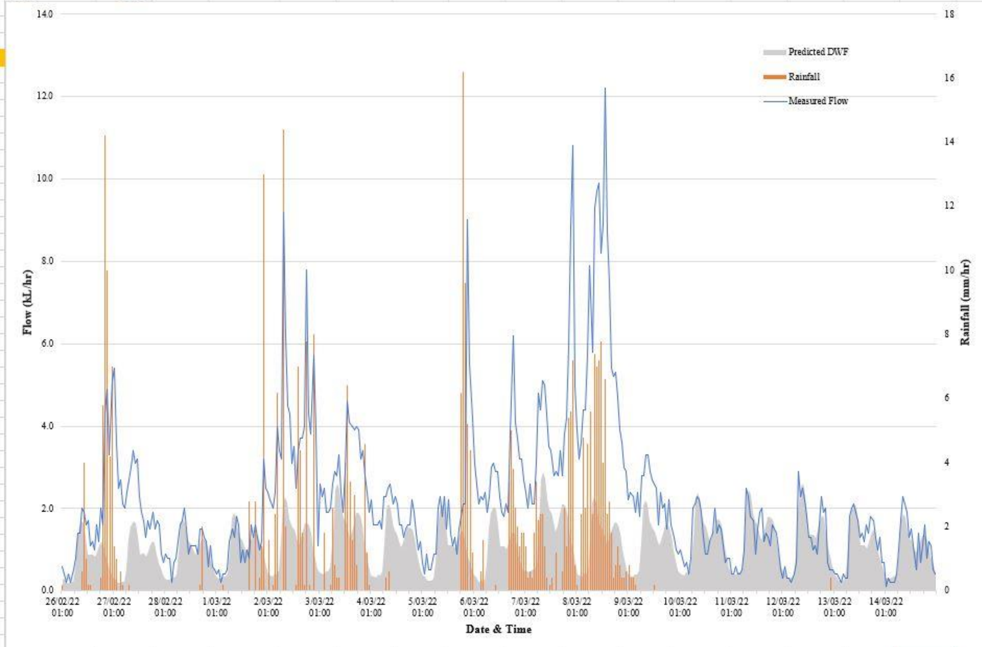


Figure H. 3: Wet Weather Period 2 Model Preliminary Analysis Example

					Flow (kL)	Rain (mm)	Daily Res Flow	Proportion	ADWF + GWI	Actual RDII
Hour	Flows until	Day of Week	Date	Time	790.50	225.00	720.45	14.00	485.58	304.92
13	6/04/22 13:00	Wednesday	6/04/22	1:00:00 PM	0.7	0	38.59	5.19%	1.349	-0.649
14	6/04/22 14:00	Wednesday	6/04/22	2:00:00 PM	2.3	2.6	38.59	4.52%	1.177	1.123
15	6/04/22 15:00	Wednesday	6/04/22	3:00:00 PM	7.5	4.8	38.59	3.95%	1.027	6.473
16	6/04/22 16:00	Wednesday	6/04/22	4:00:00 PM	9	6.4	38.59	4.37%	1.137	7.863
17	6/04/22 17:00	Wednesday	6/04/22	5:00:00 PM	12.8	19.6	38.59	5.02%	1.307	11.493
18	6/04/22 18:00	Wednesday	6/04/22	6:00:00 PM	13	5.6	38.59	5.72%	1.489	11.511
19	6/04/22 19:00	Wednesday	6/04/22	7:00:00 PM	7.9	1.2	38.59	5.76%	1.499	6.401
20	6/04/22 20:00	Wednesday	6/04/22	8:00:00 PM	4.5	2.2	38.59	5.55%	1.443	3.057
21	6/04/22 21:00	Wednesday	6/04/22	9:00:00 PM	3.8	0.4	38.59	4.83%	1.256	2.544
22	6/04/22 22:00	Wednesday	6/04/22	10:00:00 PM	2.8	0.2	38.59	3.54%	0.919	1.881
23	6/04/22 23:00	Wednesday	6/04/22	11:00:00 PM	2.7	0	38.59	2.65%	0.688	2.012
24	7/04/22 00:00	Wednesday	7/04/22	12:00:00 AM	2.2	0.4	38.59	1.82%	0.472	1.728
1	7/04/22 01:00	Thursday	7/04/22	1:00:00 AM	3.3	4.8	43.62	1.37%	0.403	2.897
2	7/04/22 02:00	Thursday	7/04/22	2:00:00 AM	3.5	21.4	43.62	1.29%	0.378	3.122
3	7/04/22 03:00	Thursday	7/04/22	3:00:00 AM	3.2	3.4	43.62	1.24%	0.364	2.836
4	7/04/22 04:00	Thursday	7/04/22	4:00:00 AM	2.2	0.8	43.62	1.46%	0.428	1.772
5	7/04/22 05:00	Thursday	7/04/22	5:00:00 AM	1.9	0.2	43.62	1.42%	0.418	1.482
6	7/04/22 06:00	Thursday	7/04/22	6:00:00 AM	5	4.4	43.62	1.77%	0.521	4.479
7	7/04/22 07:00	Thursday	7/04/22	7:00:00 AM	8.6	7.8	43.62	4.24%	1.248	7.352
8	7/04/22 08:00	Thursday	7/04/22	8:00:00 AM	9.9	14	43.62	7.42%	2.183	7.717
9	7/04/22 09:00	Thursday	7/04/22	9:00:00 AM	6	8.8	43.62	7.90%	2.323	3.677
