NOTICE OF MEETING

WATER, WASTE AND SEWER ADVISORY COMMITTEE MEETING

A Water, Waste and Sewer Advisory Committee Meeting of Byron Shire Council will be held as follows:

Venue	**Conference Room, Station Street, Mullumbimby**
Date	**Thursday, 30 January 2020**
Time	**11.30am**

Phil Holloway
Director Infrastructure Services

I2020/79
Distributed 23/01/20

CONFLICT OF INTERESTS

What is a "Conflict of Interests" - A conflict of interests can be of two types:
Pecuniary - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.
Non-pecuniary – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Code of Conduct for Councillors (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).
Remoteness – a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in the Code of Conduct for Councillors.
Who has a Pecuniary Interest? - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).
Relatives, Partners - a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:
(a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;
(b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)

No Interest in the Matter - however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

Disclosure and participation in meetings

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:
  (a) at any time during which the matter is being considered or discussed by the Council or Committee, or
  (b) at any time during which the Council or Committee is voting on any question in relation to the matter.

No Knowledge - a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.
Non-pecuniary Interests - Must be disclosed in meetings.
There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or vice-versa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as of the provisions in the Code of Conduct (particularly if you have a significant non-pecuniary interest)

RECORDING OF VOTING ON PLANNING MATTERS

Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters

(1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:
  (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
  (b) not including the making of an order under that Act.
(2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.
(3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.
(4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document, and is to include the information required by the regulations.
(5) This section extends to a meeting that is closed to the public.

BUSINESS OF MEETING

1. APOLOGIES

2. DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY

3. ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

3.1 Water, Waste and Sewer Advisory Committee Meeting held on 10 October 2019
3.2 Extraordinary Water, Waste and Sewer Advisory Committee Meeting held on 14 November 2019

4. STAFF REPORTS

Infrastructure Services

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1 **Inflow and Infiltration - Sewer Asset Management**
Directorate: Infrastructure Services
Report Author: Jason Stanley, Systems Planning Officer
File No: I2019/2060

Summary:

Following a review of the 30 year capital works plan, it was identified that various gravity sewer assessments within the Mullumbimby area were scheduled for renewal over the coming years. It was agreed that condition assessments of both the gravity sewer and adjacent stormwater assets would be undertaken to verify whether these assets were in a state that warranted their renewal.

The assessments in Mullumbimby have since been completed and the findings identified that various assets are presenting a high risk to Council that should be remedied in a risk based manner. This report presents the findings of these assessments as well as identifying the proposed way forward with regards to the ongoing management of the gravity sewer and stormwater network.

RECOMMENDATION:

That Committee note the report.

Attachments:

1 Mullumbimby Catchment 4001 - Sewer Main Inflow and Infiltration Report - Willow and Sparrow, E2019/69598 , page 12⇩
2 Mullumbimby Catchment 4001 - Sewer Maintenance Hole Inflow and Infiltration Report - Willow and Sparrow.pdf, E2019/80301 , page 241⇩
3 Mullumbimby Catchment 4001 - Storm Water Main Inflow and Infiltration Report - Willow and Sparrow, E2019/71131 , page 325⇩
4 Final Stormwater MH condition assessment report.pdf, E2019/80295 , page 530⇩

REPORT

1. Introduction

This report provides a summary of the findings relating to the sewer infrastructure that is located within sewer catchment 4001 in Mullumbimby which accounts for approximately 4km of the 195km gravity sewer network. The intent of this report is to provide a summary of the findings from the condition assessment works within Mullumbimby, present the subsequent recommendations from these assessments and proposal for the ongoing management of the remainder of the sewer network.

2. Background

Inflow and Infiltration (I&I) is the process of groundwater and stormwater entering into the sewer network.
Following a review of the 30 year capital program, it was identified that 40 gravity sewer mains within the Mullumbimby catchment were proposed for renewal within the 2022-2031 horizon. This prompted some flow monitoring of the network to identify if I&I was an issue which is a high level indication of the networks condition. It was identified that I&I was evident, hence detailed investigations were undertaken to determine each individual assets overall condition and consequence of failure scores to establish the subsequent overall risk rating.

3. Scope

3.1 Location

The current scope of works for this project has focused on a small catchment of the gravity sewer network upstream of sewer pump station (SPS) 4001 within Mullumbimby including the stormwater network encompassed by the blue hatch in the below map. Mullumbimby is a low lying town that is located adjacent to the Brunswick River. This portion of the sewer catchment consists largely of Vitrified Clay (VC) pipe which is prone to brittle failure (cracking) and is therefore subject to high rates of I&I.

Figure 1 – Mullumbimby Condition Assessment Scope Extent

3.2 Condition Assessment

Following the conclusive data obtained from the flow monitoring that identified I&I as an issue for this portion of Mullumbimby's sewage catchment, detailed assessments of both the sewage and stormwater network were undertaken. These assessments consisted of CCTV of sewer mains and stormwater culverts, visual inspections of maintenance structures, as well as smoke testing to identify potential points of entrance and incorrect stormwater connections to sewer mains.

The findings from the above assessments have all been documented in detailed condition assessment reports which can be found on HPE content manager (E2019/69598, E2019/80301, E2019/71131, and E2019/80295). These condition assessment reports provide a summary of each assets condition score. Each asset was assigned a consequence of failure based on the impact of the asset's failure and subsequent repair/replacement which then allowed an overall risk rating to be assigned. With these risk scores being considered, capital renewal and minor rectification works have been prioritised as well as a return schedule for the future assessment of each asset.

4. Mullumbimby Assessment Findings

4.1 Overall Asset Risk

In total there were 109 sewer mains and 107 stormwater culverts that were assessed including the associated maintenance holes. It was apparent through the development of the condition assessment reports that the stormwater culverts and sewer mains that were initially constructed in the 1940s and 1960s respectively were subject to significant deterioration and had not been sufficiently maintained. Below are some images of the existing sewer mains that were assessed.

Hole in pipe wall

Defective pipe repair

Major root intrusion

Major displacement at pipe replacement

Heavy infiltration

Heavy infiltration

Hole in pipe wall

Major root intrusion

Figure 3 presents the overall risk score summary for both the sewer mains and stormwater culverts.

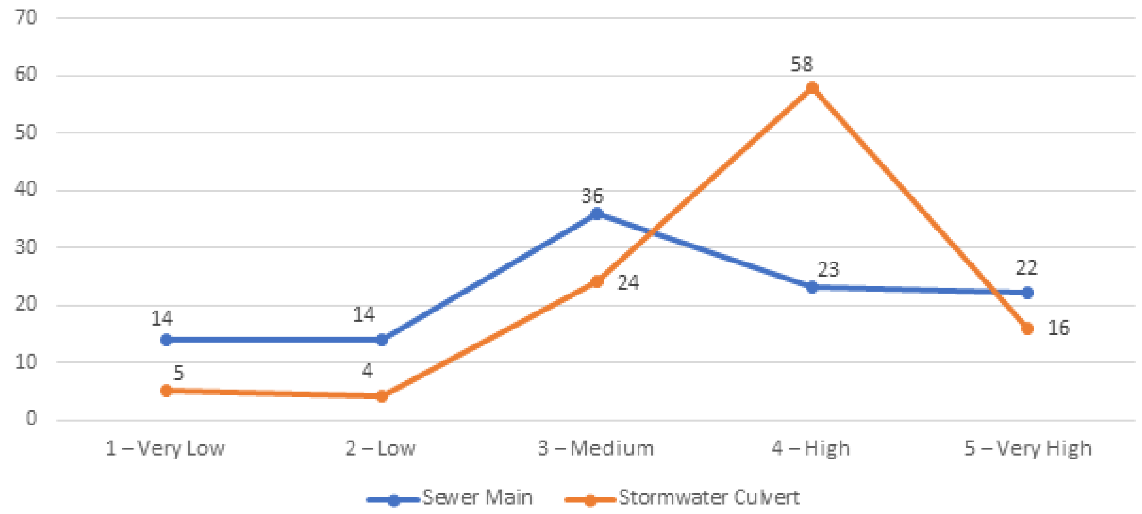

Figure 3 – Risk Score Summary

From Figure 3, it can be determined that 41% of the sewer network and 69% of the stormwater network within the project extent is either a high or very high risk of failure.

The risks that BSC is responsible for managing include but are not limited to the following:

a) Pipe collapse resulting in expensive emergency rectification works
b) Increased on-going sewerage operational costs due to capturing, transferring, and treating both groundwater and stormwater that infiltrates the sewer network
c) Poor conveyance of stormwater that can lead to flooding, resulting in damage to property and road infrastructure
d) Extensive infiltration into the sewer network that results in the migration of supportive material beneath road pavements which can result in the undermining of pavements resulting in their collapse (sink hole).

4.2 Proposed Rectification Works

In order to mitigate the risks that BSC is responsible for managing, a summary of the proposed renewal and minor rectification works for FY19/20 are noted in Table 1 below with the overall conceptual construction cost estimate for each asset type.

Table 1 – Proposed Rectification Works FY19/20

Asset Type	**# Assets Assessed**	**# Assets to Rectify**	**Nature of Scope**	**Estimated Cost (±20%)**
Gravity sewer main	109	26	Renewal	$400,000
		20	Rectification / maintenance	$40,000
Sewer MH	92	20	Rectification / maintenance	$50,000
Stormwater culvert	107*	21	Renewal	$580,000
		9	Rectification / maintenance	$20,000
Stormwater	24	7	Rectification / maintenance	$5,000
			Sewer Subtotal	$490,000
			Stormwater Subtotal	$605,000
			TOTAL	**$1,095,000**

*The assessment of only 92 stormwater mains could be completed due to obstructions

It should also be noted that budget for the necessary rectification of the highest priority stormwater culverts within Mullumbimby has not yet been established. A report specific to the asset management of the stormwater network is being submitted to the Transport and Infrastructure Advisory Committee (TIAC) in order to request funding.

Furthermore, in addition to the above scoped works there are various other assets within this catchment that have been assessed that can be justified for renewal over the subsequent years subject to budget availability and prioritisation against assets within other catchments.

5. Timing

The proposed sewer renewal and rectification / maintenance works have been verified and supported by Utilities officers and management and will be going to tender in December 2019 with an estimated completion before the end of FY19/20. It should be noted that this scope also includes the stormwater culvert and stormwater MH rectification / maintenance works totalling an estimated construction cost of $25,000 that will be funded by the available sewer capital budget. Therefore, the total estimated construction cost of the proposed sewer / stormwater works is $515k (excl GST).

As for the stormwater culvert renewals ($580k), budget needs to be sourced to facilitate these works prior to tendering and undertaking the construction works. A report has been presented to the Transport and Infrastructure Advisory Committee concerning the budget associated with the required stormwater rectification works as well as the ongoing management of the stormwater network.

6. Renewal Methodology

With advancements in technology and products, in some instances there are now alternative options to traditional open trench excavation “remove and replace” methods. There are various structurally integral liners that can be installed to rehabilitate pipes and culverts that are in poor condition. Fortunately, it has been identified that all of the gravity sewer mains that are proposed for rectification can be done so with a structural liner. Advantages of this methodology include:

a) Increased expediency of rectification works
b) Reduced capital expenditure (typically >50% savings)
c) Reduced community impact (traffic, noise, dust, amenity, etc.)
d) Reduced exposure to high risk works for site personnel

Depending on the type of structural liner, they can be easily removed if required without damaging the existing “host” pipe / culvert and typically have a design life of at least 50 years.

7. Budget

The existing budget for FY19/20 for the Mullumbimby sewer catchment is $590k. Spend/committed to date is $262k. Hence the remaining sewer budget is approximately $328k. An additional $200k will likely be required to facilitate these works including their management. However, this additional budget will be requested once external contractor price submissions have been received.

8. Ongoing Assessment

As the assessment of the Mullumbimby sewer and stormwater catchment has revealed the poor condition of a large portion of the catchment (41% sewer and 69% stormwater). It is evident that other portions of the BSC network may be in particularly poor condition as well. This presents various previously noted risks to BSC all of which have the potential to adversely impact on the public perception of BSC.

It is proposed in future to replicate the approach that has been adopted for this portion of the Mullumbimby catchment, and apply it to the remainder of the network in a prudent and efficient manner. However, due to a lack of funding for the stormwater network which has been highlighted in a report that is being presented to the Transport and Infrastructure Advisory Committee (TIAC), the gravity sewer main assessments in FY19/20 will have to be undertaken in isolation without stormwater.

A desktop risk analysis has been developed for the gravity sewer network based on various criteria such as age, depth, material composition, downstream peaking factors, etc. This risk analysis model enables the Asset Management team to identify the assets that are likely to be the highest risk to Byron Shire Council, and therefore the highest priority for assessment. Two of the highest risk sewer catchments in Byron Bay and Ocean Shores (3002 and 5012) totalling a length of 22.65km will be assessed in FY19/20 to gain a comprehensive understanding of their condition to enable the asset management team to manage any identified risks accordingly.

Though as previously noted, the intent is to undertake future assessments of both the sewer and stormwater infrastructure in concurrence due to the following benefits that this approach presents:

a) BSC will have accurate information to support the prudent and efficient asset management of its gravity sewer and stormwater infrastructure.
b) Cost savings due to single establishments for camera and assessment crews in addition to an increased length of CCTV assessments which will result in economies of scale.
c) A reduction in the impact to community from noise, amenity, traffic control, etc. due to the elimination of repeat works in the same areas.

It is imperative that BSC gains a comprehensive understanding of the condition of its gravity sewer and stormwater networks to ensure that their integrity and function are maintained in order to manage the associated risks accordingly.

Below is a summary of the proposed accelerated assessment program from the gravity sewer network risk analysis for the next 5 years. This accelerated program aims to compensate for the lack of assessments that have been undertaken historically. The summary in Table 2, details the lengths to be assessed and the estimated assessment cost.

Table 2 – Proposed 5 Year Works Summary

5 YEAR WORKS SUMMARY		
Year	Sewer	
	Length to Assess (km)	Assessment Cost
Year 1	20.9	$ 450,966
Year 2	18.0	$ 386,669
Year 3	25.1	$ 539,796
Year 4	19.7	$ 425,271
Year 5	17.3	$ 371,972
TOTAL	101.0	$ 2,174,675

There is currently $5M available for the ongoing management of the gravity sewer network over the next 5 years inclusive of Year 1 (FY19/20). This budget has been apportioned $2.5M to the Mullumbimby catchment and $2.5M to the remainder of the sewer network. When considering the degree of urgent rectification works that were required following the Mullumbimby assessment, it is likely that the budget of $5M over 5 years will be insufficient to adequately manage the sewer network. However, the Asset Management team will have a better understanding of the budget that will be required following the completion and risk assignment of the 3002 and 5012 sewer catchments scheduled for completion in FY19/20. Following this, if required, a report will be presented to the WWSC with justification supporting an increase in the available budget.

9. Conclusion

Given the findings of the assessments that were undertaken in a relatively small portion of the Mullumbimby township, it is strongly recommended that ongoing condition assessments are undertaken for both the remainder of the gravity sewer and stormwater networks. This will provide BSC with the necessary information to manage identified risks in a prudent and efficient manner.

Furthermore, there are advantages to undertaking the assessments of these two networks in parallel. Economies of scale will dictate that an increase in value for money will be achieved in addition to other benefits such as reduced establishments and interruption to the community.

A report providing an update will be presented to the WWSC following the completion of the 3002 and 5012 gravity sewer condition assessments in FY19/20 noting whether additional budget is required to continue with the ongoing assessments and required rectification works over the five year window to FY23/24.

Willow+ Sparrow

Mullumbimby (4001) – Gravity Sewer Condition Assessment

Prepared for: Byron Shire Council

DOCUMENT CONTROL

Revision number	Description	Prepared	Reviewed	Issued	Issue date
0	Final Report	JV	MC	MC	19/9/19

Document title: Mullumbimby – 4001 Gravity Sewer Condition Assessment

Document number: BSC_4001CA

Author: Julian Vivoli, *BEng*

Client name: Byron Shire Council

Client's representative: Dean Baluch

Approved for use by:

Name: Michael Chamberlain **Signature:** **Date:** 19th September 2019

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Contents

ABBREVIATIONS

AC	Asbestos Cement
BSC	Byron Shire Council
CCTV	Closed-Circuit Television
DN	Nominal Diameter
H2S	Hydrogen Sulphide
MH	Maintenance Hole
VC	Vitrified Clay

1. INTRODUCTION

Willow & Sparrow Pty Ltd has been engaged by Byron Shire Council (BSC) to prepare a Condition Assessment report for the sewerage catchment upstream of Sewer Pump Station (SPS) 4001 in Mullumbimby, NSW.

Project background

Byron Shire Council has identified peaking factors in excess of 10 x ADWF within this portion of the Mullumbimby sewerage catchment. This is a clear indication that this portion of the network is subject to the adverse impacts of inflow and infiltration (I&I). Council wishes to undertake a prudent process to confirm the actual condition of the sewer mains, determine which mains require rehabilitation or replacement in order of priority, and to then procure the rehabilitation or replacement of the selected gravity sewer mains.

Due to the uncertainty as to which mains are to be replaced, it is anticipated that the project be delivered in two stages, with a hold point at the completion of stage 1. This hold point will enable Council to review this Condition Assessment report and determine which sewer mains will be carried forward into the rehab/replace phase of the project in FY19/20.

The two stages of work are:

- Stage 1 – Condition Assessment of each sewer main, and
- Stage 2 – Procurement and delivery of the sewer main rectification works

Scope

Willow & Sparrow Pty Ltd were provided with CCTV footage of the relevant sections of gravity sewer by Interflow Pty Ltd. This Condition Assessment report provides a record of the findings of the visual CCTV inspections and a completed decision tree and risk matrix.

Site description

This Condition Assessment report has been prepared for the gravity sewer catchment as shown in Figure 1. The Mullumbimby catchment upstream of 4001 comprises a gravity sewer system that services hundreds of residential properties in addition to the Mullumbimby CBD. The gravity sewer mains encompassed by the blue hatch in Figure 1 are the mains that have been addressed in this Condition Assessment report.

Mullumbimby – 4001 Gravity Sewer Condition Assessment

Willow + Sparrow

Figure 1 | Gravity sewer catchment 4001 – Mullumbimby, NSW, Source: Byron Shire Council GeoCortex 2019

2. CCTV INSPECTION RECORDS – 4001 CATCHMENT

2.01 Azalea Street | Line EA04 - EA05 | S-4001-GMN-1115 | (35.89m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints were in particularly poor condition with various patch liners delaminating from the pipe and blocking the flow. There are numerous instances of root intrusion. There was no ponding in excess of 5% identified. The main has been subject to external forces (e.g. ground movement) which is evident throughout by various cracks which is indicative of a VC main that was installed in 1982 (37 years of age). There are no private junctions on this main. The CCTV inspection was abandoned at chge 28.20m due to the remainder of the main be lined with a liner that reduced the diameter such that the track camera could not pass. Refer to the below figures and Table 1 for a summary of findings.

Figure 2 | Liner in poor condition, Chg 0.07m

Figure 3 | Root intrusion, Chg 0.33m

Figure 4 | Root intrusion, Chg 0.79m

Figure 5 | Torn liner, Chg 1.53m

Figure 6 | Root intrusion, Chg 4.62m

Figure 7 | Cracking and liner, Chg 6.41m

Figure 8 | Root intrusion, Chg 10.77m

Figure 9 | Restricted liner, Chg 28.20m

Table 1 | Line EA04 - EA05

Chainage (m)	Figure	Item	Observation
0 – 35.89	-	Main	DN150 VC pipe with numerous patch liners
0.07	2	Defect	Patch liner partially delaminating
0.33	3	Roots	Root intrusion through pipe joint
0.79	4	Roots	Root intrusion through pipe joint
1.53	5	Defect	Torn patch liner partially obstructing flow
4.62	6	Roots	Root intrusion through pipe joint
6.41	7	Defect	Minor cracking in pipe wall 2mm thick at 2 O'clock
10.77	8	Roots	Root intrusion through pipe joint
28.20	9	Defect	Liner diameter reduced obstructing flow capacity

2.02 Azalea Street | Line EA04 – EA03 | S-4001-GMN-0405 | (87.7m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints were in particularly poor condition with various patch liners. There is some isolated root intrusion evident. There was no ponding in excess of 10% identified. The main has been subject to external forces (e.g. ground movement) which is evident throughout by various significant cracks. The extent of cracking exceeds what is considered indicative of a VC main that was installed in 1982 (37 years of age). There are no private junctions on this main. Refer to the below figures and Table 2 for a summary of findings.

Figure 10 | Delaminating liner, Chg 0.14m

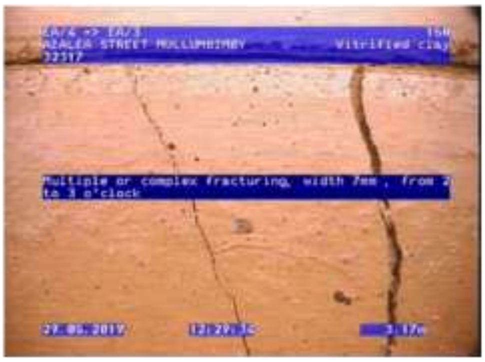

Figure 11 | Cracking, Chg 3.17m

Figure 12 | Cracking, Chg 8.07m

Figure 13 | Cracking, Chg 8.10m

Figure 14 | Cracking, Chg 25.46m

Figure 15 | Cracking, Chg 38.34m

Figure 16 | Cracking, Chg 44.57m

Figure 17 | Longitudinal displacement, Chg 86.71m

Table 2 | Line EA04 – EA03

Chainage (m)	Figure	Item	Observation
0 – 87.7	-	Main	DN150 VC pipe with numerous patch liners
0.14	10	Liner	Patch liner partially delaminating
3.17	11	Defect	Significant cracking in pipe wall 7mm wide at 2 O'clock
8.07	12	Defect	Significant cracking in pipe wall 10mm wide at 12 O'clock
8.10	13	Defect	Significant cracking in pipe wall with root intrusion
25.46	14	Defect	Significant cracking in pipe wall 6mm wide at 12 O'clock
38.34	15	Defect	Significant cracking in pipe wall 6mm wide at 4 O'clock
44.57	16	Defect	Multiple cracking in pipe wall 2mm wide
86.71	17	Defect	Longitudinal displacement of joint (10-20mm)

2.03 Azalea Street | Line EA03 – EA02 | S-4001-GMN-1130 | (63.23m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints were in fairly poor condition with minor cracking evident throughout. There was no ponding in excess of 5% identified. The main has been subject to external forces (e.g. ground movement) which is evident throughout by various cracks which is indicative of a VC main that was installed in 1982 (37 years of age). There are no private junctions on this main. Refer to the below figures and Table 3 for a summary of findings.

Figure 18 | Cracking, Chg 9.63m

Figure 19 | Cracking, Chg 28.11m

Figure 20 | Cracking and root intrusion, Chg 37.30m

Figure 21 | Root intrusion, Chg 63.23m

Table 3 | Line EA03 - EA02

Chainage (m)	Figure	Item	Observation
0 – 63.23	-	Main	DN150 VC pipe
9.63	18	Defect	Minor cracking in pipe wall 2mm wide at 4 O'clock
28.11	19	Defect	Minor cracking in pipe wall 2mm wide at 3 O'clock
37.30	20	Defect	Significant cracking in pipe wall 10mm wide at 2 O'clock
63.23	21	Roots	Root intrusion at connection to maintenance structure

2.04 Azalea Street | Line EA02 – EA01 | S-4001-GMN-1134 | (63.28m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints were in fairly poor condition with cracking evident throughout. There was no ponding in excess of 5% identified. The main has been subject to external forces (e.g. ground movement) which is evident throughout by various cracks which is indicative of a VC main that was installed in 1982 (37 years of age). There are no private junctions on this main. Refer to the below figures and Table 4 for a summary of findings.

Figure 22 | Cracking, Chg 7.63m

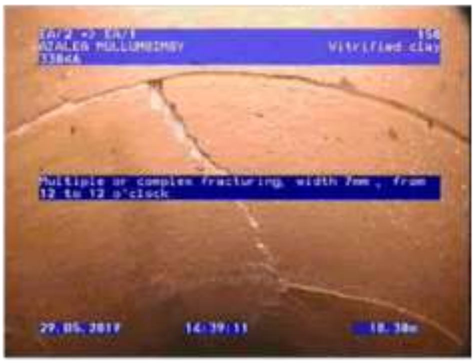

Figure 23 | Cracking, Chg 18.30m

Figure 24 | Cracking and root intrusion, Chg 18.30m

Figure 25 | Root intrusion, Chg 45.58m

Table 4 | Line EA02 - EA01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 63.28	-	Main	DN150 VC pipe
7.63	22	Defect	Cracking in pipe wall 4mm wide at 12 O'clock
18.30	23	Defect	Significant cracking in pipe wall 7mm wide throughout
18.30	24	Defect	Significant cracking in pipe wall 7mm wide throughout
45.58	25	Roots	Root intrusion at pipe joint

2.05 West Bank Road | Line EA01 – EA01/End | S-4001-GMN-4919 | (30.10m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints were in reasonable condition with no signs of cracking or other defects which is not typical for a VC main that was installed in 1982 (37 years of age). There was no ponding in excess of 5% identified. There are no private junctions on this main. Refer to the below figures and Table 5 for a summary of findings.

Figure 26 | Typical condition, Chg 0.00m

Table 5 | Line EA01 - EA01/End			
Chainage (m)	Figure	Item	Observation
0 – 30.10	26	Main	DN150 VC pipe

2.06 Azalea Street | Line EA01 – EA18 | S-4001-GMN-1133 | (53.95m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints are typically in reasonable condition with no signs of significant cracking or other defects (apart from a single joint). The majority of the main is subject to ponding with the worst being 50% depth immediately prior to the downstream maintenance hole. The main has been subject to root intrusion at a single joint which has resulted in the main cracking. The main was installed in 1982 (37 years of age). There are three private junctions on this main that are all closed and in good condition. Refer to the below figures and Table 6 for a summary of findings.

Figure 27 | Junction (closed), Chg 6.39m

Figure 28 | Root intrusion, Chg 12.06m

Figure 29 | Junction (closed), Chg 20.85m

Figure 30 | Junction (closed), Chg 36.05m

Figure 31 | Cracking and root intrusion Chg 53.40m

Figure 32 | Cracking and root intrusion Chg 53.40m

Table 6 | Line EA01 – EA18

Chainage (m)	Figure	Item	Observation
0 – 53.95	-	Main	DN150 VC pipe
6.39	27	Junction	Junction (closed) in good condition at 9 O'clock
12.06	28	Roots	Minor root intrusion
20.85	29	Junction	Junction (closed) in good condition at 9 O'clock
36.05	30	Junction	Junction (closed) in good condition at 9 O'clock
53.40	31/32	Roots	Root intrusion at joint and cracking of main

2.07 Jubilee Avenue | Line EA16 – EA14 | S-4001-GMN-1131 | (55.62m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints are typically in reasonable condition with no signs of significant cracking and only some minor joint displacement. The majority of the main has a small amount of sediment along the invert which has likely contributed to ponding throughout the line with the worst being 25% in depth. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 7 for a summary of findings.

Figure 33 | Radial Displacement, Chg 0.15m

Figure 34 | Sediment, Chg 0.43m

Figure 35 | Angular Displacement, Chg 55.15m

Table 7 | Line EA16 – EA14

Chainage (m)	Figure	Item	Observation
0 – 55.62	-	Main	DN150 VC pipe
0.15	33	Defect	Radial displacement of 5-10mm at joint
0.43	34	Sediment	Sediment in invert throughout the line
55.15	35	Defect	Angular displacement of 5-10mm at joint

2.08 Jubilee Avenue | Line EA14 – EA13 | S-4001-GMN-1129 | (57.59m)

Only 50m of the alignment was inspected in total, the remaining ~7m could not be assessed due to a restriction in the internal diameter from a patch liner and an obstruction beneath the ponding sewage. Of the main that was assessed, it is comprised of DN150 VC pipe with a patch liner. The main line and associated joints are typically in reasonable condition with no signs of significant cracking or other defects. The majority of the main has sediment along the invert which has likely contributed to ponding throughout the line with the worst being 15% in depth. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 8 for a summary of findings.