10	7/04/22 10:00	Thursday	7/04/22	10:00:00 AM	5.6	5.2	43.62	7.48%	2.198	3.402
11	7/04/22 11:00	Thursday	7/04/22	11:00:00 AM	5.4	7.4	43.62	6.08%	1.788	3.612
12	7/04/22 12:00	Thursday	7/04/22	12:00:00 PM	9	13	43.62	5.41%	1.591	7.409
13	7/04/22 13:00	Thursday	7/04/22	1:00:00 PM	10.9	6.4	43.62	5.19%	1.524	9.376
14	7/04/22 14:00	Thursday	7/04/22	2:00:00 PM	6.1	1.4	43.62	4.52%	1.330	4.770
15	7/04/22 15:00	Thursday	7/04/22	3:00:00 PM	4.1	3.2	43.62	3.95%	1.161	2.939
16	7/04/22 16:00	Thursday	7/04/22	4:00:00 PM	4.8	2.8	43.62	4.37%	1.286	3.514
17	7/04/22 17:00	Thursday	7/04/22	5:00:00 PM	4.6	1	43.62	5.02%	1.477	3.123
18	7/04/22 18:00	Thursday	7/04/22	6:00:00 PM	4.3	0.6	43.62	5.72%	1.683	2.617
19	7/04/22 19:00	Thursday	7/04/22	7:00:00 PM	5.3	0.8	43.62	5.76%	1.694	3.606
20	7/04/22 20:00	Thursday	7/04/22	8:00:00 PM	3.7	0	43.62	5.55%	1.631	2.069
21	7/04/22 21:00	Thursday	7/04/22	9:00:00 PM	2.8	0.2	43.62	4.83%	1.420	1.380
22	7/04/22 22:00	Thursday	7/04/22	10:00:00 PM	2.9	0	43.62	3.54%	1.039	1.861
23	7/04/22 23:00	Thursday	7/04/22	11:00:00 PM	2.2	0.2	43.62	2.65%	0.778	1.422
24	8/04/22 00:00	Thursday	8/04/22	12:00:00 AM	3.5	5.2	43.62	1.82%	0.534	2.966
1	8/04/22 01:00	Friday	8/04/22	1:00:00 AM	2.4	1.2	44.18	1.52%	0.452	1.948
2	8/04/22 02:00	Friday	8/04/22	2:00:00 AM	3.8	4.4	44.18	1.41%	0.419	3.381
3	8/04/22 03:00	Friday	8/04/22	3:00:00 AM	3	1.4	44.18	0.97%	0.288	2.712
4	8/04/22 04:00	Friday	8/04/22	4:00:00 AM	2.5	2.2	44.18	0.96%	0.286	2.214
5	8/04/22 05:00	Friday	8/04/22	5:00:00 AM	6.8	9.8	44.18	1.06%	0.315	6.485
6	8/04/22 06:00	Friday	8/04/22	6:00:00 AM	9.2	9	44.18	1.17%	0.347	8.853
7	8/04/22 07:00	Friday	8/04/22	7:00:00 AM	5.4	1	44.18	2.76%	0.820	4.580
8	8/04/22 08:00	Friday	8/04/22	8:00:00 AM	4.4	0.2	44.18	6.35%	1.891	2.509
9	8/04/22 09:00	Friday	8/04/22	9:00:00 AM	3.4	0	44.18	7.91%	2.356	1.044