Figure 36 | Sediment, Chg 0.15m

Figure 37 | Joint infiltration, Chg 35.38m

Figure 38 | Liner patch, Chg 45.10m

Figure 39 | Liner patch, Chg 57.27m

Table 8 | Line EA14 – EA13

Chainage (m)	Figure	Item	Observation
0 – 57.59	-	Main	DN150 VC pipe
0.15	36	Sediment	Sediment in invert throughout the line
35.38	37	Joint	Minor infiltration through joint
45.10	38	Liner	Liner restricting flow capacity and inspection
57.27	39	Liner	Patch liner indicating poor condition of pipe

2.09 Azalea Street | Line EA18 – EA17 | S-4001-GMN-1132 | (36.21m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints are in poor condition with signs of cracking and other defects. There are various points throughout the main that are subject to ponding with the worst being a depth of 25% immediately after the upstream maintenance hole. The main has been subject to root intrusion at a few joints which has resulted in the main cracking. The main appears to have a large amount of fat build up throughout the line. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 9 for a summary of findings.

Figure 40 | Cracking, Chg 1.00m

Figure 41 | Encrustation, Chg 3.87m

Figure 42 | Encrustation, Chg 9.92m

Figure 43 | Cracking, Chg 31.84m

Figure 44 | Radial displacement, Chg 34.21m

Figure 45 | Root intrusion, Chg 34.86m

Table 9 | Line EA18 – EA17

Chainage (m)	Figure	Item	Observation
0 – 36.21	-	Main	DN150 VC pipe
1.00	40	Defect	Circumferential cracking
3.87	41	Encrustation	Encrustation obstruction of 5-20% from 8-4 O'clock
9.92	42	Encrustation	Encrustation obstruction of 5-20% from 12-12 O'clock
31.84	43	Cracking	Circumferential cracking 8mm wide from 9-3 O'clock
34.21	44	Joint	Radial displacement at joint of 5-10mm at 3 O'clock
34.86	45	Roots	Root intrusion with obstruction between 5-20% at 10 O'clock

2.10 Byron Street | Line K01 – E08 | S-4001-GMN-1720 | (4.02m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints are in reasonable condition with no signs of cracking, ponding, or other defects. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 10 for a summary of findings.

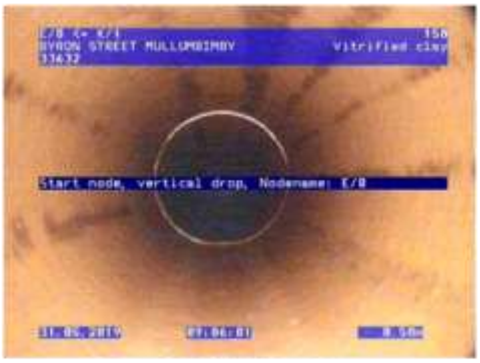

Figure 46 | Main, Chg 0.50m

Figure 47 | Upstream Structure, Chg 4.02m

Table 10 | Line K01 – E08

Chainage (m)	Figure	Item	Observation
0 – 4.02	-	Main	DN150 VC pipe
0.50	46	Main	Good condition
4.02	47	Upstream Structure	Good condition

2.11 Jubilee Avenue | Line K02 – K01 | S-4001-GMN-1717 | (25.34m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints are in reasonable condition with no signs of cracking or other defects. There is only minor ponding (≤5%) adjacent to the end structures. The main has been subject to root intrusion at multiple joints which has not yet resulted in the main cracking. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 11 for a summary of findings.

Figure 48 | Root intrusion, Chg 1.62m

Figure 49 | Root intrusion, Chg 2.57m

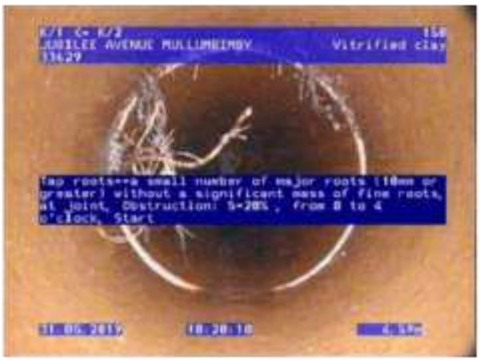

Figure 50 | Root intrusion, Chg 4.59m

Figure 51 | Root intrusion, Chg 12.21m

Table 11 | Line K02 – K01

Chainage (m)	Figure	Item	Observation
0 – 25.34	-	Main	DN150 VC pipe
1.62	48	Roots	Root intrusion with obstruction between 5-20% from 9-1 O'clock
2.57	49	Roots	Root intrusion with obstruction between 5-20% from 8-1 O'clock
4.59	50	Roots	Root intrusion with obstruction between 5-20% from 8-4 O'clock
12.21	51	Roots	Root intrusion with obstruction between 5-20% from 9-3 O'clock

2.12 Byron Street | Line E09 – E08 | S-4001-GMN-1105 | (46.00m)

The entire main is comprised of DN150 VC pipe. The main line and associated joints are in reasonable condition with only isolated signs of displacement and a single patch liner. The majority of the main is subject to ponding with the worst being a depth of 30%. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 12 for a summary of findings.

Figure 52 | Radial displacement, Chg 4.84m

Figure 53 | Junction, Chg 5.24m

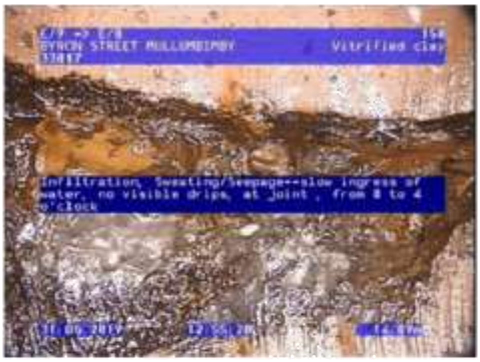

Figure 54 | Infiltration, Chg 14.89m

Figure 55 | Patch liner, Chg 45.57m

Table 12 | Line E09 – E08

Chainage (m)	Figure	Item	Observation
0 – 46.00	-	Main	DN150 VC pipe
4.84	52	Defect	Radial displacement at joint of 5-10mm at 9 O'clock
5.24	53	Junction	Open junction in good condition at 9 O'clock
14.89	54	Defect	Minor infiltration through joint
45.57	55	Patch liner	Patch liner indicating poor condition of pipe

2.13 Byron Street | Line E10 – E09 | S-4001-GMN-0393 | (45.98m)

The entire main is comprised of DN150 VC pipe. The main line was in particularly poor condition with various patch liners throughout. There is some isolated root intrusion evident. There is some ponding that does not exceed a depth of 20%. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 13 for a summary of findings.

Figure 56 | Patch liner, Chg 34.90m

Figure 57 | Junction, Chg 35.16m

Figure 58 | Patch liner, Chg 35.34m

Figure 59 | Patch liner, Chg 44.43m

Table 13 | Line E10 – E09

Chainage (m)	Figure	Item	Observation
0 – 45.98	-	Main	DN150 VC pipe
34.90	56	Patch liner	Patch liner indicating poor condition of pipe
35.16	57	Junction	Open junction with significant root intrusion. >75% obstruction at 10 O'clock
35.34	58	Patch liner	Defective patch liner
44.43	59	Patch liner	Patch liner indicating poor condition of pipe

2.14 Jubilee Avenue | Line K03 – K02 | S-4001-GMN-0987 | (58.01m)

The main is comprised of DN150 VC pipe. The main line is in fairly good condition with no signs of defects or ponding and only some minor root intrusion evident. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 14 for a summary of findings.

Figure 60 | Root intrusion, Chg 0.04m

Figure 61 | Root intrusion, Chg 44.93m

Table 14 | Line K03 – K02

Chainage (m)	Figure	Item	Observation
0 – 58.01	-	Main	DN150 VC pipe
0.04	60	Roots	Minor root intrusion at 12 O'clock
44.93	61	Roots	Minor root intrusion at 12 O'clock

2.15 Byron Street | Line L01 – E10 | S-4001-GMN-0406 | (26.98m)

The main is comprised of DN150 VC pipe with a short section (~1m) being replaced with PVC. Apart from the short PVC replacement, the main line is in reasonable condition with no major defects or ponding and only minor root intrusion evident. There is however significant radial displacement at the joints to the replaced PVC section. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 15 for a summary of findings.

Figure 62 | Root intrusion, Chg 1.17m

Figure 63 | Radial displacement, Chg 3.84m

Table 15 | Line L01 – E10

Chainage (m)	Figure	Item	Observation
0 – 26.98	-	Main	DN150 VC pipe
1.17	62	Roots	Minor root intrusion from 8 to 4 O'clock
3.84	63	Defect	Significant radial displacement ≤20mm at 8 O'clock due to PVC section replacement

2.16 Byron Street | Line L01 – DE | S-4001-GMN-0409 | (27.74m)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with no major defects or ponding and only minor root intrusion evident. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 16 for a summary of findings.

Figure 64 | Root intrusion, Chg 3.88m

Figure 65 | Radial displacement, Chg 27.64m

Table 16 | Line L01 – DE

Chainage (m)	Figure	Item	Observation
0 – 27.74	-	Main	DN150 VC pipe
3.88	64	Roots	Minor root intrusion at 2 O'clock
27.64	65	Junction	Private junction open in good condition at 10 O'clock

2.17 Byron Street | Line E11 – E10 | S-4001-GMN-0394 | (42.82m)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with no major defects and only minor isolated cracking evident. Ponding is evident throughout half of the line with the worst case having a depth of 20%. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 17 for a summary of findings.

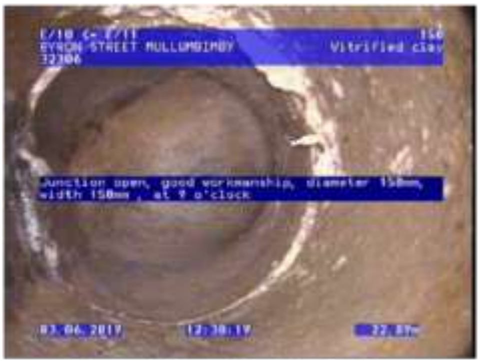

Figure 66 | Junction, Chg 22.89m

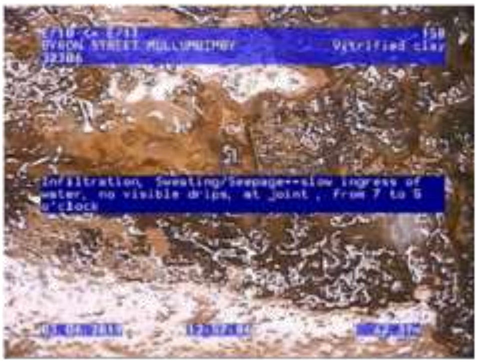

Figure 67 | Infiltration, Chg 42.39m

Figure 68 | Cracking, Chg 42.39m

Table 17 | Line E11 – E10

Chainage (m)	Figure	Item	Observation
0 – 42.82	-	Main	DN150 VC pipe
22.89	66	Junction	Private junction open in good condition at 9 O'clock
42.39	67/68	Infiltration/cracking	Cracking 2mm wide at 8 O'clock and infiltration

2.18 Byron Street | Line E08 – E07 | S-4001-GMN-1729 | (20.99m)

Only 7m of the alignment was inspected in total, the remaining 14m could not be assessed due to a restriction in the internal diameter from a patch liner. Of the main that was assessed, it is comprised of DN150 VC pipe with a patch liners throughout. The main line is in poor condition with defective patches obstructing flow capacity and assessment. There is some minor ponding no deeper than 15%. The main appears to have been patch repaired throughout which is indicative of a VC main in poor condition that was installed in 1964 (55 years of age). There is no private junction on the portion of this main that was assessed. Refer to the below figures and Table 18 for a summary of findings.

Figure 69 | Patch liner, Chg 6.14m

Figure 70 | Patch liner, Chg 6.91m

Table 18 | Line E08 – E07

Chainage (m)	Figure	Item	Observation
0 – 20.99	-	Main	DN150 VC pipe
6.14	69	Patch liner	Patch liner indicating poor condition of pipe
6.91	70	Patch liner	Patch liner obstructing flow and inspection

2.19 Byron Street | Line E07 – E06 | S-4001-GMN-1739 | (64.28m)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with no significant cracking or other defects identified. The entire line does suffer from ponding ranging from a depth of 5% and up to as much as 40% immediately prior to the downstream MH. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 19 for a summary of findings.

Figure 71 | Ponding, Chg 0.00m

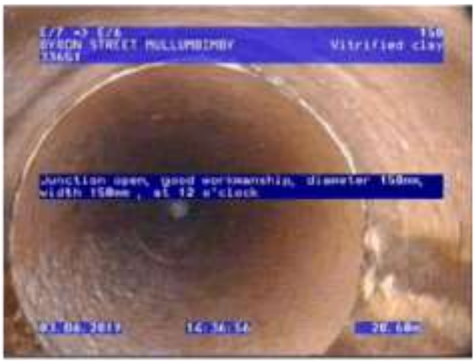

Figure 72 | Junction, Chg 20.60m

Figure 73 | Junction, Chg 31.69m

Table 19 | Line E07 – E06

Chainage (m)	Figure	Item	Observation
0 – 64.28	-	Main	DN150 VC pipe
0.00	71	Ponding	Ponding sewage due to lack of longitudinal grade
20.60	72	Junction	Private junction open in good condition at 12 O'clock
31.69	73	Junction	Private junction open in good condition at 12 O'clock

2.20 Small Lane | Line J02 – J01 | S-4001-GMN-1116 | (33.86m)

The entire main is comprised of DN150 VC pipe with a short repair (<1m) in PVC. The main line is typically in reasonable condition with only isolated cracking and joint displacement. There is no ponding evident throughout this line. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 20 for a summary of findings.

Figure 74 | Radial displacement, Chg 0.04m

Figure 75 | Root intrusion, Chg 0.10m

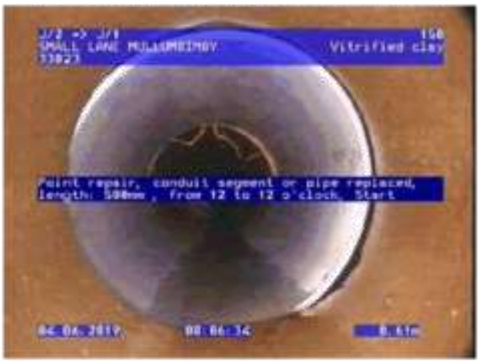

Figure 76 | Pipe replacement, Chg 0.61m

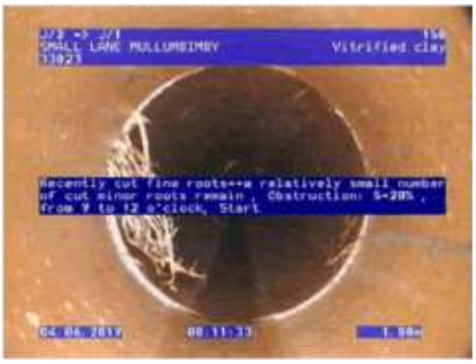

Figure 77 | Root intrusion, Chg 1.80m

Figure 78 | Junction, Chg 18.34m

Figure 79 | Junction, Chg 25.56m

Table 20 | Line J02 – J01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 33.86	-	Main	DN150 VC pipe
0.04	74	Defect	Radial displacement 5-10mm at 8 O'clock
0.10	75	Roots	Minor root intrusion at 11 O'clock
0.61	76	Pipe replacement	Pipe has been replaced with a PVC section, separation between joints
1.80	77	Roots	Minor root intrusion between 9-12 O'clock
18.34	78	Junction	Private junction open in good condition at 9 O'clock
25.56	79	Junction	Private junction open in good condition at 3 O'clock

2.21 Small Lane | Line J01 – E06 | S-4001-GMN-1106 | (27.52m)

The main is primarily comprised of DN150 VC pipe with two short sections (~1m) of PVC either side of an unnamed maintenance structure that is 9m from the upstream MH. The main line is in good condition with no signs of cracking, ponding, or other defects. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 21 for a summary of findings.

Figure 80 | Pipe material change, Chg 8.24m

Figure 81 | Unnamed MS, Chg 9.39m

Figure 82 | Pipe material change, Chg 9.99m

Figure 83 | Vertical drop, Chg 27.52m

Table 21 | Line J01 – E06

Chainage (m)	Figure	Item	Observation
0 – 27.52	-	Main	DN150 VC pipe
8.24	80	Material change	Material changes from VC to PVC with radial displacement evident at joint
9.39	81	Unnamed MS	Unnamed MS in good condition
9.99	82	Material change	Material changes from VC to PVC
27.52	83	End of line	Vertical drop in good condition

2.22 Small Lane | Line E06 – E05 | S-4001-GMN-1738 | (43.91m)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition with only isolated cracking and joint displacement. It is noted that this line was cleaned 3 times with sediment still being present in the line. Ponding is evident throughout this line with the worst depth being 50%. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 22 for a summary of findings.

Figure 84 | Radial displacement, Chg 11.18m

Figure 85 | Cracking, Chg 23.67m

Figure 86 | Encrustation, Chg 28.55m

Table 22 | Line E06 – E05			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 43.91	-	Main	DN150 VC pipe
11.18	84	Defect	Radial displacement 5-10mm at 10 O'clock
23.67	85	Defect	Significant cracking/breaking in pipe wall
28.55	86	Encrustation	Encrustation obstruction of <5% from 8-12 O'clock

2.23 Myokum Street | Line DE – E05 | S-4001-GMN-0977 | (8.97m)

The main is primarily comprised of DN150 VC pipe with ~1m immediately downstream from the upstream MH being PVC. The main line is in good condition with no cracking, joint displacement, ponding or other defects evident. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 23 for a summary of findings.

Figure 87 | Junction, Chg 5.30m

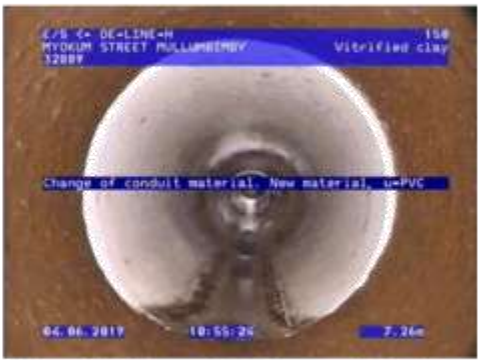

Figure 88 | Pipe material change, Chg 7.26m

Table 23 | Line DE – E05

Chainage (m)	Figure	Item	Observation
0 – 8.97	-	Main	DN150 VC pipe
5.30	87	Junction	Private junction open in good condition at 3 O'clock
7.26	88	Material change	Material changes from VC to PVC

2.24 Myokum Street | Line E05 – E04 | S-4001-GMN-0989 | (64.48m)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition with only isolated cracking and joint displacement. Ponding is evident throughout this line with the worst depth being 30%. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 24 for a summary of findings.

Figure 89 | Ponding, Chg 2.98m

Figure 90 | Junction, Chg 19.16m

Figure 91 | Breaking, Chg 23.21m

Figure 92 | Encrustation, Chg 40.47m

Figure 93 | Long Displacement, Chg 57.73m

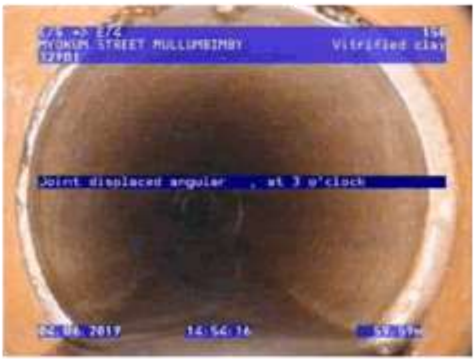

Figure 94 | Ang Displacement, Chg 59.59m

Table 24 | Line E05 – E04

Chainage (m)	Figure	Item	Observation
0 – 64.48	-	Main	DN150 VC pipe
2.98	89	Ponding	Ponding sewage due to lack of longitudinal grade
19.16	90	Junction	Private junction open in good condition at 12 O'clock
23.21	91	Defect	Pipe wall is breaking apart and chipping at 7 O'clock
40.47	92	Encrustation	Encrustation obstruction of 5-20% from 8-1 O'clock
57.73	93	Defect	Longitudinal displacement of 20-30mm
59.59	94	Defect	Angular displacement at 3 O'clock

2.25 Myokum Street | Line E04 – E03 | S-4001-GMN-1715 | (63.97m)

The entire main is comprised of DN150 VC pipe. The main line is in poor condition with multiple displaced joints, encrustation, and cracking which is resulting in infiltration. Ponding is evident throughout this line with the worst depth being 60% immediately prior to the downstream MH. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 25 for a summary of findings.

Figure 95 | Encrustation, Chg 1.03m

Figure 96 | Cracking, Chg 1.71m

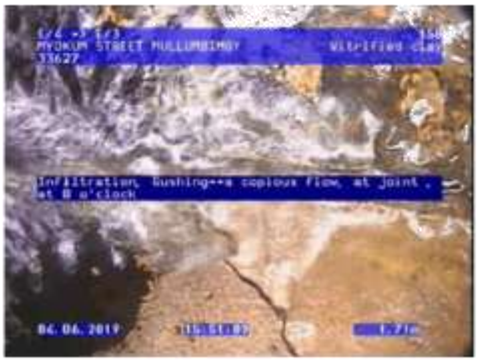

Figure 97 | Cracking/infiltration, Chg 1.71m

Figure 98 | Ang Displacement, Chg 12.73m

Figure 99 | Junction, Chg 62.11m

Figure 100 | Active infiltration, Chg 62.31m

Table 25 | Line E04 – E03			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 63.97	-	Main	DN150 VC pipe
1.03	95	Encrustation	Encrustation obstruction of <5% from 8-4 O'clock
1.71	96/97	Cracking / Infiltration	Cracking 4mm wide from 8-10 O'clock and active infiltration
12.73	98	Angular displacement	Angular displacement at 9 O'clock
62.11	99	Junction	Private junction closed in good condition at 2 O'clock
62.31	100	Active infiltration	Active infiltration through pipe joint

2.26 Whian Street | Line N05 – N04 | S-4001-GMN-0861 | (54.95m)

The entire main is comprised of DN150 VC pipe. The main line is in good condition with no displaced joints or cracking. There is no ponding evident within this main and there is only isolated and minor encrustation and root intrusion. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 26 for a summary of findings.

Figure 101 | Cracking, Chg 0.32m

Figure 102 | Root intrusion, Chg 32.85m

Figure 103 | Root intrusion, Chg 49.84m

Table 26 | Line N05 – N04

Chainage (m)	Figure	Item	Observation
0 – 54.95	-	Main	DN150 VC pipe
0.32	101	Cracking	Circumferential cracking 3mm wide from 12-12 O'clock resulting in infiltration and encrustation
32.85	102	Roots	Root intrusion with obstruction of <5% at 7 O'clock
49.84	103	Roots	Root intrusion with obstruction of <5% from 4-8 O'clock

2.27 Whian Street | Line N06 – N05 | S-4001-GMN-0858 | (47.09m)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition however there are some instances of cracking and root intrusion. There is no ponding evident within this main. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 27 for a summary of findings.

Figure 104 | Root intrusion, Chg 10.18m

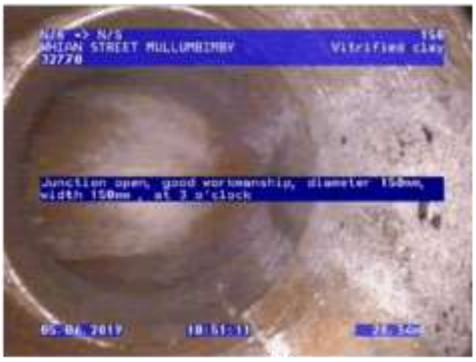

Figure 105 | Junction, Chg 28.34m

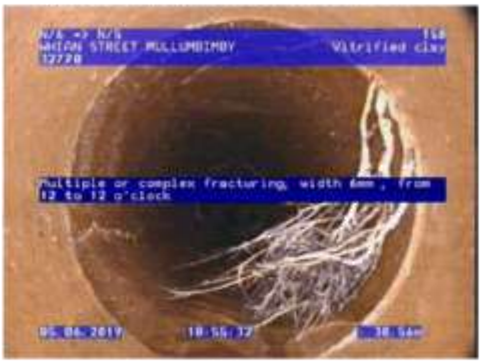

Figure 106 | Root intrusion, Chg 30.56m

Figure 107 | Junction, Chg 45.82m

Table 27 | Line N06 – N05

Chainage (m)	Figure	Item	Observation
0 – 47.09	-	Main	DN150 VC pipe
10.18	104	Roots	Root intrusion with obstruction between 5-20% from 3-5 O'clock
28.34	105	Junction	Private junction open in good condition at 3 O'clock
30.56	106	Roots/cracking	Root intrusion with obstruction between 5-20% from 2-6 O'clock and crack width of 6mm
45.82	107	Junction	Private junction open in good condition at 3 O'clock

2.28 Whian Street | Line T01 – N06 | S-4001-GMN-0855 | (36.19m)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition however there is some evidence of infiltration. There is no ponding evident within this main. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 28 for a summary of findings.

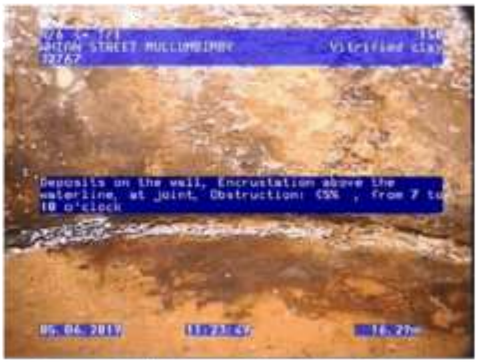

Figure 108 | Encrustation, Chg 16.29m

Figure 109 | Junction, Chg 21.47m

Figure 110 | Encrustation, Chg 24.48m

Table 28 | Line T01 – N06			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 36.19	-	Main	DN150 VC pipe
16.29	108	Encrustation	Encrustation obstruction of <5% from 7-10 O'clock
21.47	109	Junction	Private junction open in good condition at 3 O'clock
24.48	110	Encrustation	Encrustation obstruction of <5% from 7-8 O'clock

2.29 Jubilee Avenue | Line S01 – N06 | S-4001-GMN-0881 | (52.64m)

The main is primarily comprised of DN150 VC pipe with one junction tee being replaced with PVC. The main line is in reasonable condition with only an isolated joint displacement and pipe fracture and some encrustation at a couple of joints. There is some minor ponding evident within this main up to a depth of 15%. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 29 for a summary of findings.

Figure 111 | Change of material, Chg 26.99m

Figure 112 | Junction, Chg 27.36m

Figure 113 | Junction, Chg 31.80m

Figure 114 | Junction, Chg 44.57m

Figure 115 | Encrustation, Chg 46.63m

Figure 116 | Encrustation, Chg 50.43m

Figure 117 | Radial displacement, Chg 52.23m

Figure 118 | Circumferential cracking, Chg 52.23m

Table 29 | Line S01 – N06

Chainage (m)	Figure	Item	Observation
0 – 52.64	-	Main	DN150 VC pipe
26.99	111	Material change	Material changes from VC to PVC
27.36	112	Junction	Private junction open in good condition at 9 O'clock
31.80	113	Junction	Private junction closed in good condition at 3 O'clock
44.57	114	Junction	Private junction open in good condition at 9 O'clock
46.63	115	Encrustation	Encrustation obstruction of 5-20% from 4-8 O'clock
50.43	116	Encrustation	Encrustation obstruction of 5-20% from 4-8 O'clock
52.23	117	Defect	Radial displacement 10-20mm at 6 O'clock
52.23	118	Defect	Circumferential cracking 8mm wide from 12-12 O'clock

2.30 Jubilee Avenue | Line UNV – S01 | S-4001-GMN-4091 | (4.53m)

The main is primarily comprised of DN150 PVC pipe with the first 1.5m from the upstream MH being VC. The main line is in poor condition with a circumferential pipe fracture and encrustation at a couple of joints. There is no ponding evident within this main. The main was likely installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 30 for a summary of findings.

Figure 119 | Circumferential crack, Chg 0.38m

Figure 120 | Encrustation, Chg 0.38m

Figure 121 | Pipe material change, Chg 1.48m

Table 30 | Line UNV – S01

Chainage (m)	Figure	Item	Observation
0 – 4.53	-	Main	DN150 VC pipe
0.38	119	Defect	Circumferential cracking 10mm wide from 12-12 O'clock
0.38	120	Encrustation	Encrustation obstruction of 5-20% at 4 O'clock
1.48	121	Material change	Material changes from VC to PVC

2.31 Jubilee Avenue | Line S DE – UNV | S-4001-GMN-4092 | (13.93m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects identified which is to be expected for a PVC main that was laid in 2004 (15 years of age). There are two private junctions on this main. Refer to the below figures and Table 31 for a summary of findings.

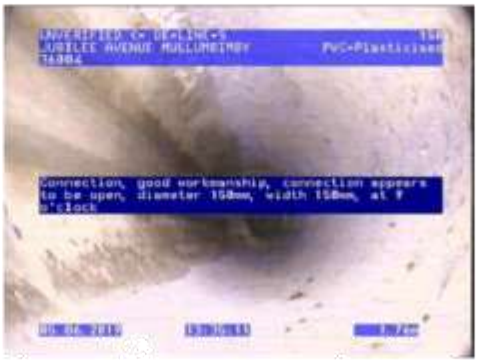

Figure 122 | Junction, Chg 1.76m

Figure 123 | Junction, Chg 13.38m

Figure 124 | End of line, Chg 13.93m

Table 31 | Line S DE – UNV

Chainage (m)	Figure	Item	Observation
0 – 13.93	-	Main	DN150 VC pipe
1.76	122	Junction	Private junction open in good condition at 9 O'clock
13.38	123	Junction	Private junction open in good condition at 9 O'clock
13.93	124	End of line	End of line cap

2.32 Whian Street | Line N07 – N06 | S-4001-GMN-4210 | (56.28m)

The entire main is comprised of DN150 VC pipe. The main line is in poor condition with various points subject to cracking and root intrusion. There is no ponding evident within this main. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 32 for a summary of findings.

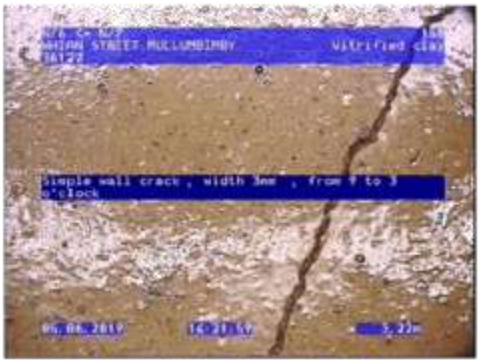

Figure 125 | Cracking, Chg 3.22m

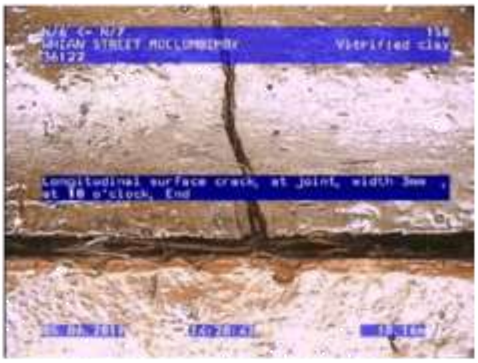

Figure 126 | Cracking, Chg 18.16m

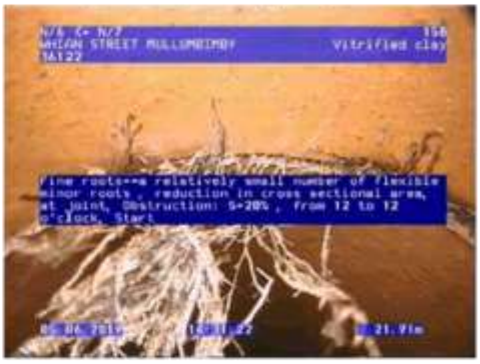

Figure 127 | Root intrusion, Chg 21.91m

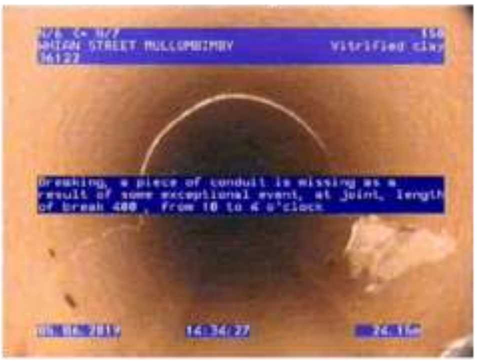

Figure 128 | Cracking, Chg 24.15m

Figure 129 | Cracking, Chg 29.15m

Figure 130 | Cracking, Chg 29.48m

Figure 131 | Cracking / roots, Chg 29.70m

Figure 132 | Breaking / roots, Chg 56.03m

Table 32 | Line N07 – N06

Chainage (m)	Figure	Item	Observation
0 – 56.28	-	Main	DN150 VC pipe
3.22	125	Defect	Cracking 3mm wide at 9-3 O'clock
18.16	126	Defect	Cracking 3mm wide at 10 O'clock
21.91	127	Roots	Root intrusion with obstruction between 5-20% from 12-12 O'clock
24.15	128	Defect	Piece of pipe wall is missing as well as spiralling cracking for a length of 400mm
29.15	129	Defect	Cracking 4mm wide at joint
29.48	130	Defect	Piece of pipe wall is missing as well as circumferential cracking for a length of 300mm
29.70	131	Defect / roots	Root intrusion with obstruction between 5-20% from 1-5 O'clock and longitudinal cracking
56.03	132	Roots	Root intrusion of major roots with obstruction between <5% from 7-11 O'clock

2.33 Station Street | Line B02 – B01 | S-4001-GMN-0942 | (27.80m)

The entire main is comprised of DN150 VC pipe. The main line is in good condition with no defects or ponding identified. The main was installed in 1982 (37 years of age). There are no private junctions on this main. Refer to the below figures and Table 33 for a summary of findings.

Figure 133 | End of line, Chg 13.93m

Table 33 | Line B02 – B01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 27.80	133	Main	DN150 VC pipe

2.34 Station Street | Line BC01 – B01 | S-4001-GMN-5147 | (61.31m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects or ponding identified. The main is in as new condition which is expected for a PVC main that was installed in 2017 (2 years of age). There is a single private junction on this main. Refer to the below figures and Table 34 for a summary of findings.

Figure 134 | Junction, Chg 59.77m

Figure 135 | Junction / line, Chg 59.77m

Table 34 | Line BC01 – B01

Chainage (m)	Figure	Item	Observation
0 – 61.31	-	Main	DN150 VC pipe
59.77	134/135	Junction	Private junction open in good condition at 3 O'clock

2.35 Fern Street | Line UNV – B02 | S-4001-GMN-3910 | (23.47m)

The main is comprised of approximately half DN150 PVC and VC pipe. The main line is in good condition with no defects or ponding identified. The main was likely installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 35 for a summary of findings.

Figure 136 | Pipe material change, Chg 11.01m

Figure 137 | Junction, Chg 23.47m

Table 35 | Line UNV – B02			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 23.47	-	Main	DN150 VC/PVC pipe
11.01	136	Material change	Material changes from VC to PVC
23.47	137	Junction	Private junction open in good condition at end of line

2.36 Station Street | Line B03 – B02 | S-4001-GMN-3806 | (77.87m)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with only a few radial joint displacements and a pipe fracture. There is no ponding evident within this main. The main was installed in 1982 (37 years of age). There are five private junctions on this main. Refer to the below figures and Table 36 for a summary of findings.

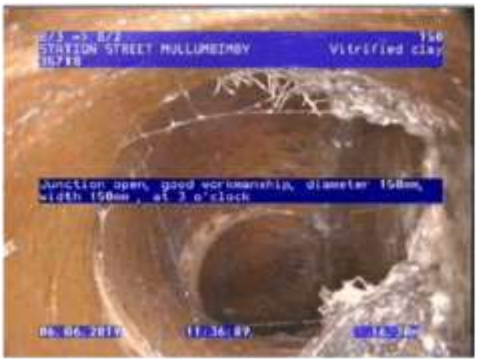

Figure 138 | Junction, Chg 16.30m

Figure 139 | Displacement, Chg 30.13m

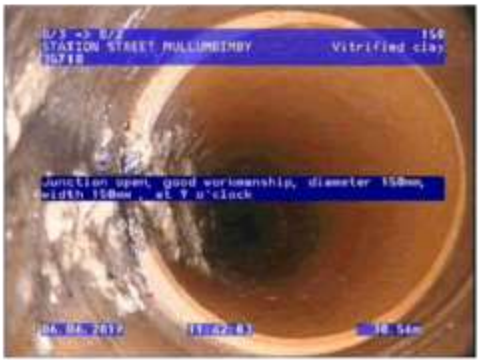

Figure 140 | Junction, Chg 30.56m

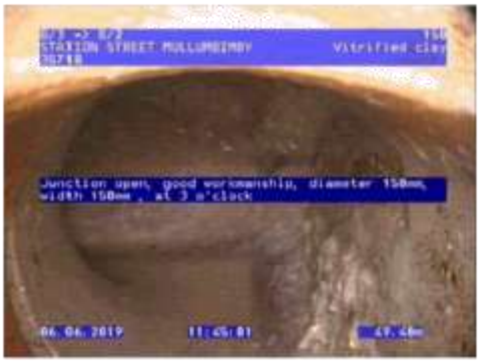

Figure 141 | Junction, Chg 49.40m

Figure 142 | Cracking, Chg 59.98m

Figure 143 | Junction, Chg 68.56m

Figure 144 | Junction, Chg 71.01m

Table 36 | Line B03 – B02

Chainage (m)	Figure	Item	Observation
0 – 77.87	-	Main	DN150 VC pipe
16.30	138	Junction	Private junction open in good condition at 3 O'clock, obstruction 10%
30.13	139	Defect	Radial displacement 10-20mm at 3 O'clock
30.56	140	Junction	Private junction open in good condition at 9 O'clock
49.40	141	Junction	Private junction open in good condition at 3 O'clock
59.98	142	Defect	Surface cracking 2mm wide at joint from 4-5 O'clock
68.56	143	Junction	Private junction open in good condition at 3 O'clock
71.01	144	Junction	Private junction open in good condition at 3 O'clock

2.37 Station Street | Line DE – B03 | S-4001-GMN-1718 | (23.73m)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition apart from a well-established root intrusion at the upstream MH joint. There is no ponding evident within this main. The main was installed in 1982 (37 years of age). There are three private junctions on this main, two of which are significantly blocked. Refer to the below figures and Table 37 for a summary of findings.

Figure 145 | Junction, Chg 3.97m

Figure 146 | Junction, Chg 6.14m

Figure 147 | Junction, Chg 23.73m

Figure 148 | Root intrusion, Chg 23.73m

Table 37 | Line DE – B03

Chainage (m)	Figure	Item	Observation
0 – 23.73	-	Main	DN150 VC pipe
3.97	145	Junction	Private junction open in good condition at 9 O'clock, junction is 75% blocked
6.14	146	Junction	Private junction open in good condition at 9 O'clock, junction is 50% blocked
23.73	147	Junction	Private junction open in good condition at 9 O'clock
23.73	148	Roots	Root intrusion at end of line. Significant mass of fine roots

2.38 Station Street | Line GB01 – SPS4010 | S-4001-GMN-1111 | (4.39m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects or ponding identified. The main was installed in 1986 (33 years of age). There are no private junctions on this main. Refer to the below figures and Table 38 for a summary of findings.

Figure 149 | Main, Chg 0.00m

Figure 150 | Pump Station, Chg 4.39m

Table 38 | Line GB01 – SPS4010

Chainage (m)	Figure	Item	Observation
0 – 4.39	149	Main	DN150 PVC pipe
4.39	150	Pump Station	Discharge point to SPS4010

2.39 Station Street | Line DE – GB01 | S-4001-GMN-0395 | (45.93m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects or ponding identified apart from a single penetration through the pipe wall. The main was installed in 1986 (33 years of age). There are five private junctions on this main. Refer to the below figures and Table 39 for a summary of findings.

Figure 151 | Junction, Chg 1.48m

Figure 152 | Hole, Chg 12.90m

Figure 153 | Junction, Chg 21.18m

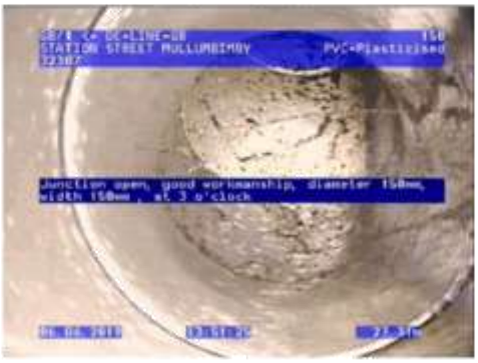

Figure 154 | Junction, Chg 23.31m

Figure 155 | Junction, Chg 45.11m

Figure 156 | Junction, Chg 45.93m

Table 39 | Line DE - GB01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 45.93	-	Main	DN150 PVC pipe
1.48	151	Junction	Private junction open in good condition at 3 O'clock
12.90	152	Defect	Large hole through the pipe wall at 12 O'clock
21.18	153	Junction	Private junction open in good condition at 9 O'clock
23.31	154	Junction	Private junction open in good condition at 3 O'clock
45.11	155	Junction	Private junction closed in good condition at 3 O'clock
45.93	156	Junction	Private junction open in good condition at 12 O'clock (DN75)

2.40 Station Street | Line GC01 – GB01 | S-4001-GMN-1112 | (32.74m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects and only minor ponding to a maximum depth of 15%. The main was installed in 1996 (23 years of age). There are no private junctions on this main. Refer to the below figures and Table 40 for a summary of findings.

Figure 157 | Main, Chg 0.00m

Table 40 | Line GC01 – GB01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 32.74	157	Main	DN150 PVC pipe, minor ponding

2.41 Station Street | Line GC01 – GB01 | S-4001-GMN-1112 | (32.74m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects identified. The main was installed in 1996 (23 years of age). There are 16 private junctions on this main. Refer to the below figures and Table 41 for a summary of findings.

Figure 158 | Junction, Chg 7.19m

Figure 159 | Junction, Chg 7.72m

Figure 160 | Junction, Chg 17.71m

Figure 161 | Junction, Chg 18.27m

Figure 162 | Junction, Chg 28.36m

Figure 163 | Junction, Chg 28.87m

Figure 164 | Junction, Chg 38.37m

Figure 165 | Junction, Chg 38.85m

Figure 166 | Junction, Chg 49.02m

Figure 167 | Junction, Chg 49.31m

Figure 168 | Junction, Chg 58.10m

Figure 169 | Junction, Chg 59.04m

Figure 170 | Junction, Chg 68.76m

Figure 171 | Junction, Chg 68.95m

Figure 172 | Junction, Chg 78.88m

Figure 173 | Junction, Chg 79.20m

Table 41 | Line GC01 - GB01

Chainage (m)	Figure	Item	Observation
0 – 45.93	-	Main	DN150 PVC pipe
7.19	158	Junction	Private junction open in good condition at 3 O'clock
7.72	159	Junction	Private junction open in good condition at 9 O'clock
17.71	160	Junction	Private junction open in good condition at 3 O'clock
18.27	161	Junction	Private junction open in good condition at 9 O'clock
28.36	162	Junction	Private junction open in good condition at 3 O'clock
28.87	163	Junction	Private junction open in good condition at 9 O'clock
38.37	164	Junction	Private junction open in good condition at 3 O'clock
38.85	165	Junction	Private junction open in good condition at 9 O'clock
49.02	166	Junction	Private junction open in good condition at 3 O'clock
49.31	167	Junction	Private junction open in good condition at 12
58.10	168	Junction	Private junction open in good condition at 3 O'clock
59.04	169	Junction	Private junction open in good condition at 12
68.76	170	Junction	Private junction open in good condition at 3 O'clock
68.95	171	Junction	Private junction open in good condition at 12
78.88	172	Junction	Private junction open in good condition at 3 O'clock
79.20	173	Junction	Private junction open in good condition at 12

2.42 Station Street | Line GC03 – GC02 | S-4001-GMN-5033 | (19.93m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects identified and was installed in 1996 (23 years of age). There are three private junctions on this main. Refer to the below figures and Table 42 for a summary of findings.

Figure 174 | Junction, Chg 0.84m

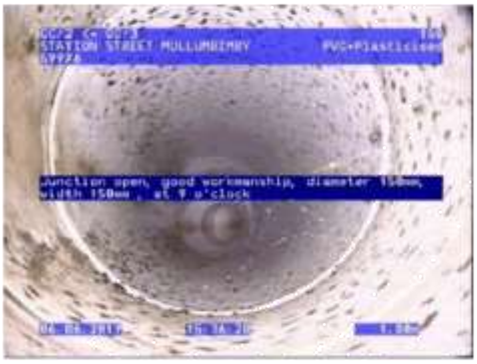

Figure 175 | Junction, Chg 1.80m

Figure 176 | Junction, Chg 12.36m

Table 42 | Line GC03 – GC02

Chainage (m)	Figure	Item	Observation
0 – 19.93	-	Main	DN150 PVC pipe
0.84	174	Junction	Private junction open in good condition at 3 O'clock
1.80	175	Junction	Private junction open in good condition at 9 O'clock
12.36	176	Junction	Private junction open in good condition at 9 O'clock

2.43 Station Street | Line DE – GC03 | S-4001-GMN-5043 | (13.10m)

The entire main is comprised of DN150 PVC pipe. The main line is in good condition with no defects identified and was installed in 2016 (3 years of age). There are two private junctions on this main. Refer to the below figures and Table 43 for a summary of findings.

Figure 177 | Junction, Chg 1.55m

Figure 178 | Junction, Chg 12.24m

Figure 179 | Junction, Chg 13.10m

Table 43 | Line DE – GC03

Chainage (m)	Figure	Item	Observation
0 – 13.10	-	Main	DN150 PVC pipe
1.55	177	Junction	Private junction open in good condition at 9 O'clock
12.24	178	Junction	Private junction open in good condition at 9 O'clock
13.10	179	End of line	Dead end – end of line cap

2.44 Dalley Street | Line U01 – N07 | S-4001-GMN-4195 | (38.49m)

The entire main is comprised of DN150 VC pipe. The main line is in poor condition with various points subject to cracking, displacement, and root intrusion. There is no ponding evident within this main. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 44 for a summary of findings.

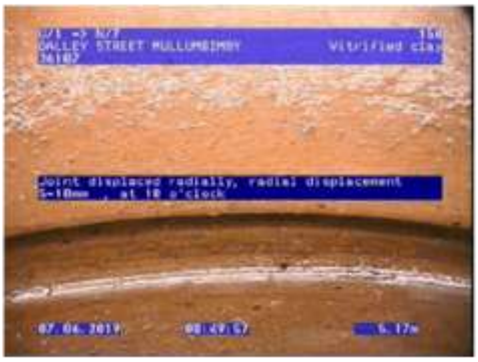

Figure 180 | Radial displacement, Chg 5.17m

Figure 181 | Junction, Chg 5.46m

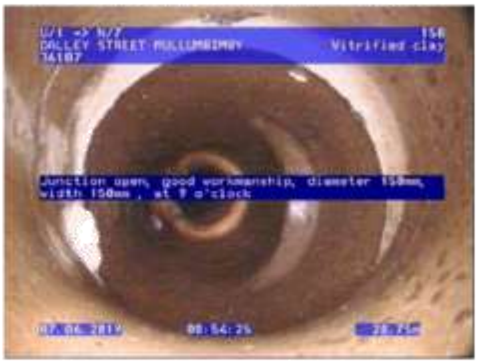

Figure 182 | Junction, Chg 28.75m

Figure 183 | Radial displacement, Chg 37.45m

Figure 184 | Cracking, Chg 37.45m

Figure 185 | Cracking, Chg 38.36m

Figure 186 | Vertical drop, Chg 38.49m

Table 44 | Line U01 – N07

Chainage (m)	Figure	Item	Observation
0 – 38.49	-	Main	DN150 VC pipe
5.17	180	Defect	Radial displacement 5-10mm at 10 O'clock
5.46	181	Junction	Private junction open in good condition at 9 O'clock
28.75	182	Junction	Private junction open in good condition at 9 O'clock
37.45	183	Defect	Radial displacement 5-10mm at 12 O'clock
37.45	184	Defect	Circumferential cracking 5mm wide from 12-12 O'clock
38.36	185	Defect	Circumferential cracking 5mm wide from 7-2 O'clock
38.49	186	End of line	Vertical drop

2.45 River Terrace | Line N08 – N07 | S-4001-GMN-4189 | (58.90m)

The entire main is comprised of DN150 VC pipe. The main line is in poor condition with various points subject to cracking, displacement, and root intrusion. There is no ponding evident within this main. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 45 for a summary of findings.

Figure 187 | Root intrusion, Chg 0.05m

Figure 188 | Cracking, Chg 12.64m

Figure 189 | Root intrusion, Chg 15.97m

Figure 190 | Root intrusion, Chg 21.65m

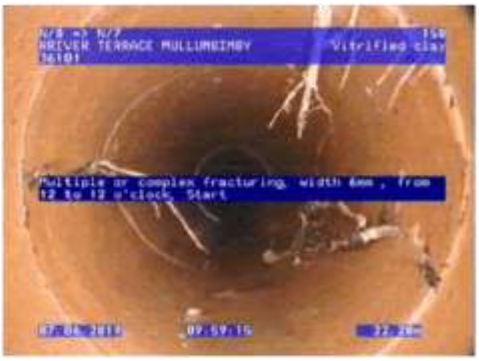

Figure 191 | Root intrusion, Chg 22.20m

Figure 192 | Junction, Chg 33.20m

Figure 193 | Root intrusion, Chg 49.51m

Figure 194 | Root intrusion, Chg 50.63m

Figure 195 | Junction, Chg 51.03m

Figure 196 | Root intrusion, Chg 51.34m

Table 45 | Line N08 – N07

Chainage (m)	Figure	Item	Observation
0 – 58.90	-	Main	DN150 VC pipe
0.05	187	Roots	Root intrusion with obstruction between 5-20% from 3-10 O'clock with circumferential crack 5mm wide
12.64	188	Defect	Circumferential cracking 2mm wide from 12-12 O'clock
15.97	189	Roots	Root intrusion with obstruction between <5% at 7 O'clock
21.65	190	Roots	Root intrusion with obstruction between 5-20% from 9-3 O'clock
22.20	191	Defect	Multiple cracks 6mm wide from 12-12 O'clock
33.20	192	Junction	Private junction open in good condition at 9 O'clock
49.51	193	Roots	Root intrusion with obstruction between 5-20% at 8 O'clock
50.63	194	Junction	Private junction open in good condition at 9 O'clock, junction is ≤50% blocked
51.03	195	Junction	Private junction closed in good condition at 12 O'clock
51.34	196	Roots	Root intrusion with obstruction between 20-50% at 12 O'clock

2.46 Whian Street | Line N04 – N03 | S-4001-GMN-0865 | (42.92m)

The entire main is comprised of DN150 VC pipe. The last ~4m of the main could not be inspected due to an obstruction. The main line is in poor condition with various points subject to encrustation, grease build up, and ponding. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 46 for a summary of findings.

Figure 197 | Encrustation, Chg 7.22m

Figure 198 | Encrustation, Chg 12.04m

Figure 199 | Encrustation, Chg 14.42m

Figure 200 | Encrustation, Chg 17.41m

Figure 201 | Encrustation, Chg 19.31m

Figure 202 | Junction, Chg 21.49m

Figure 203 | Grease, Chg 21.49m

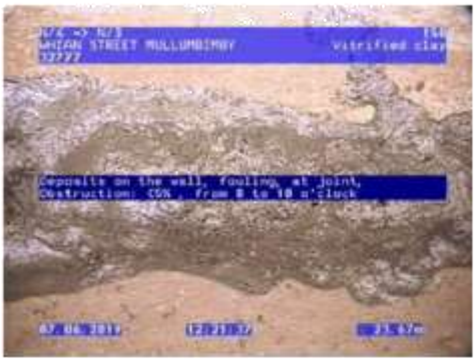

Figure 204 | Encrustation, Chg 23.67m

Figure 205 | Blockage, Chg 38.24m

Table 46 | Line N04 – N03

Chainage (m)	Figure	Item	Observation
0 – 42.92	-	Main	DN150 VC pipe
7.22	197	Encrustation	Encrustation obstruction of <5% at 8 O'clock
12.04	198	Encrustation	Encrustation obstruction of <5% from 7-5 O'clock
14.42	199	Encrustation	Encrustation obstruction of <5% from 1-5 O'clock
17.41	200	Encrustation	Encrustation obstruction of <5% from 2-5 O'clock
19.31	201	Encrustation	Encrustation obstruction between 5-20% from 7-11 O'clock
21.49	202	Junction	Private junction open in good condition at 3 O'clock
21.49	203	Grease	Grease obstruction of <5% from 7-2 O'clock
23.67	204	Encrustation	Encrustation obstruction of <5% from 8-10 O'clock
38.24	205	Blockage	Assessment abandoned due to blockage (unable to locate downstream MH)

2.47 Fern Street | Line P01 – N01 | S-4001-GMN-0920 | (69.05m)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with only isolated points subject to cracking and root intrusion. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 47 for a summary of findings.

Figure 206 | Radial displacement, Chg 0.10m

Figure 207 | Cracking, Chg 0.67m

Figure 208 | Junction, Chg 18.27m

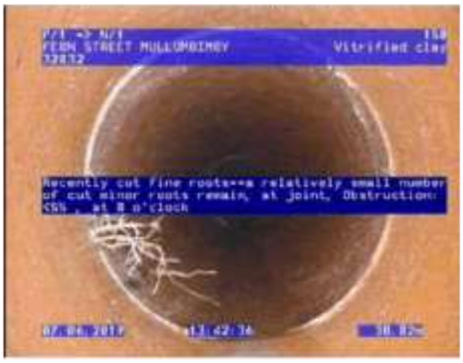

Figure 209 | Root intrusion, Chg 30.82m

Figure 210 | Root intrusion, Chg 32.77m

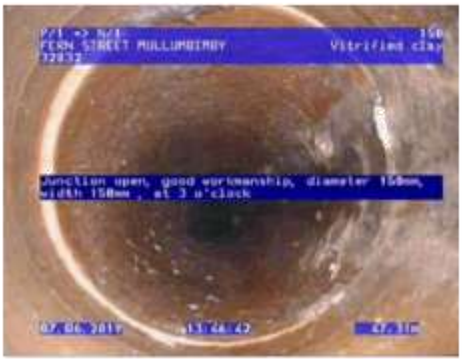

Figure 211 | Junction, Chg 47.31m

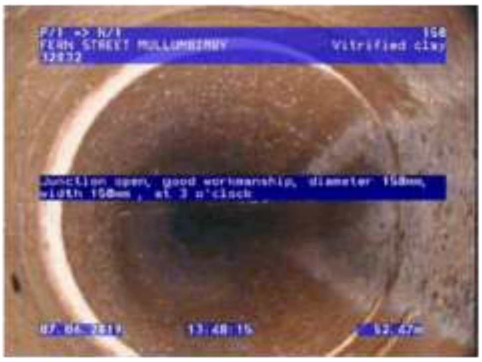

Figure 212 | Junction, Chg 52.47m

Figure 213 | Vertical drop, Chg 69.02m

Table 47 | Line P01 – N01

Chainage (m)	Figure	Item	Observation
0 – 69.05	-	Main	DN150 VC pipe
0.10	206	Defect	Radial displacement 5-10mm at 2 O'clock
0.67	207	Defect	Circumferential cracking 2mm wide from 12-12 O'clock
18.27	208	Junction	Private junction open in good condition at 3 O'clock
30.82	209	Roots	Root intrusion with obstruction of <5% at 8 O'clock
32.77	210	Roots	Root intrusion with obstruction of <5% at 8 O'clock
47.31	211	Junction	Private junction open in good condition at 3 O'clock
52.47	212	Junction	Private junction open in good condition at 3 O'clock
69.02	213	End of line	Vertical drop

2.48 Fern Street | Line DE – P01 | S-4001-GMN-0917 | (5.91m)

The entire main is comprised of DN150 VC pipe. The main line is in good condition with no defects identified and was installed in 1964 (55 years of age) which is likely to be incorrect as PVC was the material requirement at the time. There is a single private junction on this main. Refer to the below figures and Table 48 for a summary of findings.