RSF 67.4%

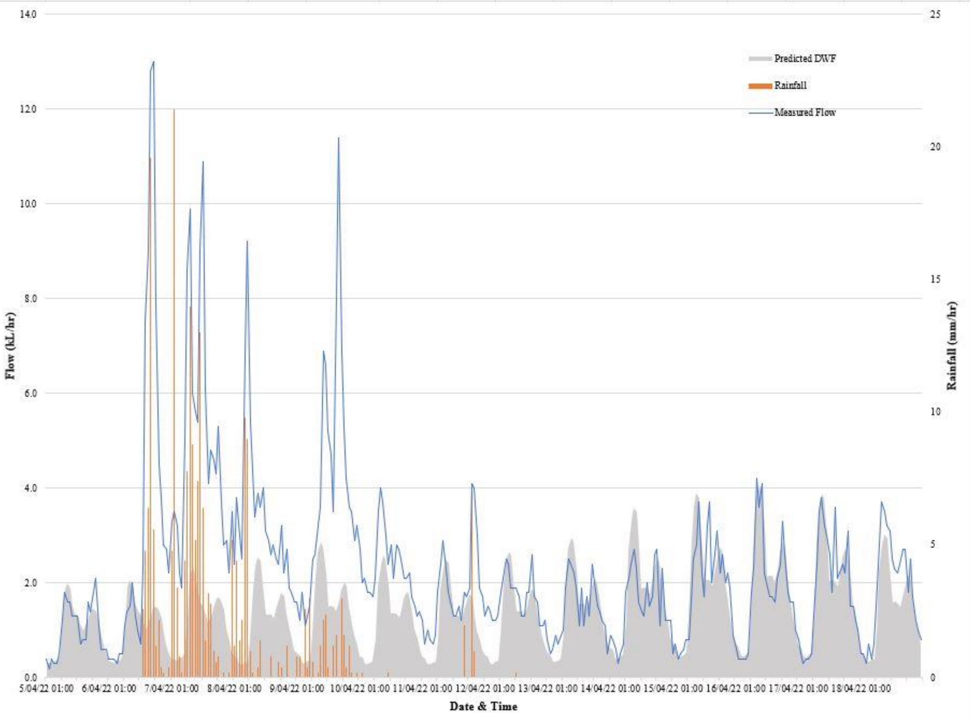


Figure H. 4: Wet Weather Period 2 Segment 1 Detailed Analysis Example

					Flow (kL)	Rain (mm)	Daily Res Flow	Proportion	ADWF + GWI	Actual RDII
Hour	Flows until	Day of Week	Date	Time	436.40	214.80	218.06	4.80	144.82	291.58
14	6/04/22 14:00	Wednesday	6/04/22	2:00:00 PM	2.3	2.6	38.59	4.52%	1.177	1.123
15	6/04/22 15:00	Wednesday	6/04/22	3:00:00 PM	7.5	4.8	38.59	3.95%	1.027	6.473
16	6/04/22 16:00	Wednesday	6/04/22	4:00:00 PM	9	6.4	38.59	4.37%	1.137	7.863
17	6/04/22 17:00	Wednesday	6/04/22	5:00:00 PM	12.8	19.6	38.59	5.02%	1.307	11.493
18	6/04/22 18:00	Wednesday	6/04/22	6:00:00 PM	13	5.6	38.59	5.72%	1.489	11.511
19	6/04/22 19:00	Wednesday	6/04/22	7:00:00 PM	7.9	1.2	38.59	5.76%	1.499	6.401
20	6/04/22 20:00	Wednesday	6/04/22	8:00:00 PM	4.5	2.2	38.59	5.55%	1.443	3.057
21	6/04/22 21:00	Wednesday	6/04/22	9:00:00 PM	3.8	0.4	38.59	4.83%	1.256	2.544
22	6/04/22 22:00	Wednesday	6/04/22	10:00:00 PM	2.8	0.2	38.59	3.54%	0.919	1.881
23	6/04/22 23:00	Wednesday	6/04/22	11:00:00 PM	2.7	0	38.59	2.65%	0.688	2.012
24	7/04/22 00:00	Wednesday	7/04/22	12:00:00 AM	2.2	0.4	38.59	1.82%	0.472	1.728
1	7/04/22 01:00	Thursday	7/04/22	1:00:00 AM	3.3	4.8	43.62	1.37%	0.403	2.897
2	7/04/22 02:00	Thursday	7/04/22	2:00:00 AM	3.5	21.4	43.62	1.29%	0.378	3.122
3	7/04/22 03:00	Thursday	7/04/22	3:00:00 AM	3.2	3.4	43.62	1.24%	0.364	2.836
4	7/04/22 04:00	Thursday	7/04/22	4:00:00 AM	2.2	0.8	43.62	1.46%	0.428	1.772
5	7/04/22 05:00	Thursday	7/04/22	5:00:00 AM	1.9	0.2	43.62	1.42%	0.418	1.482
6	7/04/22 06:00	Thursday	7/04/22	6:00:00 AM	5	4.4	43.62	1.77%	0.521	4.479
7	7/04/22 07:00	Thursday	7/04/22	7:00:00 AM	8.6	7.8	43.62	4.24%	1.248	7.352