Figure 214 | Junction, Chg 5.70m

Figure 215 | Dead end, Chg 5.91m

Table 48 | Line DE – P01

Chainage (m)	Figure	Item	Observation
0 – 5.91	-	Main	DN150 VC pipe
5.70	214	Junction	Private junction open in good condition at 9 O'clock
5.91	215	Dead end	End of line cap

2.49 Azalea Street | Line E17 – E16 | S-4001-GMN-4091 | (62.73)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition however there are a few locations that have been patch repaired and these repairs have deteriorated to the point where they are obstructing flow. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 49 for a summary of findings.

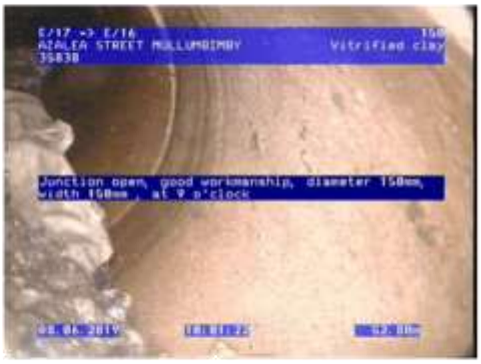

Figure 216 | Junction, Chg 52.80m

Figure 217 | Patch liner, Chg 53.18m

Figure 218 | Patch liner, Chg 53.18m

Figure 219 | Patch liner, Chg 58.78m

Figure 220 | Breaking, Chg 61.10m

Table 49 | Line E17 – E16			
Chainage (m)	Figure	Item	Observation
0 – 62.73	-	Main	DN150 VC pipe
52.80	216	Junction	Private junction open in good condition at 9 O'clock, junction obstructed 25%
53.18	217/218	Patch liner	Defective patch liner, assessment could not proceed due to restriction in diameter
58.78	219	Patch liner	Patch liner indicating poor pipe condition
61.10	220	Defect	Break of 200mm in length from 12-12 O'clock

2.50 Jubilee Avenue | Line E12 – E11 | S-4001-GMN-1121 | (55.68)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition however there are a few locations where encrustation, seepage, and root intrusion are apparent. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 50 for a summary of findings.

Figure 221 | Encrustation, Chg 8.35m

Figure 222 | Junction, Chg 13.63m

Figure 223 | Junction, Chg 45.44m

Figure 224 | Encrustation, Chg 55.68m

Table 50 | Line E12 – E11

Chainage (m)	Figure	Item	Observation
0 – 55.68	-	Main	DN150 VC pipe
8.35	221	Encrustation	Encrustation obstruction of <5% from 3-5 O'clock
13.63	222	Junction	Private junction open in good condition at 9 O'clock
45.44	223	Junction	Private junction open in good condition at 9 O'clock, junction obstructed ≤50% by root intrusion
55.68	224	Encrustation	Encrustation obstruction from 5-20% from 7-5 O'clock

2.51 Jubilee Avenue | Line E13 – E12 | S-4001-GMN-1122 | (83.11)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition however there are a few locations where encrustation, seepage, and root intrusion are apparent. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 51 for a summary of findings.

Figure 225 | Infiltration, Chg 0.14m

Figure 226 | Encrustation, Chg 11.62m

Figure 227 | Root intrusion, Chg 48.16m

Figure 228 | Root intrusion, Chg 63.81m

Table 51 | Line E13 – E12

Chainage (m)	Figure	Item	Observation
0 – 83.11	-	Main	DN150 VC pipe
0.14	225	Infiltration	Circumferential crack 2mm wide from 7-5 O'clock resulting in continuous infiltration
11.62	226	Encrustation	Encrustation obstruction between 5-20% from 4-5 O'clock
48.16	227	Roots	Root intrusion with obstruction of <5% at 4 O'clock
63.81	228	Roots	Root intrusion with obstruction of <5% from 2-4 O'clock

2.52 Studal Lane | Line W01 – A10 | S-4001-GMN-0821 | (39.55m)

The entire main is comprised of DN150 VC pipe. The main line is in poor condition as cracking, repairs, patch liners, and breaking of the pipe have all been identified. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 52 for a summary of findings.

Figure 229 | Junction, Chg 7.29m

Figure 230 | Patch liner, Chg 10.45m

Figure 231 | Pipe replacement, Chg 10.92m

Figure 232 | Cracking, Chg 10.92m

Figure 233 | Junction, Chg 11.11m

Figure 234 | Patch liner, Chg 11.37m

Figure 235 | Cracking, Chg 34.21m

Figure 236 | Extensive cracking, Chg 38.69m

Figure 237 | Vertical drop, Chg 39.55m

Table 52 | Line W01 – A10

Chainage (m)	Figure	Item	Observation
0 – 39.55	-	Main	DN150 VC pipe
7.29	229	Junction	Private junction open in poor condition at 9 O'clock. Displacement at joint
10.45	230	Patch liner	Patch liner indicating poor condition of pipe
10.92	231	Pipe replacement	Newly installed PVC junction tee has subsided resulting in ponding
10.92	232	Defect	Newly installed PVC has longitudinal cracking 2mm wide at 12 O'clock
11.11	233	Junction	Private junction open in good condition at 9 O'clock.
11.37	234	Patch liner	Patch liner indicating poor condition of pipe
34.21	235	Defect	Significant cracking in pipe wall 7mm wide throughout
38.69	236	Defect	Pipe wall breaking at joint, length of break is 100mm between 6-7 O'clock
39.55	237	End of line	Vertical drop

2.53 Studal Lane | Line W02 – W01 | S-4001-GMN-0838 | (53.17)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition however there are a few locations where cracking is apparent. The main was installed in 1964 (55 years of age). There are seven private junctions on this main. Refer to the below figures and Table 53 for a summary of findings.

Figure 238 | Junction, Chg 0.00m

Figure 239 | Junction, Chg 10.95m

Figure 240 | Cracking, Chg 11.11m

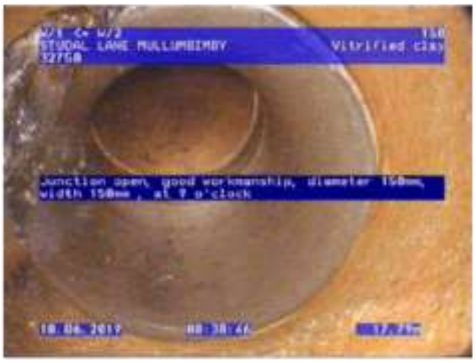

Figure 241 | Junction, Chg 17.79m

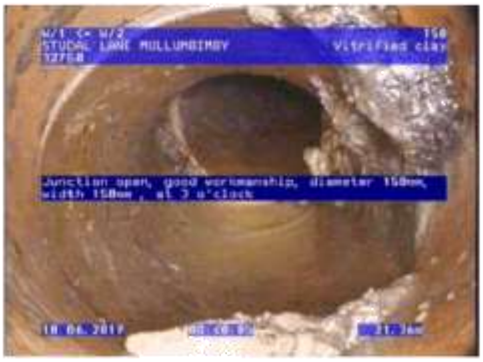

Figure 242 | Junction, Chg 21.36m

Figure 243 | Cracking, Chg 23.10m

Figure 244 | Junction, Chg 34.51m

Figure 245 | Junction, Chg 35.05m

Figure 246 | Junction, Chg 48.09m

Table 53 | Line W02 – W01

Chainage (m)	Figure	Item	Observation
0 – 53.17	-	Main	DN150 VC pipe
0.00	238	Defect	Significant cracking in pipe wall 8mm wide from 12-12 O'clock
10.95	239	Junction	Private junction open in good condition at 3 O'clock. Blockage in junction of 25%
11.11	240	Defect	Cracking in pipe wall 3mm wide from 12-12 O'clock
17.79	241	Junction	Private junction open in good condition at 9 O'clock.
21.36	242	Junction	Private junction open in good condition at 3 O'clock. Blockage in junction of 15%
23.10	243	Defect	Cracking in pipe wall 3mm wide from 9-11 O'clock
34.51	244	Junction	Private junction open in good condition at 3 O'clock.
35.05	245	Junction	Private junction open in good condition at 9 O'clock.
48.09	246	Junction	Private junction open in good condition at 3 O'clock.

2.54 Stuart Street | Line X01 – W01 | S-4001-GMN-0822 | (26.69)

The entire main is comprised of DN150 VC pipe. The main line is in good condition with no defects identified. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 54 for a summary of findings.

Figure 247 | Junction, Chg 7.97m

Figure 248 | Junction, Chg 12.50m

Figure 249 | Junction, Chg 17.66m

Table 54 | Line X01 – W01

Chainage (m)	Figure	Item	Observation
0 – 26.69	-	Main	DN150 VC pipe
7.97	247	Junction	Private junction open in good condition at 9 O'clock.
12.50	248	Junction	Private junction closed in good condition at 9 O'clock.
17.66	249	Junction	Private junction open in good condition at 3 O'clock.

2.55 Burringbar Street | Line A08 – A07 | S-4001-GMN-0827 | (48.80)

The entire main is comprised of DN150 VC pipe. The main line is in good condition with only isolated cracking identified. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 55 for a summary of findings.

Figure 250 | Cracking, Chg 14.99m

Figure 251 | Junction, Chg 39.89m

Table 55 | Line X01 – W01

Chainage (m)	Figure	Item	Observation
0 – 48.80	-	Main	DN150 VC pipe
14.99	250	Defect	Longitudinal cracking 3mm wide at 12 O'clock
39.89	251	Junction	Private junction closed with cracking at 12 O'clock.

2.56 Stuart Street | Line BK01 – A07 | S-4001-GMN-0828 | (42.41)

The entire main is comprised of DN150 VC pipe. The main line is typically in reasonable condition with only some minor cracking and root intrusion apparent. The main was installed in 1964 (55 years of age). There are four private junctions on this main. Refer to the below figures and Table 54 for a summary of findings.

Figure 252 | Junction, Chg 19.47m

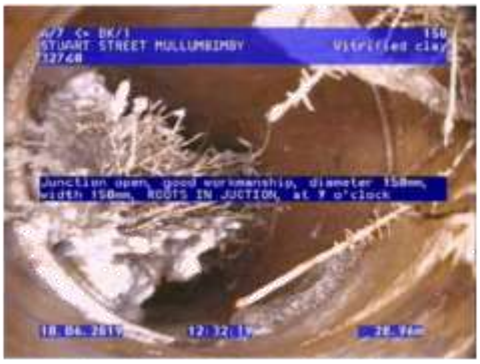

Figure 253 | Junction, Chg 20.96m

Figure 254 | Junction, Chg 28.00m

Figure 255 | Junction, Chg 33.21m

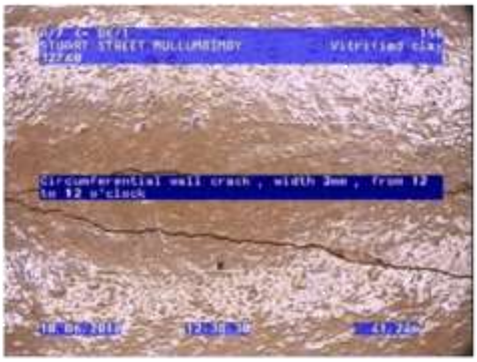

Figure 256 | Cracking, Chg 41.24m

Table 56 | Line BK01 – A07			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 42.41	-	Main	DN150 VC pipe
19.47	252	Junction	Private junction open in good condition at 3 O'clock.
20.96	253	Junction	Private junction open in good condition at 9 O'clock. Root intrusion blocking flow by 25%
28.00	254	Junction	Private junction open in good condition at 3 O'clock.
33.21	255	Junction	Private junction open in good condition at 3 O'clock.
41.24	256	Defect	Cracking 2mm wide from 12-12 O'clock

2.57 Bridgland Street | Line V01 – A07 | S-4001-GMN-0831 | (75.44)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with only isolated cracking identified. The main was installed in 1964 (55 years of age). There are six private junctions on this main. Refer to the below figures and Table 57 for a summary of findings.

Figure 257 | Deposit, Chg 14.19m

Figure 258 | Junction, Chg 26.29m

Figure 259 | Junction, Chg 29.60m

Figure 260 | Junction, Chg 35.78m

Figure 261 | Junction, Chg 44.77m

Figure 262 | Junction, Chg 50.04m

Figure 263 | Cracking, Chg 55.03m

Figure 264 | Junction, Chg 69.31m

Figure 265 | End of line, Chg 75.44m

Table 57 | Line V01 – A07

Chainage (m)	Figure	Item	Observation
0 – 75.44	-	Main	DN150 VC pipe
14.19	257	Deposit	Small hard material in invert of pipe, obstruction <5% at 5 O'clock
26.29	258	Junction	Private junction open in good condition at 3 O'clock. Obstruction 10-20%
29.60	259	Junction	Private junction open in good condition at 3 O'clock.
35.78	260	Junction	Private junction open in good condition at 9 O'clock.
44.77	261	Junction	Private junction open in good condition at 3 O'clock.
50.04	262	Junction	Private junction open in good condition at 3 O'clock.
55.03	263	Defect	Cracking 2mm wide from 12-12 O'clock
69.31	264	Junction	Private junction open in good condition at 3 O'clock. Pipe break at 12 O'clock
75.44	265	End of line	Vertical drop

2.58 Station Street | Line V02 – V01 | S-4001-GMN-0844 | (32.93)

The entire main is comprised of DN150 VC pipe. The main line is in reasonable condition with only isolated cracking identified. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 58 for a summary of findings.

Figure 266 | Junction, Chg 3.59m

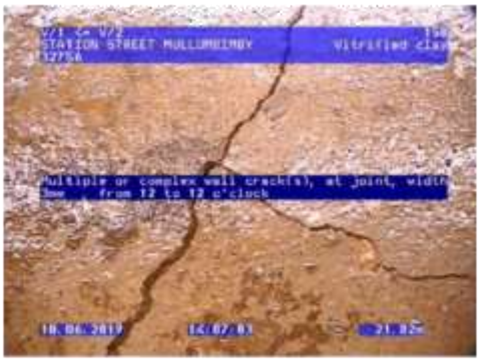

Figure 267 | Cracking, Chg 21.82m

Table 58 | Line V02 – V01

Chainage (m)	Figure	Item	Observation
0 – 32.93	-	Main	DN150 VC pipe
3.59	266	Junction	Private junction closed in good condition at 9 O'clock
21.82	267	Defect	Cracking 3mm wide from 12-12 O'clock

2.59 McGoughans Lane | Line A06 – A07 | S-4001-GMN-4185 | (79.11)

The entire main is comprised of DN150 VC pipe, however the assessment was not completed due to a restriction in a patch liner not allowing the track camera to proceed. The main line is in reasonable condition apart from two patch liners and some deposits on the pipe wall. The main was installed in 1964 (55 years of age). There are seven private junctions on this main. Refer to the below figures and Table 59 for a summary of findings.

Figure 268 | Deposit, Chg 9.34m

Figure 269 | Junction, Chg 22.12m

Figure 270 | Junction, Chg 28.35m

Figure 271 | Junction, Chg 37.50m

Figure 272 | Junction, Chg 45.29m

Figure 273 | Junction, Chg 55.74m

Figure 274 | Junction, Chg 60.98m

Figure 275 | Junction, Chg 73.15m

Figure 276 | Patch liner, Chg 74.82m

Figure 277 | Patch liner, Chg 79.11m

Table 59 | Line A06 – A07

Chainage (m)	Figure	Item	Observation
0 – 79.11	-	Main	DN150 VC pipe
9.34	268	Deposit	Small hard material in invert of pipe, obstruction <5% at 6 O'clock
22.12	269	Junction	Private junction open in good condition at 12 O'clock.
28.35	270	Junction	Private junction open in good condition at 12 O'clock.
37.50	271	Junction	Private junction open in good condition at 12 O'clock.
45.29	272	Junction	Private junction open in good condition at 12 O'clock.
55.74	273	Junction	Private junction open in good condition at 9 O'clock.
60.98	274	Junction	Private junction closed in good condition at 12 O'clock.
73.15	275	Junction	Private junction open in good condition at 12 O'clock.
74.82	276	Patch liner	Patch liner indicating poor condition of pipe
79.11	277	Patch liner	Patch liner indicating poor condition of pipe and obstructing inspection

2.60 McGoughans Lane | Line A06 – A05 | S-4001-GMN-0859 | (71.00)

The entire main is comprised of DN150 VC pipe, however the assessment was not completed due to a restriction in a patch liner not allowing the track camera to proceed. The main line is in reasonable condition apart from two patch liners, a displaced joint, and some deposits on the pipe wall. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 60 for a summary of findings.

Figure 278 | Deposit, Chg 2.22m

Figure 279 | Patch liner, Chg 9.64m

Figure 280 | Infiltration, Chg 10.89m

Figure 281 | Junction, Chg 12.91m

Figure 282 | Radial displacement, Chg 17.87m

Figure 283 | Junction, Chg 25.80m

Figure 284 | Patch liner, Chg 28.62m

Table 60 | Line A06 – A05			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 28.98	-	Main	DN150 VC pipe
2.22	278	Deposit	Grease on pipe wall, obstruction <5% from 5-7 O'clock
9.64	279	Patch liner	Patch liner indicating poor condition of pipe with encrustation at the transition of the liner
10.89	280	Infiltration	Infiltration through minor cracking in pipe wall at 12 O'clock
12.91	281	Junction	Private junction open in good condition at 3 O'clock.
17.87	282	Defect	Radial displacement 5-10mm at 12 O'clock
25.80	283	Junction	Private junction open in good condition at 9 O'clock.
28.62	284	Patch liner	Patch liner indicating poor condition of pipe and obstructing inspection

2.61 McGoughans Lane | Line AS01 – A05 | S-4001-GMN-4213 | (3.03)

The entire main is comprised of DN150 PVC pipe, however the assessment was not completed due to a bend that did not allow the track camera to proceed. Of the ~3m that was assessed, there were no defects identified. The main was installed in 2016 (3 years of age). There are no private junctions on the section of main that was assessed. Refer to the below figures and Table 61 for a summary of findings.

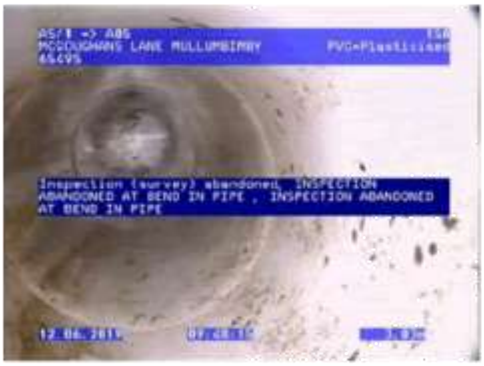

Figure 285 | Bend, Chg 3.03m

Table 61 | Line AS01 – A05

Chainage (m)	Figure	Item	Observation
0 – 3.03	-	Main	DN150 PVC pipe
3.03	285	Bend	Bend in the line that obstructed inspection

2.62 McGoughans Lane | Line AS02 – AS01 | S-4001-GMN-4212 | (8.25)

The entire main is comprised of DN150 PVC pipe. The main is in good condition and there were no defects identified. The main was installed in 2016 (3 years of age). There are no private junctions on this main. Refer to the below figures and Table 62 for a summary of findings.

Figure 286 | Main, Chg 0.00m

Figure 287 | Maintenance hole, Chg 8.25m

Table 62 | Line AS02 – AS01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 3.03	286	Main	DN150 PVC pipe
8.25	287	End structure	Maintenance hole

2.63 McGoughans Lane | Line AS03 – AS02 | S-4001-GMN-4211 | (25.65)

The entire main is comprised of DN150 PVC pipe. The main is in good condition and there were no defects identified. The main was installed in 2016 (3 years of age). There are two private junctions on this main. Refer to the below figures and Table 63 for a summary of findings.

Figure 288 | Junction, Chg 1.48m

Figure 289 | Junction, Chg 25.18m

Figure 290 | Rodding end, Chg 25.65m

Table 63 | Line AS03 – AS02

Chainage (m)	Figure	Item	Observation
0 – 25.65	-	Main	DN150 PVC pipe
1.48	288	Junction	Private junction open in good condition at 9 O'clock
25.18	289	Junction	Private junction open in good condition at 3 O'clock
25.65	290	Rodding end	Rodding end with riser

2.64 McGoughans Lane | Line A05 – A04 | S-4001-GMN-0897 | (35.62)

The main is comprised of DN225 AC pipe however the assessment was not completed due to high wastewater levels as a result of pump station bypass works that were occurring at the time of assessment. The main is in good condition with only some spalling and identified. The main was installed in 1964 (55 years of age). There are two private junctions on the portion of main that was assessed. Refer to the below figures and Table 64 for a summary of findings.

Figure 291 | Spalling, Chg 2.39m

Figure 292 | Junction, Chg 17.00m

Figure 293 | Junction, Chg 33.79m

Table 64 | Line A05 – A04			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 35.62	-	Main	DN225 AC pipe
2.39	291	Defect	Spalling of the pipe wall occurring from 7-5 O'clock
17.00	292	Junction	Private junction open in good condition at 3 O'clock
33.79	293	Junction	Private junction open in good condition at 12 O'clock

2.65 Studal Lane | Line N03 – N02 | S-4001-GMN-0892 | (60.51)

The entire main is comprised of DN150 VC pipe. The main is in good condition with only a single joint allowing infiltration. The main was installed in 1964 (55 years of age). There are four private junctions on this main. Refer to the below figures and Table 65 for a summary of findings.

Figure 294 | Junction, Chg 2.74m

Figure 295 | Junction, Chg 3.64m

Figure 296 | Junction, Chg 16.40m

Figure 297 | Junction, Chg 30.22m

Figure 298 | Infiltration, Chg 36.08m

Table 65 | Line N03 – N02			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 60.51	-	Main	DN150 VC pipe
2.74	294	Junction	Private junction open in good condition at 3 O'clock
3.64	295	Junction	Private junction open in good condition at 9 O'clock
16.40	296	Junction	Private junction open in good condition at 3 O'clock
30.22	297	Junction	Private junction open in good condition at 9 O'clock
36.08	298	Infiltration	Infiltration gushing though pipe joint at 4 O'clock

2.66 Studal Lane | Line N02 – N01 | S-4001-GMN-0919 | (58.70)

The entire main is comprised of DN150 VC pipe. The main is in good condition with only a single joint displacement and no other defects or ponding identified. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 66 for a summary of findings.

Figure 299 | Junction, Chg 14.19m

Figure 300 | Junction, Chg 24.16m

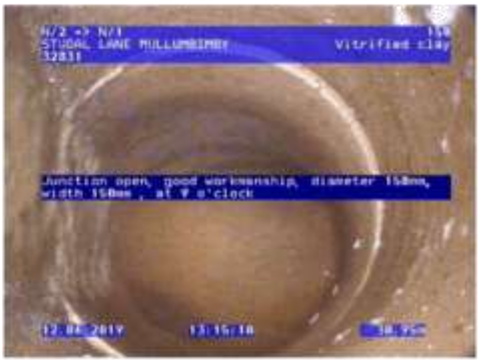

Figure 301 | Junction, Chg 30.95m

Figure 302 | Ang displacement, Chg 57.72m

Table 66 | Line N02 – N01

Chainage (m)	Figure	Item	Observation
0 – 58.70	-	Main	DN150 VC pipe
14.19	299	Junction	Private junction open in good condition at 9 O'clock
24.16	300	Junction	Private junction open in good condition at 3 O'clock
30.95	301	Junction	Private junction open in good condition at 9 O'clock
57.72	302	Defect	Angular displacement at a joint at 9 O'clock

2.67 Studal Lane | Line R01 – N03 | S-4001-GMN-0919 | (77.27)

The entire main is comprised of DN150 VC pipe. The main is in reasonable condition with only some minor encrustation, isolated cracking, a single patch liner, and no ponding identified. The main was installed in 1964 (55 years of age). There are five private junctions on this main. Refer to the below figures and Table 67 for a summary of findings.

Figure 303 | Encrustation, Chg 0.00m

Figure 304 | Encrustation, Chg 1.75m

Figure 305 | Junction, Chg 4.84m

Figure 306 | Deposits, Chg 6.93m

Figure 307 | Junction, Chg 7.10m

Figure 308 | Cracking, Chg 14.07m

Figure 309 | Junction, Chg 16.16m

Figure 310 | Junction, Chg 34.36m

Figure 311 | Junction, Chg 42.42m

Figure 312 | Patch liner, Chg 76.64m

Table 67 | Line R01 – N03			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 77.27	-	Main	DN150 VC pipe
0.00	303	Encrustation	Encrustation obstruction of <5% from 7-8 O'clock
1.75	304	Encrustation	Encrustation obstruction of <5% at 3 O'clock
4.84	305	Junction	Private junction open in good condition at 9 O'clock
6.93	306	Deposits	Solid deposits on wall, obstruction <5% from 8-4 O'clock
7.10	307	Junction	Private junction open in good condition at 3 O'clock
14.07	308	Defect	Cracking 3mm wide from 11-3 O'clock
16.16	309	Junction	Private junction open in good condition at 9 O'clock
34.36	310	Junction	Private junction open in good condition at 3 O'clock
42.42	311	Junction	Private junction open in good condition at 9 O'clock
76.64	312	Patch liner	Patch liner indicating poor condition of pipe

2.68 Studal Lane | Line R02 – R01 | S-4001-GMN-4186 | (39.24)

The entire main is comprised of DN150 VC pipe. The main is in reasonable condition apart from two sections with cracking. There was no ponding identified on this line. The main was installed in 1964 (55 years of age). There are six private junctions on this main. Refer to the below figures and Table 68 for a summary of findings.

Figure 313 | Junction, Chg 3.65m

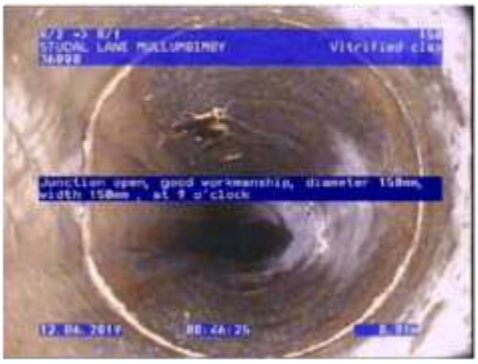

Figure 314 | Junction, Chg 8.91m

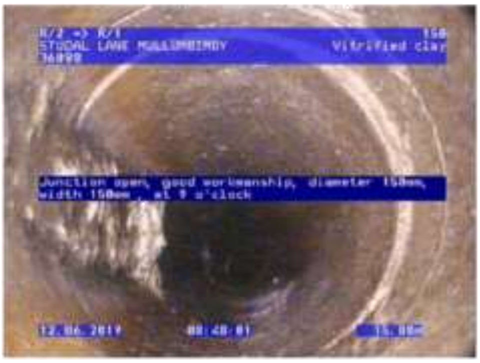

Figure 315 | Junction, Chg 15.00m

Figure 316 | Junction, Chg 15.59m

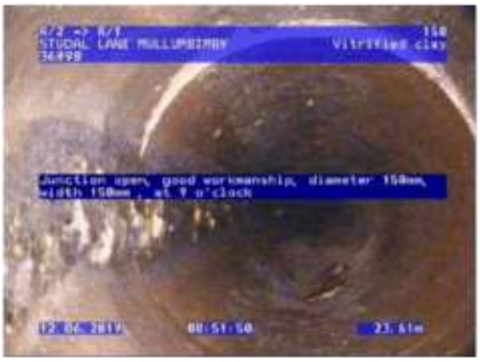

Figure 317 | Junction, Chg 23.61m

Figure 318 | Junction, Chg 24.67m

Figure 319 | Cracking, Chg 25.94m

Figure 320 | Cracking, Chg 32.65m

Table 68 | Line R02 – R01

Chainage (m)	Figure	Item	Observation
0 – 39.24	-	Main	DN150 VC pipe
3.65	313	Junction	Private junction open in good condition at 3 O'clock
8.91	314	Junction	Private junction open in good condition at 9 O'clock
15.00	315	Junction	Private junction open in good condition at 9 O'clock
15.59	316	Junction	Private junction open in good condition at 3 O'clock, large piece of pipe obstructing flow <50%
23.61	317	Junction	Private junction open in good condition at 9 O'clock
24.67	318	Junction	Private junction open in good condition at 3 O'clock
25.94	319	Defect	Cracking in pipe wall 3mm wide from 1-5 O'clock
32.65	320	Defect	Multiple cracking in pipe wall 4mm wide from 12-12 O'clock

2.69 McGoughans Lane | Line BB03 – BB02 | S-4001-GMN-0779 | (26.23)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with three patch liners and multiple infiltration points. There was no ponding identified on this line. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 69 for a summary of findings.

Figure 321 | Patch liner, Chg 0.55m

Figure 322 | Junction, Chg 10.50m

Figure 323 | Junction, Chg 10.94m

Figure 324 | Patch liner, Chg 12.81m

Figure 325 | Infiltration, Chg 13.44m

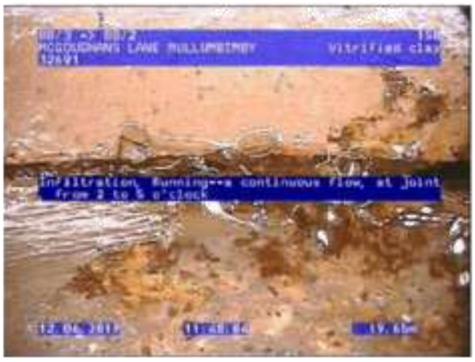

Figure 326 | Infiltration, Chg 19.65m

Figure 327 | Cracking, Chg 19.98m

Figure 328 | Junction, Chg 19.98m

Figure 329 | Patch liner, Chg 20.43m

Table 69 | Line BB03 – BB02

Chainage (m)	Figure	Item	Observation
0 – 26.23	-	Main	DN150 VC pipe
0.55	321	Patch liner / infiltration	Patch liner indicating poor condition of pipe and infiltration
10.50	322	Junction	Private junction open in good condition at 9 O'clock
10.94	323	Junction	Private junction open in good condition at 3 O'clock
12.81	324	Patch liner / infiltration	Patch liner indicating poor condition of pipe and infiltration
13.44	325	Infiltration / cracking	Cracking 2mm wide from 12-12 O'clock and infiltration
19.65	326	Infiltration / cracking	Cracking 2mm wide from 2-5 O'clock and infiltration
19.98	327	Defect	Cracking in pipe wall 3mm wide from 1-5 O'clock
19.98	328	Junction	Private junction open in good condition at 3 O'clock
20.43	329	Patch liner / infiltration	Patch liner indicating poor condition of pipe and infiltration

2.70 Burringbar Street | Line BB02 – BB01 | S-4001-GMN-0808 | (53.60)

The main is comprised of DN150 VC pipe, however the entire line was unable to be assessed due to a defective liner obstructing the track camera, approximately 7m of the main was not assessed. The main is in poor condition with five patch liners, a displaced joint, and multiple infiltration points over the first 24m of the line and another three patch liners over the other 17.93m length that was assessed from MH BB01. There was no ponding identified on this line. The main was installed in 1964 (55 years of age). There are two private junctions. Refer to the below figures and Table 70 for a summary of findings.

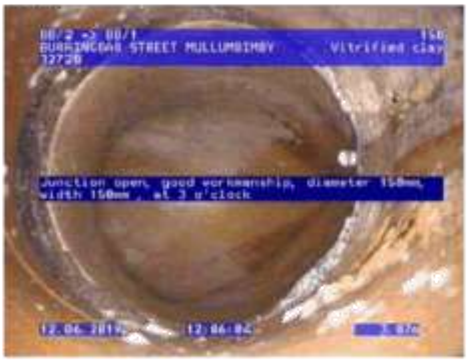

Figure 330 | Junction, Chg 3.07m

Figure 331 | Patch liner, Chg 3.99m

Figure 332 | Patch liner, Chg 6.91m

Figure 333 | Patch liner, Chg 12.63m

Figure 334 | Displacement, Chg 14.02m

Figure 335 | Junction, Chg 14.02m

Figure 336 | Encrustation, Chg 15.20m

Figure 337 | Patch liner, Chg 21.94m

Figure 338 | Patch liner, Chg 27.34m

Figure 339 | Defective patch liner, Chg 28.70m

Figure 340 | Defective patch liner, Chg 36.41m

Figure 341 | Patch liner, Chg 51.75m

Table 70 | Line BB02 – BB01			
Chainage (m)	Figure	Item	Observation
0 – 53.60	-	Main	DN150 VC pipe
3.07	330	Junction	Private junction open in good condition at 3 O'clock
3.99	331	Patch liner	Patch liner indicating poor condition of pipe

6.91	332	Patch liner	Patch liner indicating poor condition of pipe
12.63	333	Patch liner	Patch liner indicating poor condition of pipe
14.02	334	Defect	Radial displacement at joint of 5-10mm at 9 O'clock
14.02	335	Junction	Private junction open in good condition at 9 O'clock
15.20	336	Encrustation	Encrustation obstruction of <5% from 3-9 O'clock with continuous infiltration
21.94	337	Patch liner	Patch liner indicating poor condition of pipe
27.34	338	Patch liner	Patch liner indicating poor condition of pipe
28.70	339	Defective patch liner	Patch liner indicating poor condition of pipe with large piece missing and obstructing assessment
36.41	340	Defective patch liner	Patch liner indicating poor condition of pipe and obstructing assessment
51.75	341	Patch liner	Patch liner indicating poor condition of pipe

2.71 McGoughans Lane | Line BB04 – BB03 | S-4001-GMN-0757 | (82.79)

The main is comprised of DN150 VC pipe. The main is in reasonable condition with only isolated root intrusion, cracking, and two patch liners. There was no ponding identified on this line. The main was installed in 1964 (55 years of age). There are 13 private junctions on this main. Refer to the below figures and Table 71 for a summary of findings.

Figure 340 | Root intrusion, Chg 0.85m

Figure 341 | Junction, Chg 1.98m

Figure 342 | Junction, Chg 7.35m

Figure 343 | Junction, Chg 15.36m

Figure 344 | Junction, Chg 16.68m

Figure 345 | Junction, Chg 27.59m

Figure 346 | Junction, Chg 29.01m

Figure 347 | Buried manhole, Chg 32.17m

Figure 348 | Cracking, Chg 34.15m

Figure 349 | Junction, Chg 34.34m

Figure 350 | Junction, Chg 41.45m

Figure 351 | Junction, Chg 48.51m

Figure 352 | Junction, Chg 55.69m

Figure 353 | Junction, Chg 60.80m

Figure 354 | Patch liner, Chg 72.00m

Figure 355 | Junction, Chg 76.28m

Figure 356 | Junction, Chg 78.24m

Figure 357 | Patch liner, Chg 81.48m

Table 71 | Line BB04 – BB03

Chainage (m)	Figure	Item	Observation
0 – 82.79	-	Main	DN150 VC pipe
0.85	340	Roots	Root intrusion with obstruction of <5% at 8 O'clock
1.98	341	Junction	Private junction open in good condition at 3 O'clock with obstruction 25%

7.35	342	Junction	Private junction open in good condition at 9 O'clock
15.36	343	Junction	Private junction open in good condition at 9 O'clock
16.68	344	Junction	Private junction open in good condition at 3 O'clock
27.59	345	Junction	Private junction open in good condition at 9 O'clock
29.01	346	Junction	Private junction open in good condition at 3 O'clock
32.17	347	Buried MH	Buried maintenance structure with lid
34.15	348	Defect	Cracking 3mm wide from 4-6 O'clock
34.34	349	Junction	Private junction open in good condition at 3 O'clock
41.45	350	Junction	Private junction open in good condition at 9 O'clock
48.51	351	Junction	Private junction open in good condition at 3 O'clock
55.69	352	Junction	Private junction open in good condition at 9 O'clock
60.80	353	Junction	Private junction open in good condition at 3 O'clock
72.00	354	Patch liner	Patch liner indicating poor condition of pipe
76.28	355	Junction	Private junction open in good condition at 9 O'clock
78.24	356	Junction	Private junction open in good condition at 3 O'clock
81.48	357	Patch liner	Patch liner indicating poor condition of pipe

2.72 Burringbar Street | Line BB01 – A08 | S-4001-GMN-0816 | (13.67)

The main is comprised of DN150 VC pipe. The main is in reasonable condition with only a single displaced joint and isolated ponding to a depth of 40%. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 72 for a summary of findings.

Figure 358 | Radial displacement, Chg 13.53m

Figure 359 | Vertical drop, Chg 13.67m

Table 72 | Line BB01 – A08

Chainage (m)	Figure	Item	Observation
0 – 13.67	-	Main	DN150 VC pipe
13.53	358	Defect	Radial joint displacement 10-20mm at 11 O'clock
13.67	359	Vertical drop	End of line vertical drop

2.73 Burringbar Street | Line DE – BB01 | S-4001-GMN-0809 | (45.53)

The main is comprised of DN150 VC pipe. The main is in reasonable condition apart from a significantly radially displaced PVC replacement and isolated cracking and ponding to a depth of 25%. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 73 for a summary of findings.

Figure 360 | Radial displacement, Chg 14.91m

Figure 361 | Junction, Chg 17.25m

Figure 362 | Cracking, Chg 28.07m

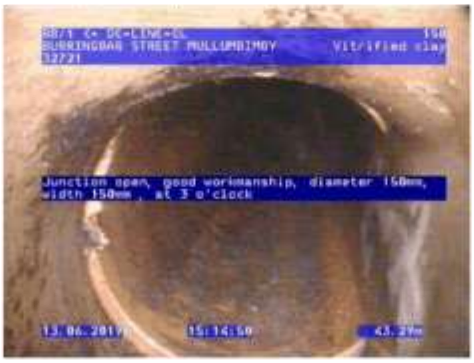

Figure 363 | Junction, Chg 43.29m

Figure 364 | Junction, Chg 43.81m

Figure 365 | Ponding, Chg 43.81m

Table 73 | Line DE – BB01			
Chainage (m)	Figure	Item	Observation
0 – 45.53	-	Main	DN150 VC pipe
14.91	360	Defect	Significant radial joint displacement >20mm at 6 O'clock likely resulting in substantial infiltration
17.25	361	Junction	Private junction closed in good condition at 3 O'clock
28.07	362	Defect	Cracking 3mm wide from 8-3 O'clock
43.29	363	Junction	Private junction open in good condition at 3 O'clock
43.81	364	Junction	Private junction open in good condition at 3 O'clock
43.81	365	Ponding	Ponding of flow due to lack of longitudinal grade

2.74 Burringbar Street | Line A10 – A09 | S-4001-GMN-0814 | (72.07)

The main is comprised of DN150 VC pipe. The main is in poor condition due to various locations in which encrustation, infiltration, cracking, and ponding to a depth of 25% were observed. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 74 for a summary of findings.

Figure 366 | Infiltration, Chg 25.27m

Figure 367 | Infiltration, Chg 27.11m

Figure 368 | Infiltration, Chg 28.07m

Figure 369 | Encrustation, Chg 41.25m

Figure 370 | Junction, Chg 41.57m

Figure 371 | Encrustation, Chg 43.66m

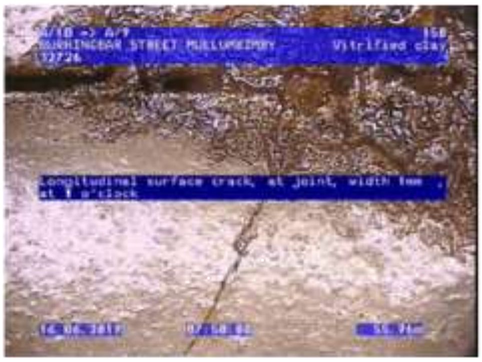

Figure 372 | Cracking, Chg 55.96m

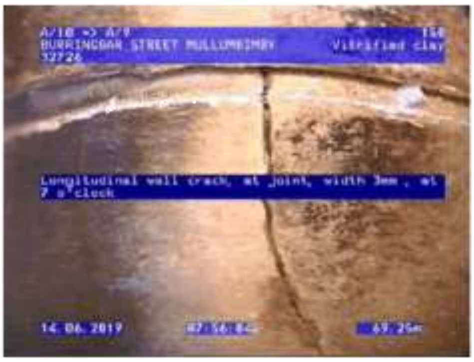

Figure 373 | Cracking, Chg 69.25m

Table 74 | Line A10 – A09

Chainage (m)	Figure	Item	Observation
0 – 72.07	-	Main	DN150 VC pipe
25.27	366	Infiltration	Infiltration of water through pipe joint from 7-10 O'clock
27.11	367	Infiltration	Infiltration of water through pipe joint from 8-4 O'clock
28.07	368	Infiltration	Infiltration of water through pipe joint from 8-4 O'clock
41.25	369	Encrustation	Encrustation obstruction of <5% from 8-4 O'clock
41.57	370	Junction	Private junction closed in good condition at 3 O'clock
43.66	371	Encrustation	Encrustation obstruction of <5% from 8-4 O'clock
55.96	372	Defect	Longitudinal cracking 2mm wide at 1 O'clock
69.25	373	Defect	Longitudinal cracking 3mm wide at 7 O'clock

2.75 Burringbar Street | Line A09 – A08 | S-4001-GMN-0817 | (64.75)

The main is comprised of DN150 VC pipe, however the entire line was unable to be assessed due to a defective liner obstructing the track camera, a central section of the main approximately 14m in length was not assessed. The main is in poor condition due to various locations in which defective patch liners are in place in addition to consistent ponding throughout up to a depth of 40% was observed. The main was installed in 1964 (55 years of age). There are no private junctions on the portions of this main that were assessed. Refer to the below figures and Table 75 for a summary of findings.

Figure 374 | Ponding, Chg 27.77m

Figure 375 | Patch liner, Chg 28.53m

Figure 376 | Defective patch liner, Chg 49.51m

Table 75 | Line A09 – A08			
Chainage (m)	Figure	Item	Observation
0 – 64.75	-	Main	DN150 VC pipe
27.77	374	Ponding	Ponding of flow due to lack of longitudinal grade
28.53	375	Patch liner	Patch liner indicating poor condition of pipe and obstructing assessment
49.51	376	Defective patch liner	Defective patch liner indicating poor condition of pipe and obstructing assessment

2.76 Burringbar Street | Line A12 – A11 | S-4001-GMN-0800 | (70.41)

The main is comprised of DN150 VC pipe. The main is in poor condition due to various locations exhibiting cracking, infiltration, and encrustation. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 76 for a summary of findings.

Figure 377 | Cracking, Chg 3.16m

Figure 378 | Infiltration, Chg 14.82m

Figure 379 | Encrustation, Chg 18.82m

Figure 380 | Cracking, Chg 30.87m

Figure 381 | Root intrusion, Chg 37.06m

Figure 382 | Infiltration, Chg 62.38m

Table 76 | Line A12 – A11			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 70.41	-	Main	DN150 VC pipe
3.16	377	Defect	Cracking in pipe wall 4mm wide from 7-10 O'clock
14.82	378	Infiltration	Infiltration through pipe joint from 8-10 O'clock
18.82	379	Encrustation	Encrustation obstruction of <5% from 8-4 O'clock
30.87	380	Defect	Longitudinal cracking in pipe wall 2mm wide at 8 O'clock
37.06	381	Roots	Root intrusion with obstruction <5% at 5 O'clock
62.38	382	Infiltration	Infiltration through crack 3mm wide at pipe joint from 7-8 O'clock

2.77 Burringbar Street | Line A11 – A10 | S-4001-GMN-0805 | (44.58)

The main is comprised of DN150 VC pipe. The main is in poor condition due to various locations exhibiting cracking, infiltration, and encrustation. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 77 for a summary of findings.

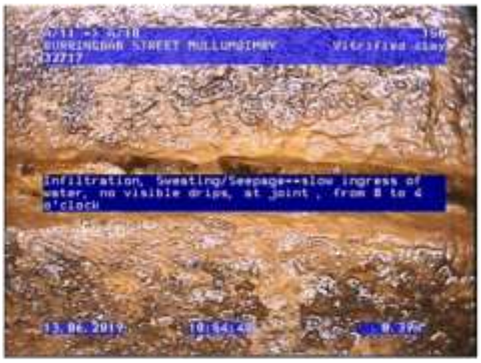

Figure 383 | Infiltration, Chg 0.39m

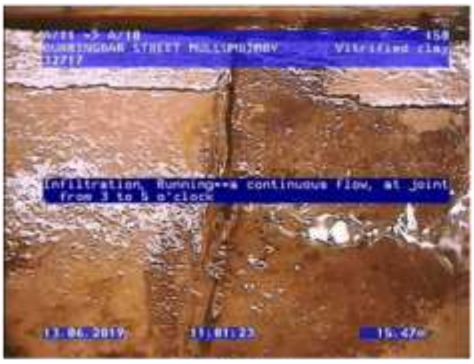

Figure 384 | Cracking/infiltration, Chg 15.47m

Figure 385 | Infiltration, Chg 20.21m

Figure 386 | Cracking/infiltration, Chg 25.73m

Table 77 | Line A11 – A10

Chainage (m)	Figure	Item	Observation
0 – 44.58	-	Main	DN150 VC pipe
0.39	383	Infiltration	Infiltration through pipe joint from 8-4 O'clock
15.47	384	Defect/infiltration	Longitudinal cracking in pipe wall 6mm wide from 3-5 O'clock including infiltration
20.21	385	Infiltration	Infiltration through pipe joint at 8 O'clock
25.73	386	Defect/infiltration	Longitudinal cracking in pipe wall 5mm wide from 3-5 O'clock

2.78 Argyle Street | Line CM01 – BA01 | S-4001-GMN-0796 | (42.26)

The main is comprised of DN150 VC pipe. The main is in good condition with only isolated but significant root intrusion at the upstream MH CM01. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 78 for a summary of findings.

Figure 387 | Root intrusion, Chg 42.26m

Table 78 | Line CM01 – BA01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 42.82	-	Main	DN150 VC pipe
42.26	387	Root intrusion	Root intrusion with obstruction between 5-20% at 6 O'clock. Roots initially obstructed assessment and had to be cut

2.79 Station Street | Line BA02 – BA01 | S-4001-GMN-0784 | (41.54)

The main is comprised of DN150 VC pipe. The main is in good condition with no defects or ponding identified. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 79 for a summary of findings.

Figure 388 | Junction, Chg 18.64m

Table 79 | Line BA02 – BA01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 41.54	-	Main	DN150 VC pipe
18.64	388	Junction	Private junction open in good condition at 3 O'clock

2.80 McGoughans Lane | Line BB02 – BA01 | S-4001-GMN-0785 | (73.73)

The main is comprised of DN150 VC pipe. The main is in poor condition with various defects identified including root intrusion, cracking/breaking, and infiltration. The main was installed in 1964 (55 years of age). There are four private junctions on this main. Refer to the below figures and Table 80 for a summary of findings.

Figure 389 | Root intrusion, Chg 33.56m

Figure 390 | Junction, Chg 33.93m

Figure 391 | Junction, Chg 46.61m

Figure 392 | Breaking, Chg 50.58m

Figure 393 | Radial displacement, Chg 50.58m

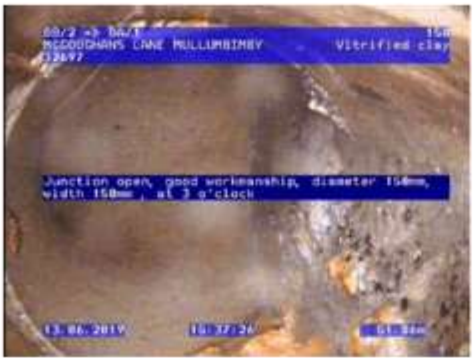

Figure 394 | Junction, Chg 51.86m

Figure 395 | Change of material, Chg 54.65m

Figure 396 | Junction, Chg 55.11m

Figure 397 | Change of material, Chg 55.42m

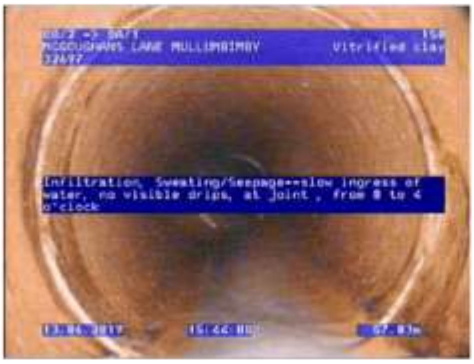

Figure 398 | Infiltration, Chg 57.03m

Figure 399 | Infiltration/encrustation, Chg 73.62m

Table 80 | Line BB02 – BA01

Chainage (m)	Figure	Item	Observation
0 – 73.73	-	Main	DN150 VC pipe
33.56	389	Significant root intrusion	Root intrusion with obstruction between 20-50% from 12-5 O'clock
33.93	390	Junction	Private junction open in good condition at 9 O'clock. Large obstruction 20-50% from 3-9 O'clock

46.61	391	Junction	Private junction open in good condition at 9 O'clock
50.58	392	Breaking	Pipe wall breaking at joint, length of break is 100mm between 8-3 O'clock
50.58	393	Displacement	Radial joint displacement of 5-10% at 4 O'clock
51.86	394	Junction	Private junction open in good condition at 3 O'clock
54.65	395	Change of material	Change of pipe material from VC to PVC for a junction tee that was replaced
55.11	396	Junction	Private junction open in good condition at 9 O'clock
55.42	397	Change of material	Change of pipe material from VC to PVC for a junction tee that was replaced
57.03	398	Infiltration	Infiltration at joint from 8-4 O'clock
73.62	399	Infiltration / encrustation	Infiltration at joint from 8-4 O'clock and encrustation with obstruction between 5-10% from 12-12 O'clock

2.81 Burringbar Street | Line A13 – A12 | S-4001-GMN-0790 | (73.86)

The main is comprised of DN150 VC pipe. The main is in poor condition with various defects identified including cracking, infiltration, and defective repairs. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 81 for a summary of findings.

Figure 400 | Cracking, Chg 22.76m

Figure 401 | Cracking, Chg 24.18m

Figure 402 | Infiltration, Chg 24.24m

Figure 403 | Radial displacement, Chg 36.93m

Figure 404 | Junction, Chg 37.69m

Figure 405 | Displacement, Chg 39.00m

Figure 406 | Cracking, Chg 61.20m

Table 81 | Line A13 – A12

Chainage (m)	Figure	Item	Observation
0 – 73.86	-	Main	DN150 VC pipe
22.76	400	Defect	Radial joint displacement of 5-10% at 4 O'clock
24.18	401	Defect	Various cracking 4mm wide from 12-12 O'clock
24.24	402	Infiltration	Cracking 2mm wide from 12-12 O'clock and infiltration
36.93	403	Defective repair	Change of pipe material from VC to PVC for a junction tee that was replaced. Repair is defective and subject to major radial displacement of 40mm
37.69	404	Junction	Private junction open in good condition at 12 O'clock
39.00	405	Defect	Longitudinal displacement of 10-20mm between VC and PVC repair section
61.20	406	Defect	Longitudinal cracking at joint 1mm wide at 2 O'clock

2.82 Cenotaph Lane | Line Y02 – Y01 | S-4001-GMN-0765 | (70.56)

The entire main is comprised of DN150 VC pipe apart from multiple junction tees that have been replaced with PVC (~1m lengths). The main is in poor condition with various defects identified including cracking, and defective repairs. The main was installed in 1964 (55 years of age). There are five private junctions on this main. Refer to the below figures and Table 82 for a summary of findings.

Figure 407 | Change of material, Chg 16.68m

Figure 408 | Junction, Chg 17.20m

Figure 409 | Change of material, Chg 17.58m

Figure 410 | Change of material, Chg 31.10m

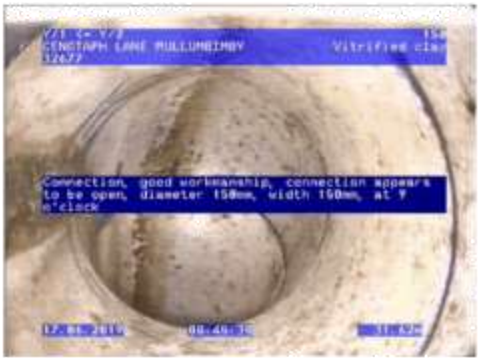

Figure 411 | Junction, Chg 31.62m

Figure 412 | Change of material, Chg 31.92m

Figure 413 | Change of material, Chg 40.57m

Figure 414 | Junction, Chg 40.96m

Figure 415 | Change of material, Chg 41.27m

Figure 416 | Radial displacement, Chg 43.80m

Figure 417 | Junction, Chg 44.25m

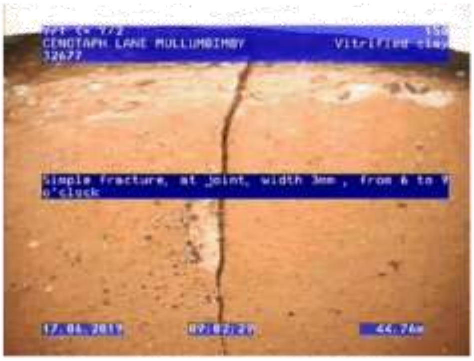

Figure 418 | Cracking, Chg 44.76m

Figure 419 | Radial displacement, Chg 64.61m

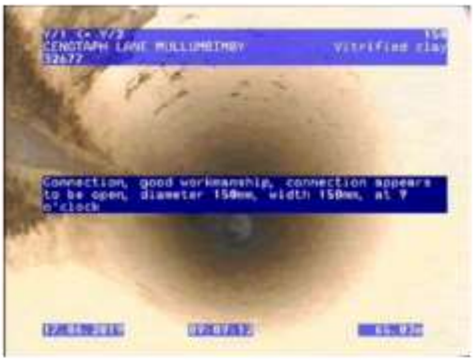

Figure 420 | Junction, Chg 65.03m

Table 82 | Line Y02 – Y01

Chainage (m)	Figure	Item	Observation
0 – 70.56	-	Main	DN150 VC pipe
16.68	407	Pipe material change	Material changes from VC to PVC with significant radial displacement of 11-20mm at 6 O'clock
17.20	408	Junction	Private junction open in good condition at 3 O'clock
17.58	409	Pipe material change	Material changes from PVC to VC
31.10	410	Pipe material change	Material changes from VC to PVC
31.62	411	Junction	Private junction open in good condition at 9 O'clock
31.92	412	Pipe material change	Material changes from PVC to VC
40.57	413	Pipe material change	Material changes from VC to PVC
40.96	414	Junction	Private junction open in good condition at 12 O'clock
41.27	415	Pipe material change	Material changes from PVC to VC with radial displacement of 5-10mm at 4 O'clock
43.80	416	Displacement	Material changes from VC to PVC with significant radial displacement of 11-20mm at 6 O'clock
44.25	417	Junction	Private junction open in good condition at 3 O'clock
44.76	418	Defect	Longitudinal cracking 3mm wide from 6-9 O'clock
64.61	419	Displacement	Material changes from VC to PVC with significant radial displacement of 11-20mm at 8 O'clock
65.03	420	Junction	Private junction open in good condition at 9 O'clock

2.83 River Terrace | Line DE – Z01 | S-4001-GMN-0830 | (21.62)

The entire main is comprised of DN150 VC pipe. The main is typically in reasonable condition apart for ~2m of pipe immediately downstream of the dead end which is breaking apart leaving a large void in the roof of the pipe. There are no other defects or ponding evident along this main. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 83 for a summary of findings.

Figure 421 | Junction, Chg 10.90m

Figure 422 | Hole in pipe, Chg 20.33m

Figure 423 | Defect, Chg 21.16m

Figure 424 | Junction, Chg 21.32m

Table 83 | Line DE – Z01

Chainage (m)	Figure	Item	Observation
0 – 21.62	-	Main	DN150 VC pipe
10.90	421	Junction	Private junction open in good condition at 9 O'clock
20.33	422	Defect	Large hole ~100mm in the pipe wall at 12 O'clock
21.16	423	Defect	Large pipe break ~200mm piece missing from 8-4 O'clock
21.32	424	Junction	Private junction open in poor condition at 9 O'clock, connection pipe is damaged with obstruction of 20-50%

2.84 River Terrace | Line Z01 – A12 | S-4001-GMN-0825 | (80.55)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various locations throughout subject to cracking. There are no other defects or ponding evident along this main apart from a significantly blocked private junction. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 84 for a summary of findings.