8	7/04/22 08:00	Thursday	7/04/22	8:00:00 AM	9.9	14	43.62	7.42%	2.183	7.717
9	7/04/22 09:00	Thursday	7/04/22	9:00:00 AM	6	8.8	43.62	7.90%	2.323	3.677
10	7/04/22 10:00	Thursday	7/04/22	10:00:00 AM	5.6	5.2	43.62	7.48%	2.198	3.402
11	7/04/22 11:00	Thursday	7/04/22	11:00:00 AM	5.4	7.4	43.62	6.08%	1.788	3.612
12	7/04/22 12:00	Thursday	7/04/22	12:00:00 PM	9	13	43.62	5.41%	1.591	7.409
13	7/04/22 13:00	Thursday	7/04/22	1:00:00 PM	10.9	6.4	43.62	5.19%	1.524	9.376
14	7/04/22 14:00	Thursday	7/04/22	2:00:00 PM	6.1	1.4	43.62	4.52%	1.330	4.770
15	7/04/22 15:00	Thursday	7/04/22	3:00:00 PM	4.1	3.2	43.62	3.95%	1.161	2.939
16	7/04/22 16:00	Thursday	7/04/22	4:00:00 PM	4.8	2.8	43.62	4.37%	1.286	3.514
17	7/04/22 17:00	Thursday	7/04/22	5:00:00 PM	4.6	1	43.62	5.02%	1.477	3.123
18	7/04/22 18:00	Thursday	7/04/22	6:00:00 PM	4.3	0.6	43.62	5.72%	1.683	2.617
19	7/04/22 19:00	Thursday	7/04/22	7:00:00 PM	5.3	0.8	43.62	5.76%	1.694	3.606
20	7/04/22 20:00	Thursday	7/04/22	8:00:00 PM	3.7	0	43.62	5.55%	1.631	2.069
21	7/04/22 21:00	Thursday	7/04/22	9:00:00 PM	2.8	0.2	43.62	4.83%	1.420	1.380
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5	8/04/22 05:00	Friday	8/04/22	5:00:00 AM	6.8	9.8	44.18	1.06%	0.315	6.485
6	8/04/22 06:00	Friday	8/04/22	6:00:00 AM	9.2	9	44.18	1.17%	0.347	8.853
7	8/04/22 07:00	Friday	8/04/22	7:00:00 AM	5.4	1	44.18	2.76%	0.820	4.580
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9	8/04/22 09:00	Friday	8/04/22	9:00:00 AM	3.4	0	44.18	7.91%	2.356	1.044
10	8/04/22 10:00	Friday	8/04/22	10:00:00 AM	3.9	0.4	44.18	8.53%	2.540	1.360

RSF	67.4%
Rain : I/I	1.357
ADWF	1.238
PDWF	2.855
PWWF	13