Figure 425 | Cracking, Chg 0.02m

Figure 426 | Cracking, Chg 9.70m

Figure 427 | Cracking, Chg 17.09m

Figure 428 | Junction, Chg 18.65m

Figure 429 | Junction, Chg 19.89m

Figure 430 | Cracking, Chg 32.81m

Figure 431 | Junction, Chg 44.93m

Figure 432 | Cracking, Chg 50.34m

Table 84 | Line Z01 – A12

Chainage (m)	Figure	Item	Observation
0 – 80.55	-	Main	DN150 VC pipe
0.02	425	Defect	Circumferential cracking in pipe wall 3mm wide from 12-12 O'clock
9.70	426	Defect	Multiple cracks in pipe wall 4mm wide from 7-5 O'clock
17.09	427	Defect	Longitudinal cracking 1mm wide at 10 O'clock
18.65	428	Junction	Private junction open in good condition at 3 O'clock
19.89	429	Junction	Private junction open in poor condition at 3 O'clock, major obstruction 75%
32.81	430	Defect	Longitudinal cracking 1mm wide at 11 O'clock
44.93	431	Junction	Private junction open in good condition at 3 O'clock
50.34	432	Defect	Longitudinal cracking 1mm wide at joint at 10 O'clock

2.85 Studal Lane | Line BD01 – A10 | S-4001-GMN-0804 | (65.06)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various locations throughout subject to cracking, infiltration, and displacement. There are no other defects or ponding evident along this main. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 85 for a summary of findings.

Figure 433 | Infiltration, Chg 13.59m

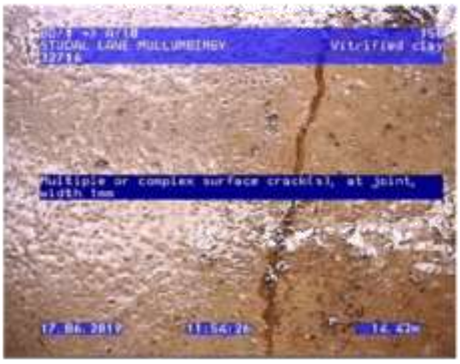

Figure 434 | Cracking, Chg 14.42m

Figure 435 | Cracking, Chg 21.66m

Figure 436 | Cracking, Chg 25.71m

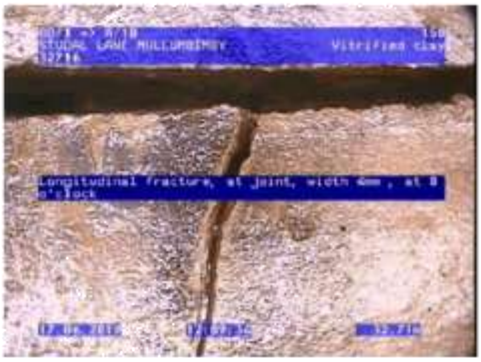

Figure 437 | Cracking, Chg 32.71m

Figure 438 | Cracking, Chg 38.29m

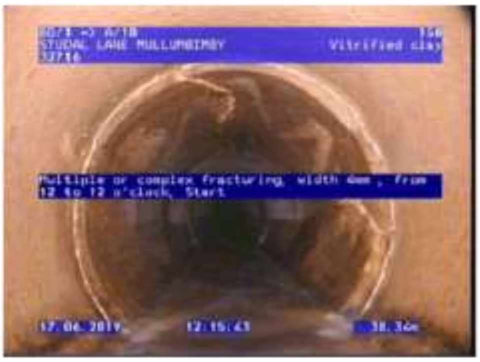

Figure 439 | Cracking, Chg 38.34m

Figure 440 | Cracking, Chg 48.94m

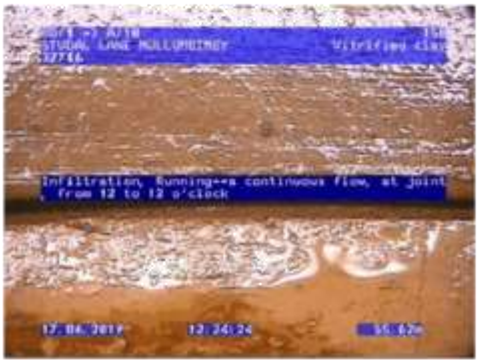

Figure 441 | Infiltration, Chg 55.62m

Figure 442 | Displacement, Chg 64.93m

Table 85 | Line BD01 – A10

Chainage (m)	Figure	Item	Observation
0 – 65.06	-	Main	DN150 VC pipe
13.59	433	Infiltration	Infiltration seeping through pipe joint from 7-5 O'clock
14.42	434	Defect	Multiple cracks in pipe wall 1mm wide from 12-12 O'clock
21.66	435	Defect	Multiple cracks in pipe wall 3mm wide from 12-12 O'clock
25.71	436	Defect	Multiple cracks in pipe wall at pipe joint 3mm wide from 8-4 O'clock
32.71	437	Defect	Longitudinal crack in pipe wall 4mm wide at 8 O'clock
38.29	438	Defect	Multiple cracks in pipe wall 4mm wide from 12-12 O'clock
38.34	439	Defect	Multiple cracks in pipe wall 4mm wide from 12-12 O'clock
48.94	440	Defect	Infiltration seeping through cracking at pipe joint from 7-9 O'clock
55.62	441	Infiltration	Infiltration seeping through pipe joint from 12-12 O'clock
64.93	442	Displacement	Significant radial displacement >20mm at 6 O'clock

2.86 Stuart Street | Line BE01 – BD01 | S-4001-GMN-0773 | (26.72)

The entire main is comprised of DN150 VC pipe apart from a 2m section that has been replaced in PVC at a private junction with two horizontal bends. The main is in good condition with no defects or ponding identified. The main was installed in 1964 (55 years of age). There are three private junctions and an inspection point on this main. Refer to the below figures and Table 86 for a summary of findings.

Figure 443 | Junction, Chg 11.99m

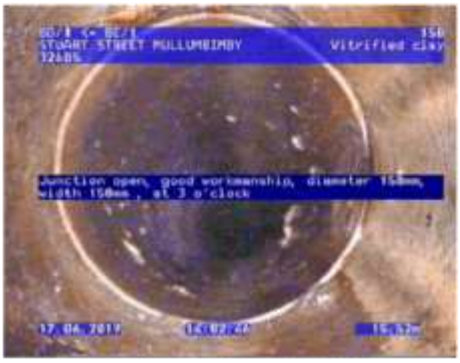

Figure 444 | Junction, Chg 15.52m

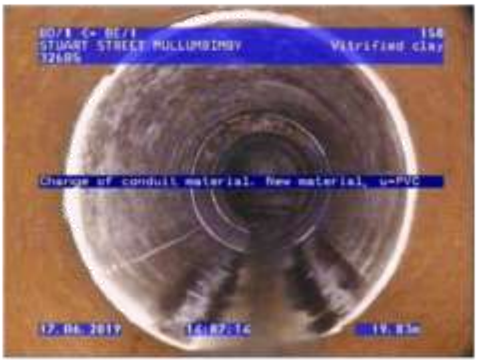

Figure 445 | Change of material, Chg 19.83m

Figure 446 | Inspection point, Chg 20.29m

Figure 447 | Change of material, Chg 22.04m

Figure 448 | Junction, Chg 25.46m

Table 86 | Line BE01 – BD01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 26.72	-	Main	DN150 VC pipe
11.99	443	Junction	Private junction open in good condition at 9 O'clock
15.52	444	Junction	Private junction open in good condition at 3 O'clock
19.83	445	Material change	Change of pipe material from VC to PVC
20.29	446	Inspection point	Inspection point open in good condition at 12 O'clock
22.04	447	Material change	Change of pipe material from PVC to VC
25.46	448	Junction	Private junction open in good condition at 3 O'clock

2.87 Stuart Street | Line DE – BE01 | S-4001-GMN-0775 | (9.42)

The entire main is comprised of DN150 VC pipe. The main is in good condition with no defects or ponding identified. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 87 for a summary of findings.

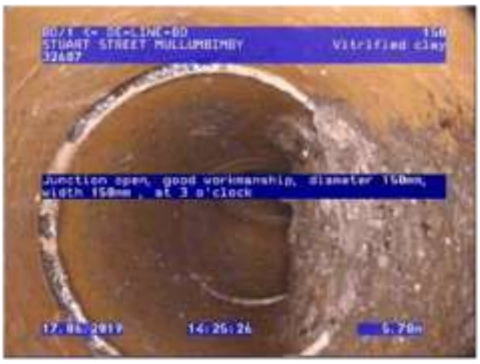

Figure 449 | Junction, Chg 5.78m

Figure 450 | Junction, Chg 9.31m

Figure 451 | End of line, Chg 9.42m

Table 87 | Line DE – BE01

Chainage (m)	Figure	Item	Observation
0 – 9.42	-	Main	DN150 VC pipe
5.78	449	Junction	Private junction open in good condition at 3 O'clock, partial obstruction 15%
9.31	450	Junction	Private junction open in good condition at 3 O'clock, partial obstruction 15%
9.42	451	End of line	Dead end cap

2.88 Dalley Street | Line DE – BD01 | S-4001-GMN-0774 | (30.27)

The entire main is comprised of DN150 VC pipe. The main is in good condition with only a single location subject to breaking and minor ponding to a depth of 15% identified. The main was installed in 1964 (55 years of age). There are five private junctions on this main. Refer to the below figures and Table 88 for a summary of findings.

Figure 452 | Junction, Chg 3.43m

Figure 453 | Junction, Chg 8.29m

Figure 454 | Junction, Chg 14.95m

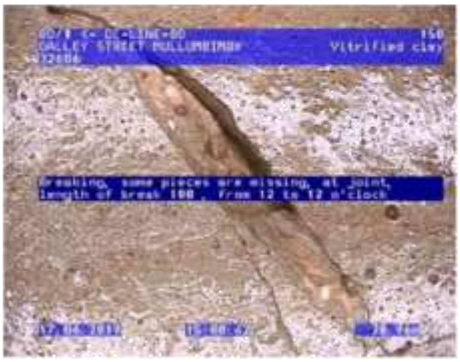

Figure 455 | Breaking, Chg 20.96m

Figure 456 | Junction, Chg 23.98m

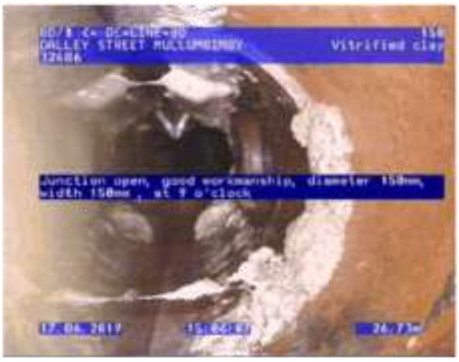

Figure 457 | Junction, Chg 26.73m

Figure 458 | End of line, Chg 30.27m

Table 88 | Line DE – BD01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 30.27	-	Main	DN150 VC pipe
3.43	452	Junction	Private junction open in good condition at 9 O'clock
8.29	453	Junction	Private junction open in good condition at 9 O'clock
14.95	454	Junction	Private junction open in good condition at 9 O'clock
20.96	455	Defect	Pipe break 100mm in length at 12 O'clock
23.98	456	Junction	Private junction open in good condition at 3 O'clock
26.73	457	Junction	Private junction open in good condition at 3 O'clock, partial obstruction 10%
30.27	458	End of line	Dead end cap

2.89 Studal Lane | Line BD02 – BD01 | S-4001-GMN-0771 | (50.97)

The entire main is comprised of DN150 VC pipe. The main is in reasonable condition with only a few locations subject to minor cracking, no ponding or other defects were identified. The main was installed in 1964 (55 years of age). There are six private junctions on this main. Refer to the below figures and Table 89 for a summary of findings.

Figure 459 | Junction, Chg 6.83m

Figure 460 | Cracking, Chg 15.73m

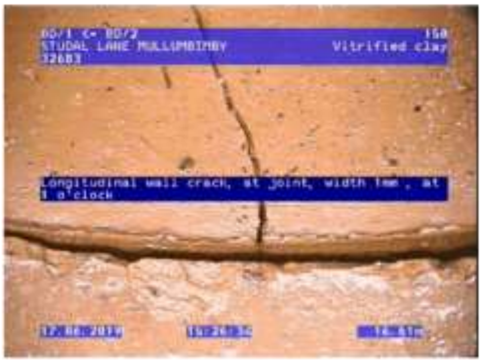

Figure 461 | Cracking, Chg 16.61m

Figure 462 | Junction, Chg 18.48m

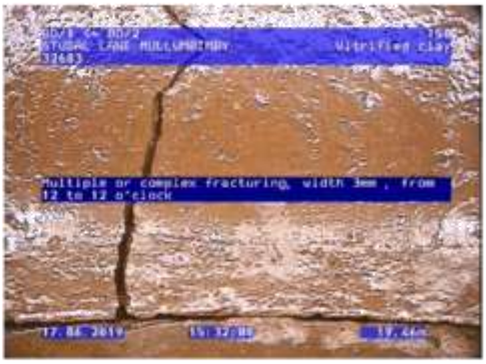

Figure 463 | Cracking, Chg 19.46m

Figure 464 | Junction, Chg 22.17m

Figure 465 | Junction, Chg 28.79m

Figure 466 | Junction, Chg 34.08m

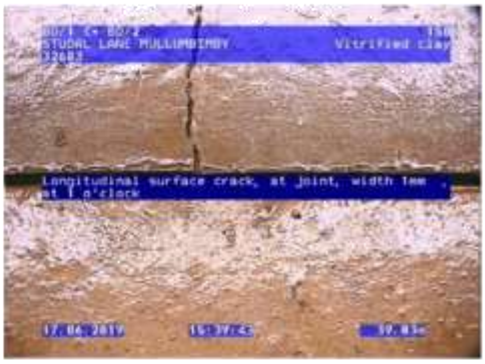

Figure 467 | Cracking, Chg 39.03m

Figure 468 | Junction, Chg 40.14m

Table 89 | Line BD02 – BD01

Chainage (m)	Figure	Item	Observation
0 – 50.97	-	Main	DN150 VC pipe
6.83	459	Junction	Private junction open in good condition at 9 O'clock
15.73	460	Defect	Longitudinal cracking 1mm wide at 8 O'clock
16.61	461	Defect	Longitudinal cracking 1mm wide at 1 O'clock
18.48	462	Junction	Private junction open in good condition at 9 O'clock, partial obstruction 10%
19.46	463	Defect	Multiple cracking 3mm wide from 12-12 O'clock
22.17	464	Junction	Private junction open in good condition at 3 O'clock
28.79	465	Junction	Private junction open in good condition at 9 O'clock
34.08	466	Junction	Private junction open in good condition at 3 O'clock
39.03	467	Defect	Longitudinal cracking 1mm wide at 1 O'clock
40.14	468	Junction	Private junction open in good condition at 3 O'clock

2.90 Studal Lane | Line BD03 – BD02 | S-4001-GMN-0762 | (49.16)

The entire main is comprised of DN150 VC pipe. The main is in reasonable condition with only a few locations subject to cracking, no ponding or other defects were identified. The main was installed in 1964 (55 years of age). There are six private junctions on this main. Refer to the below figures and Table 90 for a summary of findings.

Figure 469 | Junction, Chg 1.39m

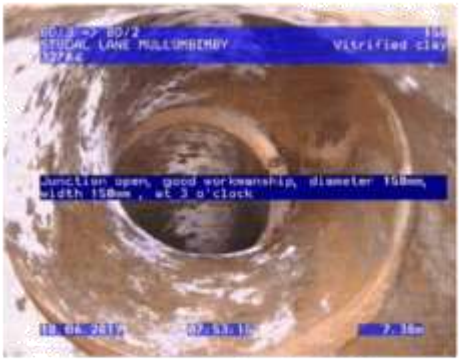

Figure 470 | Junction, Chg 7.38m

Figure 471 | Cracking, Chg 13.19m

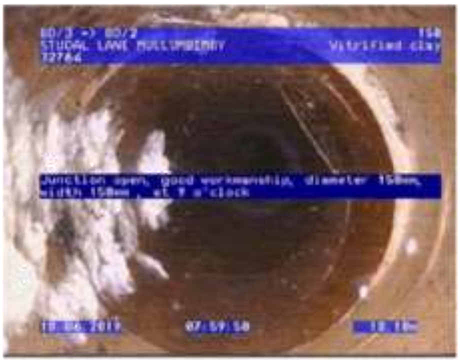

Figure 472 | Junction, Chg 18.10m

Figure 473 | Cracking, Chg 20.74m

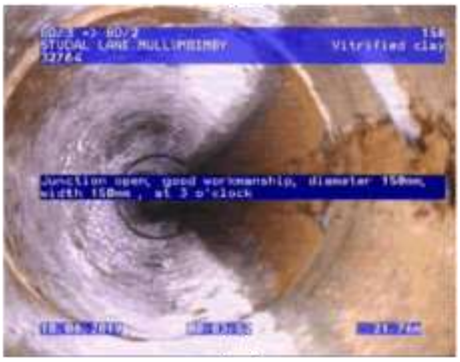

Figure 474 | Junction, Chg 21.76m

Figure 475 | Junction, Chg 27.81m

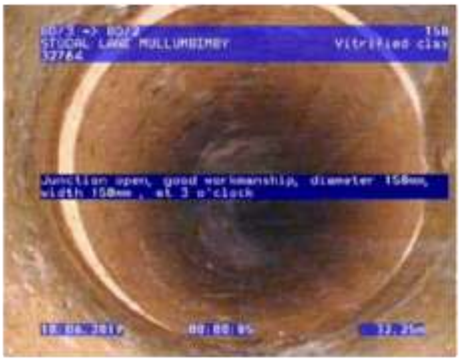

Figure 476 | Junction, Chg 32.25m

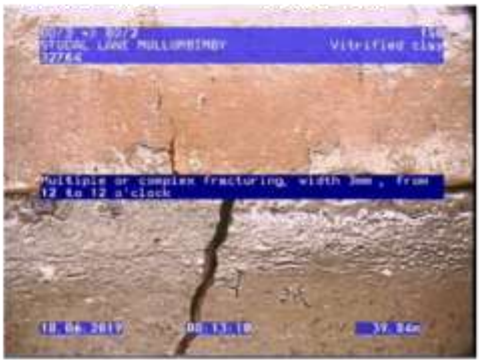

Figure 477 | Cracking, Chg 39.84m

Table 90 | Line BD03 – BD02

Chainage (m)	Figure	Item	Observation
0 – 49.16	-	Main	DN150 VC pipe
1.39	469	Junction	Private junction open in good condition at 9 O'clock
7.38	470	Junction	Private junction open in good condition at 3 O'clock
13.19	471	Defect	Multiple cracking 1mm wide at joint from 12-12 O'clock
18.10	472	Junction	Private junction open in good condition at 9 O'clock, partial obstruction 10%
20.74	473	Defect	Multiple cracking 1mm wide at 8 O'clock
21.76	474	Junction	Private junction open in good condition at 3 O'clock
27.81	475	Junction	Private junction open in good condition at 9 O'clock
32.25	476	Junction	Private junction open in good condition at 3 O'clock
39.84	477	Defect	Multiple cracking 3mm wide at joint from 12-12 O'clock

2.91 Riley Lane | Line A16 – A15 | S-4001-GMN-0763 | (82.72)

The entire main is comprised of DN150 VC pipe apart from two short (~1m) section that have been replaced with PVC junction tees. The main is in reasonable condition with only a few locations subject to cracking, minor radial displacement, and patch liners, no ponding or other defects were identified. The main was installed in 1964 (55 years of age). There are ten private junctions on this main. Refer to the below figures and Table 91 for a summary of findings.

Figure 478 | Junction, Chg 14.62m

Figure 479 | Junction, Chg 15.70m

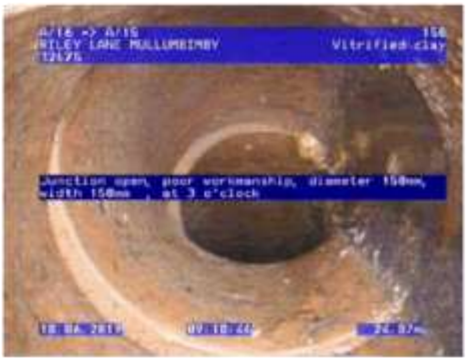

Figure 480 | Junction, Chg 24.87m

Figure 481 | Junction, Chg 32.12m

Figure 482 | Patch liner, Chg 37.22m

Figure 483 | Junction, Chg 38.27m

Figure 484 | Junction, Chg 41.78m

Figure 485 | Junction, Chg 53.55m

Figure 486 | Displacement, Chg 54.36m

Figure 487 | Junction, Chg 54.76m

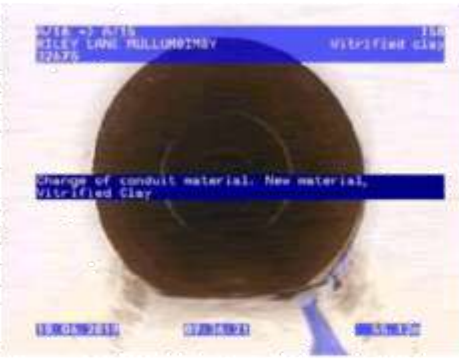

Figure 488 | Change of material, Chg 55.12m

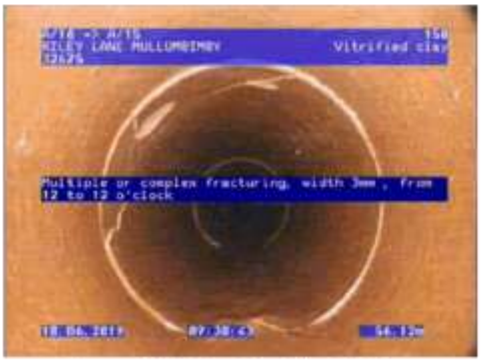

Figure 489 | Cracking, Chg 56.12m

Figure 490 | Change of material, Chg 70.51m

Figure 491 | Junction, Chg 70.97m

Figure 492 | Change of material, Chg 71.29m

Figure 493 | Junction, Chg 79.26m

Table 91 | Line A16 – A15

Chainage (m)	Figure	Item	Observation
0 – 82.72	-	Main	DN150 VC pipe
14.62	478	Junction	Private junction open in good condition at 9 O'clock
15.70	479	Junction	Private junction open in good condition at 3 O'clock
24.87	480	Junction	Private junction open in good condition at 3 O'clock
32.12	481	Junction	Private junction open in good condition at 9 O'clock
37.22	482	Patch liner	Patch liner indicating poor condition of pipe
38.27	483	Junction	Private junction open in good condition at 3 O'clock, partial obstruction 10%
41.78	484	Junction	Private junction open in good condition at 9 O'clock
53.55	485	Junction	Private junction open in good condition at 9 O'clock
54.36	486	Change of material	Change of pipe material from VC to PVC and radial displacement of 5-10mm at 6 O'clock
54.76	487	Junction	Private junction open in good condition at 3 O'clock

55.12	488	Change of material	Change of pipe material from PVC to VC
56.12	489	Defect	Multiple cracking 3mm wide at joint from 12-12 O'clock
70.51	490	Change of material	Change of pipe material from VC to PVC and radial displacement of 5-10mm at 6 O'clock
70.97	491	Junction	Private junction open in good condition at 9 O'clock
71.29	492	Change of material	Change of pipe material from PVC to VC
79.26	493	Junction	Private junction open in good condition at 9 O'clock

2.92 Tincogan Street | Line DE – A16 | S-4001-GMN-0744 | (25.12)

The entire main is comprised of DN150 VC pipe. The main is in reasonable condition with only two locations subject to cracking, no ponding or other defects were identified. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 92 for a summary of findings.

Figure 494 | Cracking, Chg 1.12m

Figure 495 | Junction, Chg 12.06m

Figure 496 | Cracking, Chg 22.24m

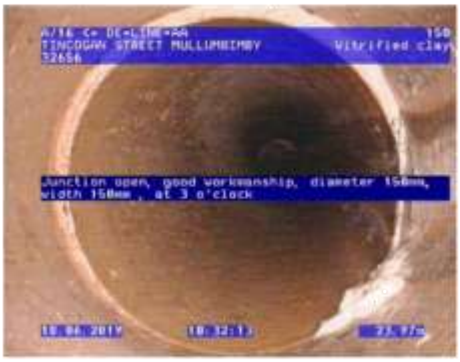

Figure 497 | Junction, Chg 23.97m

Table 92 | Line DE – A16

Chainage (m)	Figure	Item	Observation
0 – 25.12	-	Main	DN150 VC pipe
1.12	494	Defect	Circumferential cracking of pipe wall 3mm wide from 12-12 O'clock
12.06	495	Junction	Private junction open in good condition at 9 O'clock
22.24	496	Defect	Multiple cracking 4mm wide at joint from 12-12 O'clock
23.97	497	Junction	Private junction open in good condition at 3 O'clock

2.93 Brunswick Terrace | Line UNV – A16 | S-4001-GMN-4683 | (32.12)

The entire main is comprised of DN150 VC pipe. The main is in good condition with no defects identified and only a single private junction tee being replaced with PVC. No ponding was identified on this main. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 93 for a summary of findings.

Figure 498 | Junction, Chg 14.35m

Figure 499 | Change of material, Chg 23.29m

Figure 500 | Junction, Chg 23.80m

Figure 501 | Change of material, Chg 24.30m

Table 93 | Line UNV – A16

Chainage (m)	Figure	Item	Observation
0 – 32.12	-	Main	DN150 VC pipe
14.35	498	Junction	Private junction open in good condition at 3 O'clock
23.29	499	Change of material	Change of pipe material from VC to PVC
23.80	500	Junction	Private junction open in good condition at 3 O'clock
24.30	501	Change of material	Change of pipe material from PVC to VC

2.94 Brunswick Terrace | Line CN01 – A15 | S-4001-GMN-0764 | (62.23)

The entire main is comprised of DN150 VC pipe. The main is in good condition with only a minor joint displacement and a short section (~1m) that has been replaced with PVC. Minor Ponding to a depth of 15% was identified on this main. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 94 for a summary of findings.

Figure 502 | Change of material, Chg 21.83m

Figure 503 | Change of material, Chg 22.49m

Figure 504 | Junction, Chg 44.62m

Table 94 | Line CN01 – A15			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 62.23	-	Main	DN150 VC pipe
21.83	502	Change of material	Change of pipe material from VC to PVC
22.49	503	Change of material	Change of pipe material from PVC to VC with radial displacement of 5-10mm at 6 O'clock
44.62	504	Junction	Private junction open in good condition at 9 O'clock

2.95 Mcgoughans Lane | Line BB03 – BB02 | S-4001-GMN-0779 | (77.73)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects identified including cracking, infiltration, encrustation, and patch liner repairs. No Ponding was identified on this main. The main was installed in 1964 (55 years of age). There are nine private junctions on this main. Refer to the below figures and Table 95 for a summary of findings.

Figure 505 | Cracking, Chg 0.25m

Figure 506 | Cracking, Chg 1.09m

Figure 507 | Junction, Chg 1.32m

Figure 508 | Junction, Chg 8.36m

Figure 509 | Junction, Chg 16.37m

Figure 510 | Cracking, Chg 20.00m

Figure 511 | Junction, Chg 23.52m

Figure 512 | Junction, Chg 28.21m

Figure 513 | Patch liner, Chg 39.96m

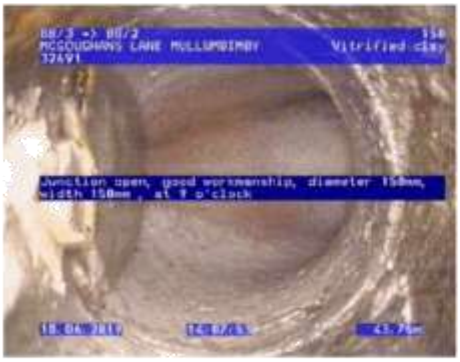

Figure 514 | Junction, Chg 43.75m

Figure 515 | Junction, Chg 45.19m

Figure 516 | Patch liner, Chg 48.74m

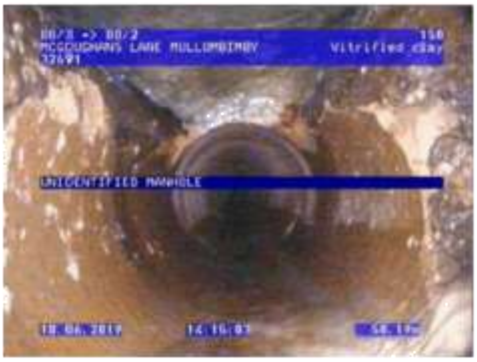

Figure 517 | Buried MH, Chg 50.19m

Figure 518 | Patch liner, Chg 52.04m

Figure 519 | Junction, Chg 62.27m

Figure 520 | Patch liner, Chg 63.86m

Figure 521 | Patch liner, Chg 65.17m

Figure 522 | Infiltration, Chg 71.41m

Figure 523 | Patch liner, Chg 72.13m

Table 95 | Line BB03 – BB02

Chainage (m)	Figure	Item	Observation
0 – 77.73	-	Main	DN150 VC pipe
0.25	505	Defect	Circumferential cracking 3mm wide from 12-12 O'clock
1.09	506	Defect	Cracking at joint 3mm wide from 3-6 O'clock
1.32	507	Junction	Private junction open in good condition at 3 O'clock
8.36	508	Junction	Private junction open in good condition at 3 O'clock longitudinal joint displacement >20mm
16.37	509	Junction	Private junction open in good condition at 3 O'clock
20.00	510	Defect	Longitudinal crack 1mm wide at 4 O'clock
23.52	511	Junction	Private junction open in good condition at 9 O'clock
28.21	512	Junction	Private junction open in good condition at 3 O'clock
39.96	513	Patch liner	Patch liner indicating poor pipe condition and infiltration from 12-12 O'clock
43.75	514	Junction	Private junction open in good condition at 9 O'clock
45.19	515	Junction	Private junction open in good condition at 3 O'clock
48.74	516	Patch liner	Patch liner indicating poor pipe condition and infiltration from 12-12 O'clock
50.19	517	Buried MH	Buried maintenance hole structure
52.04	518	Patch liner	Patch liner indicating poor pipe condition and infiltration from 12-12 O'clock
62.27	519	Junction	Private junction open in good condition at 3 O'clock, partial obstruction 10%
63.86	520	Patch liner	Patch liner indicating poor pipe condition and infiltration from 12-12 O'clock
65.17	521	Patch liner	Patch liner indicating poor pipe condition and infiltration from 12-12 O'clock
71.41	522	Infiltration	Continuous infiltration through pipe joint
72.13	523	Patch liner	Patch liner indicating poor pipe condition

2.96 Whian Street | Line DE – N03 | S-4001-GMN-3907 | (21.07)

The entire main is comprised of DN150 VC pipe. The main is in good condition with no defects or ponding identified. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 96 for a summary of findings.

Figure 524 | Vertical drop, Chg 0.00m

Figure 525 | Junction, Chg 18.49m

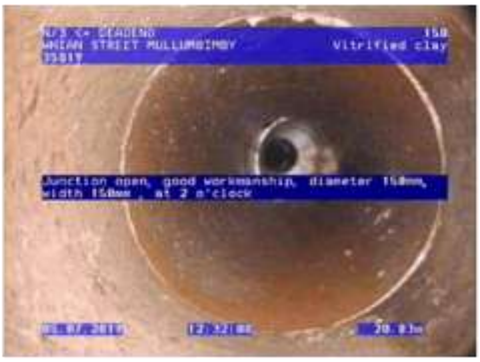

Figure 526 | Junction, Chg 20.83m

Table 96 | Line DE – N03			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 21.07	-	Main	DN150 VC pipe
0.00	524	Vertical drop	Vertical main
18.49	525	Junction	Private junction open in good condition at 2 O'clock
20.83	526	Junction	Private junction open in good condition at 2 O'clock

2.97 Stuart Street | Line D02 – E01 | S-4001-GMN-0975 | (30.93)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects identified including cracking and displacement. No Ponding was identified in this main. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 97 for a summary of findings.

Figure 527 | Displacement, Chg 0.87m

Figure 528 | Cracking, Chg 1.66m

Figure 529 | Cracking, Chg 8.60m

Figure 530 | Junction, Chg 18.92m

Figure 531 | Junction, Chg 19.69m

Figure 532 | Displacement, Chg 19.69m

Figure 533 | Junction, Chg 19.92m

Figure 534 | Breaking, Chg 25.16m

Figure 535 | Displacement, Chg 30.10m

Figure 536 | Cracking, Chg 30.74m

Table 97 | Line D02 – E01

Chainage (m)	Figure	Item	Observation
0 – 30.93	-	Main	DN150 VC pipe
0.87	527	Defect	Longitudinal joint displacement 10-20mm
1.66	528	Defect	Cracking 4mm wide from 10-3 O'clock
8.60	529	Defect	Cracking 1mm wide at 11 O'clock
18.92	530	Junction	Private junction closed in good condition at 3 O'clock
19.69	531	Junction	Private junction open in good condition at 9 O'clock
19.69	532	Defect	Longitudinal joint displacement 10-20mm
19.92	533	Junction	Private junction open in good condition at 3 O'clock
25.16	534	Defect	Breaking of pipe wall 100m length from 6-7 O'clock
30.10	535	Defect	Longitudinal joint displacement 10-20mm
30.74	536	Defect	Circumferential cracking 3mm wide from 12-12 O'clock

2.98 Stuart Street | Line G01 – E01 | S-4001-GMN-0971 | (21.39)

The main is reportedly ~21m in length, however only 3.67m was assessed due to an obstruction from root intrusion that was unable to be cleared as the upstream MH was buried. The assessed portion of the main is comprised of DN150 VC pipe and is in poor condition with cracking and heavy root intrusion identified. The main was installed in 1964 (55 years of age). There are no private junctions on the portion of the main that was assessed. Refer to the below figures and Table 98 for a summary of findings.

Figure 537 | Cracking, Chg 0.78m

Figure 538 | Root intrusion, Chg 0.78m

Figure 539 | Root intrusion, Chg 3.67m

Table 98 | Line G01 – E01			
Chainage (m)	Figure	Item	Observation
0 – 21.39	-	Main	DN150 VC pipe
0.78	537	Defect	Circumferential cracking at joint 3mm wide from 4-8 O'clock
0.78	538	Roots	Root intrusion with obstruction between 5-20% from 3-9 O'clock
3.67	539	Roots	Root intrusion with obstruction >75% from 1-11 O'clock

2.99 Stuart Street | Line E02 – E01 | S-4001-GMN-1722 | (47.99)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects identified including cracking, displacement, and infiltration. No Ponding was identified in this main. The main was installed in 1964 (55 years of age). There are no private junctions on this main. Refer to the below figures and Table 99 for a summary of findings.

Figure 540 | Heavy infiltration, Chg 0.00m

Figure 541 | Displacement, Chg 0.00m

Figure 542 | Displacement, Chg 1.26m

Figure 543 | Displacement, Chg 5.29m

Figure 544 | Displacement, Chg 8.17m

Figure 545 | Encrustation, Chg 9.13m

Figure 546 | Displacement, Chg 10.11m

Figure 547 | Displacement, Chg 21.82m

Figure 548 | Encrustation, Chg 33.26m

Table 99 | Line E02 – E01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 47.99	-	Main	DN150 VC pipe
0.00	540	Heavy infiltration	Infiltration gushing through pipe joint at 4 O'clock
0.00	541	Displacement	Longitudinal joint displacement between 20-30mm
1.26	542	Displacement	Radial joint displacement between 10-20mm at 4 O'clock
5.29	543	Displacement	Radial joint displacement between 5-10mm at 8 O'clock
8.17	543	Displacement	Longitudinal joint displacement between 10-20mm
9.13	545	Encrustation	Encrustation obstruction of <5% from 7-11 O'clock with infiltration
10.11	546	Displacement	Longitudinal joint displacement between 10-20mm
21.82	547	Displacement	Longitudinal joint displacement between 10-20mm
33.26	548	Encrustation	Encrustation obstruction of <5% from 7-12 O'clock with infiltration

2.100 Fern Street | Line B01 – A03 | S-4001-GMN-0935 | (72.44)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects identified including cracking, displacement, infiltration, and ponding. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 100 for a summary of findings.

Figure 549 | Junction, Chg 2.34m

Figure 550 | Junction, Chg 29.51m

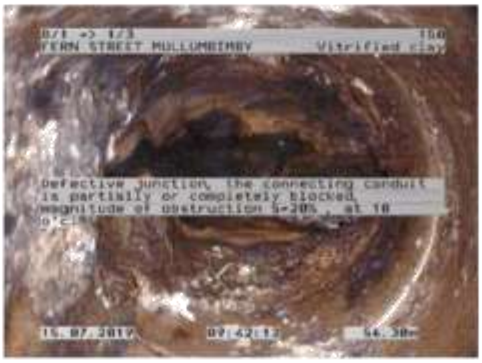

Figure 551 | Junction, Chg 56.30m

Figure 552 | Displacement, Chg 70.81m

Figure 553 | Various defects, Chg 71.74m

Figure 554 | Heavy infiltration, Chg 72.23m

Table 100 | Line B01 – A03			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 72.44	-	Main	DN150 VC pipe
2.34	549	Junction	Private junction open in good condition at 10 O'clock
29.51	550	Junction	Private junction open in good condition at 10 O'clock
56.30	551	Junction	Private junction open in good condition at 10 O'clock, partially obstructed <40%
70.81	552	Displacement	Radial joint displacement between 5-10mm at 10 O'clock
71.74	553	Various defects	Encrustation obstruction of <5% from 3-10 O'clock with deleterious material beneath the flow at the invert of the pipe
72.23	554	Heavy infiltration	Infiltration gushing through pipe joint at 6 O'clock

2.101 McGoughans Lane | Line A04 – A03 | S-4001-GMN-0932 | (68.44)

The entire main is comprised of DN225 AC pipe. The main is in reasonable condition with only isolated breaking identified however the pipe walls are visibly roughened throughout due to corrosion. The entire main is subject to ponding up to a depth of 50%. The main was installed in 1964 (55 years of age). There are four private junctions on this main. Refer to the below figures and Table 101 for a summary of findings.

Figure 555 | Roughened wall, Chg 0.00m

Figure 556 | Breaking wall, Chg 0.33m

Figure 557 | Junction, Chg 5.72m

Figure 558 | Junction, Chg 25.26m

Figure 559 | Junction, Chg 36.34m

Figure 560 | Junction, Chg 55.19m

Table 101 | Line A04 – A03

Chainage (m)	Figure	Item	Observation
0 – 68.44	-	Main	DN225 AC pipe
0.00	555	Roughened wall	Internal pipe wall is visibly roughened due to corrosion
0.33	556	Breaking	Pipe wall is breaking/spalling due to corrosion
5.72	557	Junction	Private junction open in good condition at 12 O'clock
25.26	558	Junction	Private junction open in good condition at 12 O'clock
36.34	559	Junction	Private junction open in good condition at 12 O'clock
55.19	560	Junction	Private junction open in good condition at 12 O'clock

2.102 McGoughans Lane | Line DE – A04 | S-4001-GMN-0902 | (26.72)

The entire main is comprised of DN150 VC pipe. The main is in good condition with no defects identified, however two private junctions have root intrusion. No Ponding was identified in this main. The main was installed in 1964 (55 years of age). There are three private junctions on this main. Refer to the below figures and Table 102 for a summary of findings.

Figure 561 | Junction, Chg 19.26m

Figure 562 | Junction, Chg 25.99m

Figure 563 | Junction, Chg 26.44m

Table 102 | Line DE – A04			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 26.72	-	Main	DN150 VC pipe
19.26	561	Junction	Private junction open in good condition at 10 O'clock, partial obstruction due to root intrusion 5-20%
25.99	562	Junction	Private junction open in good condition at 10 O'clock
26.44	563	Junction	Private junction open in good condition at 2 O'clock, partial obstruction due to root intrusion <5%

2.103 Fern Street | Line A03 – A02 | S-4001-GMN-0933 | (64.64)

The entire main is comprised of DN225 AC pipe. The main is in reasonable condition with only a few joints having minor displacements, however the pipe walls are visibly roughened throughout due to corrosion. The main is subject to ponding up to a depth of 60%. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 103 for a summary of findings.

Figure 564 | Roughened wall, Chg 0.19m

Figure 565 | Displacement, Chg 2.43m

Figure 566 | Deposits on wall, Chg 12.33m

Figure 567 | Junction, Chg 16.72m

Figure 568 | Displacement, Chg 37.08m

Figure 569 | Displacement, Chg 39.20m

Figure 570 | Junction, Chg 41.51m

Figure 571 | Displacement, Chg 41.88m

Figure 572 | Displacement, Chg 49.95m

Figure 573 | Ponding, Chg 49.95m

Table 103 | Line A03 – A02

Chainage (m)	Figure	Item	Observation
0 – 64.64	-	Main	DN225 AC pipe
0.19	564	Corrosion	Pipe wall has become roughened due to corrosion
2.43	565	Displacement	Longitudinal joint displacement between 10-20mm
12.33	566	Deposits	Build-up of deposits on pipe wall resulting in roughening and minor obstruction <5%
16.72	567	Junction	Private junction open in good condition at 12 O'clock
37.08	568	Displacement	Longitudinal joint displacement between 10-20mm
39.20	569	Displacement	Longitudinal joint displacement between 10-20mm
41.51	570	Junction	Private junction open in good condition at 12 O'clock
41.88	571	Displacement	Longitudinal joint displacement between 10-20mm
49.95	572	Displacement	Longitudinal joint displacement between 10-20mm
49.95	573	Ponding	Ponding of wastewater due to insufficient longitudinal grade

2.104 Fern Street | Line N01 – A02 | S-4001-GMN-0926 | (71.04)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects including cracking, joint displacement, encrustation, infiltration, patch liners, and ponding to a depth of 50%. The main was installed in 1964 (55 years of age). There are two private junctions on this main. Refer to the below figures and Table 104 for a summary of findings.

Figure 574 | Cracking, Chg 0.00m

Figure 575 | Displacement, Chg 0.00m

Figure 576 | Junction, Chg 5.45m

Figure 577 | Junction, Chg 24.27m

Figure 578 | Infiltration, Chg 26.48m

Figure 579 | Encrustation, Chg 37.02m

Figure 580 | Obstruction, Chg 43.75m

Figure 581 | Displacement, Chg 45.69m

Figure 582 | Infiltration, Chg 53.79m

Figure 583 | Patch liner, Chg 61.64m

Figure 584 | Ponding, Chg 67.37m

Figure 585 | Patch liner, Chg 69.78m

Figure 586 | Patch liner, Chg 70.94m

Figure 587 | Vertical drop, Chg 71.04m

Table 104 | Line N01 – A02

Chainage (m)	Figure	Item	Observation
0 – 71.04	-	Main	DN150 VC pipe
0.00	574	Defect	Cracking 2mm wide from 10-2 O'clock
0.00	575	Displacement	Radial joint displacement between 5-10mm at 3 O'clock
5.45	576	Junction	Private junction open in good condition at 2 O'clock
24.27	577	Junction	Private junction open in good condition at 2 O'clock
26.48	578	Infiltration	Infiltration through pipe joint from 2-4 O'clock
37.02	579	Encrustation	Encrustation obstruction of <5% from 3-5 O'clock
43.75	580	Obstruction	Obstruction of 5-20% due to piece of plastic being wedged in pipe joint from 6-8 O'clock
45.69	581	Displacement	Longitudinal joint displacement between 10-20mm
53.79	582	Infiltration	Infiltration through pipe joint from 12-12 O'clock
61.64	583	Patch liner	Patch liner indicating poor condition of pipe
67.63	584	Ponding	Ponding of wastewater due to insufficient longitudinal grade
69.78	585	Patch liner	Patch liner indicating poor condition of pipe
70.94	586	Patch liner	Patch liner indicating poor condition of pipe
71.04	587	Vertical drop	Vertical drop

2.105 Stuart Street | Line A02 – A01 | S-4001-GMN-0946 | (40.28)

The assessment was terminated at 4.70m due to an obstruction that could not be cleared due to third party works, the entire alignment is recorded as being 40.28m in length. Of the main that was assessed it is comprised of DN225 AC pipe. The main is in reasonable condition with only roughening of the pipe wall being identified due to corrosion. The main was installed in 1964 (55 years of age). There are no private junctions on the portion of this main that was assessed. Refer to the below figures and Table 105 for a summary of findings.

Figure 588 | Roughening, Chg 0.00m

Figure 589 | Obstruction, Chg 4.70m

Table 105 | Line A02 – A01

Chainage (m)	Figure	Item	Observation
0 – 40.28	-	Main	DN225 AC pipe
0.00	588	Roughening	Roughening of pipe wall due to corrosion
4.70	589	Obstruction	Assessment terminated due to obstruction which is resulting in ponding to a depth of 40%

2.106 Stuart Street | Line EAA01 – E02 | S-4001-GMN-1733 | (13.65)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects including cracking, joint displacement, Patch liner, infiltration, and ponding to a depth of 25%. The main was likely installed in 1964 (55 years of age) despite records showing a PVC main being installed in 2004. There is a single private junction on this main. Refer to the below figures and Table 106 for a summary of findings.

Figure 590 | Displacement, Chg 6.36m

Figure 591 | Cracking, Chg 9.04m

Figure 592 | Junction, Chg 12.88m

Figure 593 | Junction liner, Chg 12.88m

Figure 594 | Displacement, Chg 13.65m

Figure 595 | Vertical drop, Chg 13.65m

Table 106 | Line EAA01 – E02			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 13.65	-	Main	DN150 VC pipe
6.36	590	Displacement	Radial joint displacement of 5-10mm at 4 O'clock
9.04	591	Cracking	Circumferential cracking 2mm wide from 12-12 O'clock
12.88	592	Junction	Private junction closed in good condition at 10 O'clock
12.88	593	Junction liner	Junction liner indicating poor condition of junction tee
13.65	594	Displacement	Longitudinal joint displacement of 10-20mm allowing minor infiltration
13.65	595	Vertical drop	Vertical drop, cast iron pipe

2.107 Stuart Street | Line EAA02 – EAA01 | S-4001-GMN-1734 | (15.51)

The entire main is comprised of DN150 PVC pipe. The main is in good condition with the only defects identified being two joints either side of a junction tee having significant longitudinal displacement. The main was installed in 1999 (20 years of age). There are two private junctions on this main. Refer to the below figures and Table 107 for a summary of findings.

Figure 596 | Junction, Chg 0.18m

Figure 597 | Displacement, Chg 13.54m

Figure 598 | Junction, Chg 13.90m

Figure 599 | Displacement, Chg 14.21m

Table 107 | Line EAA02 – EAA01			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 15.51	-	Main	DN150 PVC pipe
0.18	596	Junction	Private junction open in good condition at 2 O'clock
13.54	597	Displacement	Longitudinal joint displacement >30mm
13.90	598	Junction	Private junction open in good condition at 2 O'clock
14.21	599	Displacement	Longitudinal joint displacement between 20-30mm

2.108 Stuart Street | Line EAA03 – EAA02 | S-4001-GMN-0991 | (5.85)

The entire main is comprised of DN150 PVC pipe. The main is in good condition with only a single joint having a minor radial displacement. The main was installed in 1999 (20 years of age). There are no private junctions on this main. Refer to the below figures and Table 108 for a summary of findings.

Figure 600 | Displacement, Chg 0.45m

Table 108 | Line EAA03 – EAA02

Chainage (m)	Figure	Item	Observation
0 – 5.85	-	Main	DN150 PVC pipe
0.45	600	Displacement	Radial displacement of 5-10mm at 2 O'clock

2.109 Myokum Street | Line E03 – E02 | S-4001-GMN-1723 | (78.66)

The entire main is comprised of DN150 VC pipe. The main is in poor condition with various defects including cracking, joint displacement, encrustation, infiltration, and ponding to a depth of 30%. The main was installed in 1964 (55 years of age). There is a single private junction on this main. Refer to the below figures and Table 109 for a summary of findings.

Figure 601 | Displacement, Chg 1.94m

Figure 602 | Displacement, Chg 1.94m

Figure 603 | Encrustation, Chg 3.90m

Figure 604 | Displacement, Chg 7.73m

Figure 605 | Pipe section missing, Chg 8.71m

Figure 606 | Obstruction, Chg 10.84m

Figure 607 | Junction, Chg 28.11m

Figure 608 | Displacement, Chg 48.54m

Figure 609 | Displacement, Chg 78.27m

Figure 610 | Displacement, Chg 78.27m

Table 109 | Line E03 – E02

Chainage (m)	Figure	Item	Observation
0 – 78.66	-	Main	DN150 VC pipe
1.94	601	Displacement	Longitudinal joint displacement between 20-30mm
1.94	602	Displacement	Radial joint displacement between 10-20mm at 8 O'clock
3.90	603	Encrustation	Encrustation obstruction of <5% from 4-8 O'clock
7.73	604	Displacement	Longitudinal joint displacement between 10-20mm
8.71	605	Pipe section missing	Pipe wall has broken away for a length of 200mm between 12-12 O'clock
10.84	606	Obstruction	Deleterious material (MH liner) is obstructing flow 20-50%
28.11	607	Junction	Private junction open in good condition at 12 O'clock, partial obstruction of 5-10% due to material build-up
48.54	608	Displacement	Longitudinal joint displacement between 10-20mm
78.27	609	Displacement	Longitudinal joint displacement between 10-20mm
78.27	610	Displacement	Radial joint displacement between 10-20mm at 6 O'clock

3. SUMMARY OF FINDINGS

Table 110 | Summary Table

PIPE INFORMATION									INSPECTION		JUNCTION				MAIN						
#	Pipe section	Asset ID (S-4001-GMN-XXXX)	Street Name	Mat	Dia. (mm)	Year Const.	Pipe Age (yrs)	Length (m)	Cleaning Complete (Y/N)	CCTV Complete (Y/N-m)	Total # of Junctions	Minor Defects (Cracking, Displacement)	Moderate Defects (Cracking, Displacement)	Major Defects (Cracking, Displacement)	Root Intrusion Score (1-5)	Ponding (%)	Infiltration Score (1-5)	Patch liners/repairs (#)	Minor Defects (Cracking, Displacement) (#)	Moderate Defects (Cracking, Displacement) (#)	Major Defects (Cracking, Displacement) (#)
1	EA04-EA05	1115	Azalea St	VC	150	1982	37	35.89	Y	N-7m patch liner restricting dia.	-	-	-	-	4	5%	-	3	2	6	-
2	EA03-EAO4	0405	Azalea St	VC	150	1982	37	87.7	Y	Y	-	-	-	-	2	10%	-	1	2	6	-
3	EA02-EA03	1130	Azalea St	VC	150	1982	37	63.23	Y	Y	-	-	-	-	3	5%	-	-	3	1	-
4	EA01-EA02	1134	Azalea St	VC	150	1982	37	63.28	Y	Y	-	-	-	-	2	5%	-	-	2	2	-
5	EA01-EA01/End	4919	West Bank Road	VC	150	1982	37	30.10	Y	Y	-	-	-	-	-	5%	-	-	-	-	-
6	E18-EA01	1133	Azalea Street	VC	150	1982	37	53.95	Y	Y	3 (all closed)	-	-	-	4	50%	-	-	1	-	1
7	E14-E16	1131	Jubilee Avenue	VC	150	1964	55	55.62	Y	Y	-	-	-	-	-	25%	-	-	3	-	-
8	E13-E14	1129	Jubilee Avenue	VC	150	1964	55	57.59	Y	N-12m patch liner restricting dia.	-	-	-	-	-	15%	-	2	3	1	-
9	E17-E18	1132	Azalea Street	VC/CI	150	1964	55	36.21	Y	Y	-	-	-	-	2	25%	-	-	2	4	-
10	K01 -E08	1720	Byron Street	VC	150	1964	55	4.02	Y	Y	-	-	-	-	-	-	-	-	-	-	-
11	K01-K02	1717	Jubilee Avenue	VC	150	1964	55	25.34	Y	Y	-	-	-	-	4	5%	-	-	-	4	-
12	E08-E09	1105	Byron Street	V	150	1964	55	46	Y	Y	1	-	-	-	-	30%	2	-	3	-	-
13	E09-E10	0393	Byron Street	VC	150	1964	55	45.98	Y	Y	1	-	-	1	3	20%	-	2	-	3	1
14	K02-K03	0987	Jubilee Avenue	VC	150	1964	55	58.01	Y	Y	-	-	-	-	1	-	-	-	2	-	-
15	E10-L01	0406	Byron Street	VC	150	1964	55	26.98	Y	Y	-	-	-	-	1	-	-	1	1	1	-
16	L01-DE	0409	Byron Street	VC	150	1964	55	27.74	Y	Y	1	-	-	-	1	-	-	-	1	-	-
17	E10-E11	0394	Byron Street	VC	150	1964	55	42.82	Y	Y	1	-	-	-	-	20%	2	-	1	-	-
18	E07-E08	1729	Byron Street	VC	150	1964	55	21.00	Y	N-14m patch liner restricting dia.	-	-	-	-	-	15%	-	1	-	2	-
19	E06-E07	1739	Byron Street	VC	150	1964	55	64.28	Y	Y	2	-	-	-	-	40%	-	-	1	-	-
20	J01-J02	1116	Small Lane	VC	150	1964	55	30.11	Y	Y	2	-	-	-	3	-	-	1	4	-	-
21	E06-J01	1106	Small Lane	VC	150	1964	55	27.52	Y	Y	-	-	-	-	-	-	-	2	1	-	-
22	E05-E06	1738	Small Lane	VC	150	1964	55	43.91	N-Still rubble in line after 3 passes	Y	-	-	-	-	-	50%	-	-	2	-	1
23	E05-DE	0977	Myokum Street	VC	150	1964	55	8.97	Y	Y	1	-	-	-	-	-	-	1	-	-	-
24	E04-E05	0989	Myokum Street	VC	150	1964	55	64.48	Y	Y	1	-	-	-	-	30%	1	-	5	-	-

Mullumbimby – 4001 Gravity Sewer Condition Assessment

Willow+ Sparrow

25	E03-E04	1715	Myokum Street	VC	150	1964	55	63.97	Y	Y	1-Closed	-	-	-	-	60%	5	-	2	-	2
26	N04-N05	0861	Whian Street	VC	150	1964	55	54.95	Y	Y	-	-	-	-	3	-	1	-	3	-	-
27	N05-N06	0858	Whian Street	VC	150	1964	55	47.09	Y	Y	2	-	-	-	4	-	-	-	-	2	-
28	N06-T01	0855	Whian Street	VC	150	1964	55	36.19	Y	Y	1	-	-	-	-	-	1	-	2	-	-
29	N06-S01	0881	Jubilee Avenue	VC	150	1964	55	52.64	Y	Y	3	-	-	-	-	15%	-	-	2	2	-
30	UNV-S01	4091	Jubilee Avenue	VC	150	1964	55	4.53	Y	Y	-	-	-	-	-	-	-	1	1	1	-
31	DE-UNV	4092	Jubilee Avenue	PVC	150	2004	15	13.93	Y	Y	2	-	-	-	-	-	-	-	-	-	-
32	N06-NO7	4210	Whian Street	VC	150	1964	55	56.28	Y	Y	-	-	-	-	4	-	-	-	3	5	-
33	B01-B02	0942	Station Street	VC	150	1982	37	27.8	Y	Y	-	-	-	-	-	-	-	-	-	-	-
34	B01-BC01	5147	Station Street	PVC	150	2017	2	61.31	Y	Y	1	-	-	-	-	-	-	-	-	-	-
35	UNV-B02	3910	Fern Street	VC/PVC	150	1982	37	23.47	Y	Y	1	-	-	-	-	-	-	-	-	-	-
36	B02-B03	3806	Station Street	V	150	1982	37	77.87	Y	Y	5	1	-	-	-	-	-	-	2	1	-
37	B03-DEA	1718	Station Street	VC	150	1982	37	23.73	Y	Y	3	-	-	2	1	-	-	-	-	1	2
38	SPS4010-GB01	1111	Station Street	VC	150	1986	33	4.39	Y	Y	-	-	-	-	-	-	-	-	-	-	-
39	GB01-DE	0395	Station Street	PVC	150	1986	33	45.93	Y	Y	5	-	-	-	-	-	-	-	-	-	1
40	GB01-GC01	1112	Station Street	PVC	150	1996	23	32.74	Y	Y	-	-	-	-	-	-	-	-	-	-	-
41	GC01-GC02	1109	Station Street	PVC	150	1996	23	80.78	Y	Y	16	-	-	-	-	-	-	-	-	-	-
42	GC02-GC03	5033	Station Street	PVC	150	2016	3	19.93	Y	Y	3	-	-	-	-	-	-	-	-	-	-
43	GC03-DE	5034	Station Street	PVC	150	2016	3	13.1	Y	Y	2	-	-	-	-	-	-	-	-	-	-
44	N07-U01	4195	Dalley Street	VC	150	1964	55	38.49	Y	Y	2	-	-	-	-	-	-	-	2	2	-
45	N07-NO8	4189	River Terrace	VC	150	1964	55	58.9	Y	Y	3	-	-	1	4	-	-	-	2	4	2
46	N03-NO4	0865	Whian Street	VC	150	1964	55	42.92	Y	N-4m Obstruction beneath ponding flow	1	-	-	-	-	20%	1	-	6	2	-
47	N01-P01	0920	Fern Street	VC	150	1964	55	69.05	Y	Y	3	-	-	-	1	-	-	-	4	-	-
48	DE-P01	0717	Fern Street	VC	150	1964	55	5.91	Y	Y	1	-	-	-	-	-	-	-	-	-	-
49	E17-E16	3926	Azalea Street	VC	150	1964	55	62.73	Y	Y	1	-	1	-	-	-	-	2	1	2	1
50	E11-E12	1121	Jubilee Avenue	VC	150	1964	55	55.68	Y	Y	2	-	-	1	-	-	2	-	1	1	1
51	E12-E13	1122	Jubilee Avenue	VC	150	1964	55	83.11	Y	Y	-	-	-	-	2	-	4	-	3	1	-
52	A10-W01	0821	Studal Lane	VC	150	1964	55	39.55	Y	Y	2	-	1	-	-	-	-	2	4	3	-
53	W01-W02	0838	Studal Lane	VC	150	1964	55	53.17	Y	Y	7	-	2	-	-	-	-	-	2	3	-
54	W01-X01	0822	Stuart Street	VC	150	1964	55	26.69	Y	Y	3	-	-	-	-	-	-	-	-	-	-
55	A07-A08	0827	Burringbar Street	VC	150	1964	55	48.8	Y	Y	1	-	-	-	-	-	-	-	2	-	-
56	A07-BK01	0828	Stuart Street	VC	150	1964	55	42.41	Y	Y	4	-	1	-	2	-	-	-	1	1	-
57	A07-V01	0831	Bridgland Street	VC	150	1964	55	75.44	Y	Y	6	-	2	-	-	-	-	-	3	1	-
58	V01-V02	0844	Station Street	VC	150	1964	55	32.93	Y	Y	1	-	-	-	-	-	-	-	1	-	-
59	A06-A07	4185	McGoughans Lane	VC	150	1964	55	79.11	Y	Y	7	-	-	-	-	-	-	2	3	-	-

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60	A05-A06	0859	McGoughans Lane	VC	150	1964	55	71.00	Y	N-42m patch liner restricting dia.	2	-	-	-	-	-	2	2	5	-	-
61	AS1-A05	4213	McGoughans Lane	PVC	150	2016	3	3.03	Y	N-? Bend in pipe limiting inspection	-	-	-	-	-	-	-	-	-	-	-
62	AS02-AS01	4212	McGoughans Lane	PVC	150	2016	3	8.25	Y	Y	-	-	-	-	-	-	-	-	-	-	-
63	AS03-AS02	4211	McGoughans Lane	PVC	150	2016	3	25.65	Y	Y	2	-	-	-	-	-	-	-	-	-	-
64	A04-A05	0897	McGoughans Lane	AC	225	1964	55	79.22	Y	N-43.6 high flow level due to SPS works	2	-	-	-	-	-	-	-	1	-	-
65	N03-N02	0892	Studal Lane	VC	150	1964	55	60.51	Y	Y	4	-	-	-	-	-	5	-	-	-	1
66	N02-N01	0919	Studal Lane	VC	150	1964	55	58.7	Y	Y	3	-	-	-	-	-	-	-	1	-	-
67	R01-N03	0864	Studal Lane	VC	150	1964	55	77.27	Y	Y	5	-	-	-	-	1	-	1	5	-	-
68	R02-R01	4186	Studal Lane	VC	150	1964	55	39.24	Y	Y	6	-	-	1	-	-	-	-	1	1	1
69	BB02-BB03	0779	McGoughans Lane	VC	150	1964	55	26.23	Y	Y	3	-	-	-	-	-	5	3	1	5	-
70	BB01-BB02	0808	Burringbar Street	VC	150	1964	55	53.62	Y	N-7m patch liner restricting dia.	2	-	-	-	-	-	2	8	7	1	2
71	BB03-BB04	0757	McGoughans Lane	VC	150	1964	55	82.79	Y	Y	13	-	1	-	2	-	-	2	4	2	-
72	A08-BB01	0816	Burringbar Street	VC	150	1964	55	13.67	Y	Y	-	-	-	-	-	40%	-	-	1	-	-
73	DE-BB01	0809	Burringbar Street	VC	150	1964	55	45.53	Y	Y	3	-	-	-	-	25%	-	-	1	1	1
74	A09-A10	0814	Burringbar Street	VC	150	1964	55	72.07	Y	Y	1	-	-	-	-	25%	4	-	4	3	-
75	A08-A09	0817	Burringbar Street	VC	150	1964	55	64.75	Y	N-14m patch liner restricting dia.	-	-	-	-	-	40	4	2	-	1	2
76	A11-A12	0800	Burringbar Street	VC	150	1964	55	70.41	Y	Y	-	-	-	-	-	40	3	-	3	3	-
77	A10-A11	0805	Burringbar Street	VC	150	1964	55	44.58	Y	Y	-	-	-	-	-	-	5	-	2	2	-
78	BA01-CM01	0796	Argyle Street	VC	150	1964	55	42.82	Y	Y	-	-	-	-	5	-	-	-	-	1	-
79	BA01-BA02	0784	Station Street	VC	150	1964	55	41.54	Y	Y	1	-	-	-	-	-	-	-	-	-	-
80	BB02-BA01	0785	McGoughans Lane	VC	150	1964	55	73.73	Y	Y	4	-	-	1	5	-	2	-	2	2	2
81	A12-A13	0790	Burringbar Street	VC	150	1964	55	73.86	Y	Y	1	-	-	-	-	-	2	-	3	2	1
82	Y01-Y02	0765	Cenotaph Lane	VC	150	1964	55	70.56	Y	Y	5	-	-	-	-	-	2	3	2	3	-
83	Z01-DE	0830	River Terrace	VC	150	1964	55	21.62	Y	Y	2	-	-	1	-	-	-	-	-	-	3
84	A12-Z01	0825	River Terrace	VC	150	1964	55	80.55	Y	Y	3	-	-	1	-	-	-	-	3	2	1
85	A10-BD01	0804	Studal Lane	VC	150	1964	55	65.06	Y	Y	-	-	-	-	-	-	4	-	1	9	-
86	BE01-BD01	0773	Stuart Street	VC	150	1964	55	26.72	Y	Y	3	-	-	-	-	-	-	-	-	-	-
87	BE01-DE	0775	Stuart Street	VC	150	1964	55	9.42	Y	Y	2	2	-	-	-	-	-	-	2	-	-
88	BD01-DE	0774	Studal Lane	VC	150	1964	55	30.27	Y	Y	5	1	-	-	-	15%	-	-	1	1	-
89	BD01-BD02	0771	Studal Lane	VC	150	1964	55	50.97	Y	Y	6	1	-	-	-	-	-	-	5	-	-

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90	BD02-BD03	0762	Studal Lane	VC	150	1964	55	49.16	Y	Y	6	1	-	-	-	-	-	-	4	-	-
91	A15-A16	0763	Riley Lane	VC	150	1964	55	82.72	Y	Y	10	1	-	-	-	-	-	3	5	-	-
92	A16-DE	0744	Tincogan Street	VC	150	1964	55	25.12	Y	Y	2	-	-	-	-	-	-	-	1	1	-
93	UNV-A16	4683	Brunswick Terrace	VC	150	1964	55	32.12	Y	Y	2	-	-	-	-	-	-	1	-	-	-
94	A15-CN01	0764	Brunswick Terrace	VC	150	1964	55	62.23	Y	Y	1	-	-	-	-	15%	-	1	1	-	-
95	BB02-BB03	0779	McGoughans Lane	VC	150	1964	55	77.73	Y	Y	9	2	-	-	-	-	5	4	5	7	-
96	DE-N03	3907	Whian Street	VC	150	1964	55	21.07	Y	Y	2	-	-	-	-	-	-	-	-	-	-
97	D02-E01	0975	Stuart Street	V	150	2004	15	30.93	Y	Y	3	-	-	-	-	-	-	-	4	3	-
98	G01-E01	0971	Stuart Street	V	150	2004	15	21.39	N-root intrusion obstruction could not be cleared as upstream MH is buried	N-17.7m root intrusion obstruction could not be cleared as upstream MH is buried	-	-	-	-	5	-	-	-	-	2	1
99	E01-E02	1722	Stuart Street	VC	150	1964	55	47.99	Y	Y	-	-	-	-	-	-	5	-	5	3	1
100	A03-B01	0935	Fern Street	VC	150	1964	55	72.44	Y	Y	3	-	-	1	-	10%	5	-	1	1	2
101	A03-A04	0932	McGoughans Lane	AC	225	1964	55	68.44	Y	Y	4	-	-	-	-	50%	-	-	1	1	
102	A04-DE	0902	McGoughans Lane	VC	150	1964	55	26.72	Y	Y	3	2	-	-	3	-	-	-	2	-	-
103	A02-A03	0933	Fern Street	AC	225	1964	55	64.64	Y	Y	2	-	-	-	-	60%	-	-	8	-	-
104	N01-A02	0926	Fern Street	VC	150	1964	55	71.04	Y	Y	2	-	-	-	-	50%	4	3	8	3	
105	A01-A02	0946	Stuart Street	AC	225	1964	55	40.28	N-thrid party works limited the ability to clear the main	N-35m obstruction beneath ponding flow could not be cleared due to SPS works	-	-	-	-	-	40%	-	-	-	-	-
106	EAA01-E02	1733	Stuart Street	VC	150	2004	15	13.65	N-thrid party works limited the ability to clear the main	Y	1	-	-	-	-	25%	2	-	4	-	-
107	EAA02-EAA01	1734	Stuart Street	PVC	150	1999	20	15.51	N-thrid party works limited the ability to clear the main	Y	2	-	-	-	-	-	-	-	-	2	-
108	EAA03-EAA02	0991	Stuart Street	PVC	150	1999	20	5.85	Y	Y	-	-	-	-	-	-	-	-	1	-	-
109	E02-E03	1723	Myokum Street	VC	150	1964	55	78.66	Y	Y	1	1	-	-	-	30%	-	-	2	7	1

4. DECISION TREE AND RISK MATRIX

A Decision Tree and Risk Matrix (Replacement Matrix) has been provided by Byron Shire Council to determine the actions required for the sections of sewer gravity mains assessed in this report. Decision Tree and Risk Matrix is provided below in Table 111 and shows the relationship between the Consequence and the Likelihood of Failure.

Each decision level is also broken down further into Categories (Cat), which defines the level of priority within both 'Monitor' and 'Leave' risk decision levels. Note the 'Replace' decision has not been allocated a Category rating, simply on the basis that the asset is no longer prudent to maintain in its current condition, in which case, prompt attention is required. The Category rating of the risk decision will assist in designating timeframes for follow-up assessment on the 'Monitor' and 'Leave' risk decision levels and therefore enable scheduling of future Capital Works programs.

Table 111 | Decision Tree and Risk Matrix (Replacement Matrix)

Likelihood of Failure \ Consequence	Very Low	Low	Medium	High	Very High
Very High	Replace	Replace	Replace	Replace	Replace
High	Monitor (Cat 2)	Monitor (Cat 1)	Replace	Replace	Replace
Medium	Leave (Cat 3)	Monitor (Cat 2)	Monitor (Cat 1)	Replace	Replace
Low	Leave (Cat 4)	Leave (Cat 3)	Monitor (Cat 2)	Monitor (Cat 1)	Replace
Very Low	Leave (Cat 4)	Leave (Cat 4)	Monitor (Cat 2)	Monitor (Cat 2)	Replace

Cat' = Category - referring to ranking within the risk decision matrix, 1 being higher priority over 2, 2 being higher priority over 3 etc.

The above categories for the 'Monitor' and 'Leave' outcomes have been determined through a combination of the most applicable levels from the Likelihood of Failure and Consequence matrix's detailed in Tables 112 and 113. Table 114 provides the outcomes of the assessment for each pipe considered in the 4001 catchment. Table 115 provides an outlook of the proposed scheduling for follow up assessments on each section of the sewer gravity mains. Typically, each category level incurs an additional 4 year follow up timeframe.

Table 112 | Determining the Likelihood of Failure

Level	Likelihood	Criteria
1	Very High	• >3 blockages per annum, or • Affected by future road reconstruction, or • Pipe wall pitting well into design wall thickness, or • Lining not effective corrosion of substrate has commenced, or • Age >=75% of adopted useful life in aggressive environment
2	High	• >3 bloackages over past two years, or • Asset with an increasing failure rate e.g. >20% per annum increase, or • Numerous wall pits exceed corrosion allowance, or • Effective lining reduced to <25% of original thickness major splits or cracks, or • Age between >=60% and 75% of adopted useful life in aggressive environment
3	Medium	• Performance is acceptable and • Loss of wall thickness to corrosion allowance and • >50% effective lining thickness with some cracking or splitting, or • Age between >40% of adopted useful life in aggressive environment
4	Low	• Performance is acceptable and • Minor surface damage and • Minor loss of lining
5	Very Low	• Performance is acceptable and • As new wall and • As new lining

Table 113 | Determining Consequence

Level	Descriptor	Severity				
		Environmental	PR/ Reputation	Legal/ Regulatory	Quantity	Customer Type
1	Very Low	Minor effects on biological or physical environment	Public complaint retained in-house or dealt with via normal procedures	• Minor legal issues	< 10 Retail customers affected	• Low Density Residential • Rural
2	Low	Moderate, short term effects but not affecting ecosystem functions	Minor adverse local public or media attention or complaints	• Minor non compliance with regulation	< 50 Retail customers affected	• High Density Residential
3	Medium	Serious Medium term environment effects	Attention from media and/or heightened concern by local community	• Breach of regulation with investigation and report to authority and/or moderate fine possible	< 200 Retail customers affected	• Small Industry • Small Commercial
4	High	Very serious long-term environmental impairment of ecosystem functions	Significant adverse national media attention	• Major breach of regulation. • Major litigation	> 500 Retail customers affected >8 hours unplanned outage	• Institutional • CBD Premises • Large Industry
5	Very High	Most serious irreversible environment impairment of ecosystem functions	Serious public or media outcry	• Loss of licence • Significant prosecution and fines • Very serious litigation including class action	> 2000 Retail customers affected >24 hours unplanned outage	• Critical Facilities le Hospital

Table 114 | Decision Table – 4001 Catchment

#	Line	Length (m)	Likelihood of Failure	Primary Justification	Consequence of Failure	Primary Justification	Decision Outcome	Comments and Recommendations
1	EA04-EA05	35.89	High	- Age > 60% of the life expectancy - Major root intrusion - 3 x patch repairs - 2 x minor and 6 x moderate defects	Medium	- <50 customers upstream - Low environmental impact - 1.6m deep - Within road pavement	Replace	Replacement of this line is recommended. High number of defects on this line including a patch liner that obstructed 7m of the assessment
2	EA03-EA04	87.7	High	- Age > 60% of the life expectancy - Minor root intrusion - 1 x patch repairs main - 2 x minor and 6 x moderate defects	Low	- <50 customers upstream - Low environmental impact - 1.7m deep - Within the verge	Monitor (Cat 1)	Monitor as recommended
3	EA02-EA03	63.23	Medium	- Age > 60% of the life expectancy - Medium root intrusion - 3 x minor and 1 x moderate defects	Low	- <50 customers upstream - Low environmental impact - 1.8m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended
4	EA01-EA02	63.28	Medium	- Age > 60% of the life expectancy - Minor root intrusion - 2 x minor and 2 x moderate defects	Low	- <50 customers upstream - Low environmental impact - 1.7m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended
5	EA01-EA01/End	30.10	Low	- Age > 60% of the life expectancy - No defects	Medium	- <200 customers upstream - Low environmental impact - 1.7m deep - Within road pavement	Monitor (Cat 2)	Monitor as recommended
6	E18-EA01	53.95	Medium*	- Age > 60% of the life expectancy - Major root intrusion - Ponding to 50% depth - 1 x minor defect	Low	- <50 customers upstream - Low environmental impact - 1.7m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended. Patch liner repair recommended at joint subject to cracking and root intrusion
7	E14-E16	55.62	Low	- Age > 90% of the life expectancy - Ponding to 25% depth - 3 x minor defects	Low	- <200 customers upstream - Low environmental impact - 1.8m deep - Within concrete footpath	Leave (Cat 3)	Monitor as recommended
8	E13-E14	57.59	Medium	- Age > 90% of the life expectancy - Ponding to 15% depth - 2 x patch repairs - 3 x minor and 1 x moderate defects	Low	- <200 customers upstream - Low environmental impact - 2.3m deep - Within concrete footpath	Monitor (Cat 2)	Monitor as recommended
9	E17-E18	36.21	High	- Age > 90% of the life expectancy - Minor root intrusion - Ponding to 25% depth - 2 x minor and 4 x moderate defects	Low	- <50 customers upstream - Low environmental impact - 1.2m deep - Within the verge	Monitor (Cat 1)	Monitor as recommended
10	K01 -E08	4.02	Low	- Age > 90% of the life expectancy - No defects	Low	- <200 customers upstream - Low environmental impact - 2.3m deep - Within the verge	Leave (Cat 3)	Monitor as recommended
11	K01-K02	25.34	High	- Age > 90% of the life expectancy - Major root intrusion - 4 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 2.3m deep - Within road pavement	Replace	Replacement of this line is recommended

12	E08-E09	46.00	Medium	- Age > 90% of the life expectancy - Ponding to 30% depth - Minor infiltration - 3 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 3.6m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended
13	E09-E10	45.98	High*	- Age > 90% of the life expectancy - 1 x major defect in a private junction - Moderate root intrusion - Ponding to 20% depth - 2 x patch repairs - 3 x moderate and 1 x major defects	Medium	- <200 customers upstream - Low environmental impact - 3.4m deep - Within the verge	Replace	Replacement of this line is recommended
14	K02-K03	58.01	Medium	- Age > 90% of the life expectancy - 2 x minor defects	Low	- <200 customers upstream - Low environmental impact - 1.4m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended
15	E10-L01	26.98	Medium*	- Age > 90% of the life expectancy - 1 x patch repair - 1 x minor and 1 moderate defect	Low	- <200 customers upstream - Low environmental impact - 2.3m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended. Radial displacement of short repair to be rectified with patch liner repair
16	L01-DE	27.74	Low	- Age > 90% of the life expectancy - 1 x patch repair - 1 x minor defect	Low	- <200 customers upstream - Low environmental impact - 0.9m deep - Within the verge	Leave (Cat 3)	Monitor as recommended
17	E10-E11	42.82	Low	- Age > 90% of the life expectancy - Ponding to 20% depth - Minor infiltration - 1 x minor defect	Medium	- <200 customers upstream - Low environmental impact - 3.6m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
18	E07-E08	21.00	Medium	- Age > 90% of the life expectancy - Ponding to 15% depth - 1 x patch repair - 2 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 5.2m deep - Within road pavement / verge	Monitor (Cat 1)	Monitor as recommended. 14m of this main was not assessed due to a defective patch repair restricting the diameter, reassess to confirm condition.
19	E06-E07	64.28	Low	- Age > 90% of the life expectancy - Ponding to 40% depth - 1 x minor defect	Medium	- <10 customers upstream - Low environmental impact - 4.3m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
20	J01-J02	30.11	Medium	- Age > 90% of the life expectancy - Moderate root intrusion - 1 x patch repair - 4 x minor defects	Low	- <10 customers upstream - Low environmental impact - 1.7m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
21	E06-J01	27.52	Medium	- Age > 90% of the life expectancy - 2 x patch repair - 1 x minor defect	Low	- <10 customers upstream - Low environmental impact - 1.4m deep - Within road pavement	Monitor (Cat 2)	Monitor as recommended
22	E05-E06	43.91	Medium*	- Age > 90% of the life expectancy - Ponding to 50% depth - 2 x minor and 1 x major defects	Medium	- <10 customers upstream - Low environmental impact - 4.5m deep - Within road pavement	Monitor (Cat 1)	Monitor as recommended. Clear line of rubble that remained after 3 passes of the jet cleaner
23	E05-DE	8.97	Low	- Age > 90% of the life expectancy - 1 x patch repair - No defects	Very Low	- <50 customers upstream - Low environmental impact - 1.4m deep - Within the verge	Leave (Cat 4)	Monitor as recommended

24	E04-E05	64.48	Medium	- Age > 90% of the life expectancy - Ponding to 30% depth - 5 x minor defects	Medium	- <50 customers upstream - Low environmental impact - 6.0m deep - Within the verge	Monitor (Cat 1)	Monitor as recommended
25	E03-E04	63.97	Very High	- Age > 90% of the life expectancy - Ponding to 60% depth - 2 x joints with gushing infiltration - 2 x minor defects	Medium	- <50 customers upstream - Low environmental impact - 6.1m deep - Within the verge	Replace	Replacement of this line is recommended
26	N04-N05	54.95	Medium	- Age > 90% of the life expectancy - Moderate root intrusion - 3 x minor defects	Medium	- <50 customers upstream - Low environmental impact - 1.1m deep - Within the road pavement and verge	Monitor (Cat 1)	Monitor as recommended
27	N05-N06	47.09	Medium*	- Age > 90% of the life expectancy - Major root intrusion - 2 x moderate defects	Very Low	- <50 customers upstream - Low environmental impact - 1.1m deep - Within the verge	Leave (Cat 3)	Monitor as recommended. 2 x patch liners to be installed over joints suffering major root intrusion
28	N06-T01	36.19	Low	- Age > 90% of the life expectancy - 2 x minor defects	Very Low	- <10 customers upstream - Low environmental impact - 1.5m deep - Within the verge	Leave (Cat 4)	Monitor as recommended
29	N06-S01	52.64	Medium	- Age > 90% of the life expectancy - Ponding to 15% depth - 2 x minor and 2 x moderate defects	Very Low	- <10 customers upstream - Low environmental impact - 1.1m deep - Within the verge	Leave (Cat 3)	Monitor as recommended
30	UNV-S01	4.53	High	- Age > 90% of the life expectancy - 1 x patch repair - 1 x minor and 1 x moderate defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Monitor (Cat 1)	Monitor as recommended
31	DE-UNV	13.93	Very Low	- Age ~25% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 4)	Monitor as recommended
32	N06-NO7	56.28	High	- Age > 90% of the life expectancy - Major root intrusion - 3 x minor and 5 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.1m deep - Within private property, road pavement, and verge	Monitor (Cat 1)	Monitor as recommended.
33	B01-B02	27.80	Low	- Age > 60% of the life expectancy - No defects	Medium	- <50 customers upstream - Low environmental impact - 4.3m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
34	B01-BC01	61.31	Very Low	- Main constructed in 2017 - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the road pavement	Leave (Cat 4)	Monitor as recommended
35	UNV-B02	23.47	Low	- Age > 60% of the life expectancy - No defects	Very Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the verge	Leave (Cat 4)	Monitor as recommended

36	B02-B03	77.87	Medium	- Age > 60% of the life expectancy - 1 x private junction with minor defect - 2 x minor and 1 x moderate defects	Very Low	- <10 customers upstream - Low environmental impact - 3.0m deep - Within the verge	Leave (Cat 3)	Monitor as recommended
37	B03-DEA	23.73	Medium*	- Age > 60% of the life expectancy - 2 x private junctions with major root intrusion - 1 x moderate and 2 x major defects (junctions)	Very Low	- <10 customers upstream - Low environmental impact - 1.8m deep - Within the verge	Leave (Cat 3)	Monitor as recommended. Clear 2 x junctions of major root intrusion.
38	SPS4010-GB01	4.39	Very Low	- Age > 50% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - 2.2m deep - Within private property	Leave (Cat 4)	Monitor as recommended
39	GB01-DE	45.93	Low*	- Age > 50% of the life expectancy - 1 x major defect	Low	- <10 customers upstream - Low environmental impact - 2.0m deep - Within private property	Leave (Cat 3)	Monitor as recommended. Recommended to install a patch liner repair over a large hole in the roof of the pipe to prevent infiltration or material entering the system
40	GB01-GC01	32.74	Very Low	- Age ~40% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - 2.0m deep - Within private property	Leave (Cat 4)	Monitor as recommended
41	GC01-GC02	80.78	Very Low	- Age ~40% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - 2.0m deep - Within private property	Leave (Cat 4)	Monitor as recommended
42	GC02-GC03	19.93	Very Low	- Main was constructed in 2016 - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 4)	Monitor as recommended
43	GC03-DE	13.10	Very Low	- Main was constructed in 2016 - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 4)	Monitor as recommended
44	N07-U01	38.49	Medium	- Age > 90% of the life expectancy - 2 x minor and 2 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
45	N07-NO8	58.90	Very High	- Age > 90% of the life expectancy - 1 x private junction with major root intrusion - Major root intrusion - 2 x minor, 4 x moderate, and 2 x major defects	Very Low	- <10 customers upstream - Low environmental impact - 1.3m deep - Within the verge	Replace	Replacement of this line is recommended
46	N03-NO4	42.92	Medium	- Age > 90% of the life expectancy - Ponding to 20% depth - 6 x minor and 2 x moderate defects	Very Low	- <50 customers upstream - Low environmental impact - 0.9m deep - Within the verge	Leave (Cat 3)	Monitor as recommended. Clear obstruction (piece of plastic liner) from the main
47	N01-P01	69.05	Medium	- Age > 90% of the life expectancy - 4 x minor defects	Very Low	- <10 customers upstream - Low environmental impact - 1.3m deep - Within the verge	Leave (Cat 3)	Monitor as recommended

48	DE-P01	5.91	Low	- Age > 90% of the life expectancy - No defects	Very Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the verge	Leave (Cat 4)	Monitor as recommended
49	E17-E16	62.73	High	- Age > 90% of the life expectancy - 1 x private junction with 25% obstruction - 2 x patch repairs - 1 x minor and 2 x moderate defects	Medium	- <50 customers upstream - Low environmental impact - Depth unknown - Within private property	Replace	Replacement of this line is recommended
50	E11-E12	55.68	Medium*	- Age > 90% of the life expectancy - 1 x private junction with 50% obstruction - Minor infiltration - 1 x minor, 1 x moderate, and 1 x major defects	Medium	- <200 customers upstream - Low environmental impact - 3.0m deep - Within private property	Monitor (Cat 1)	Monitor as recommended. Clear private junction of obstruction
51	E12-E13	83.11	High	- Age > 90% of the life expectancy - Minor root intrusion - Major infiltration - 3 x minor and 1 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 2.7m deep - Within the road pavement and verge	Replace	Replacement of this line is recommended
52	A10-W01	39.55	High	- Age > 90% of the life expectancy - 1 x private junction with joint displacement - 2 x patch repairs - 4 x minor and 3 x moderate defects	Medium	- <50 customers upstream - Low environmental impact - 2.0m deep - Within the road pavement	Replace	Replacement of this line is recommended
53	W01-W02	53.17	High	- Age > 90% of the life expectancy - 2 x private junction with partial obstruction - 2 x minor and 3 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.5m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended
54	W01-X01	26.69	Low	- Age > 90% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within private property	Leave (Cat 3)	Monitor as recommended
55	A07-A08	48.80	Medium	- Age > 90% of the life expectancy - 2 x minor defects	Medium	- <200 customers upstream - Low environmental impact - 5.0m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended
56	A07-BK01	42.41	Medium*	- Age > 90% of the life expectancy - 1 x private junction with root intrusion - 1 x minor and 1 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.0m deep - Within private property	Monitor (Cat 2)	Monitor as recommended. Clear junction of root intrusion
57	A07-V01	75.44	Medium*	- Age > 90% of the life expectancy - 1 x private junction with obstruction - 1 x private junction with pipe break - 2 x minor and 2 x moderate defects	Medium	- <50 customers upstream - Low environmental impact - 1.2m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended. Clear 1 x junction of obstruction and reline 1 x junction to prevent further collapse of pipe
58	V01-V02	32.93	Medium	- Age > 90% of the life expectancy - 1 x minor defects	Low	- <10 customers upstream - Low environmental impact - 1.5m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
59	A06-A07	79.11	Medium	- Age > 90% of the life expectancy - 2 x patch repairs - 3 x minor defects	Medium	- <200 customers upstream - Low environmental impact - 5.5m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended

60	A05-A06	71.00	Medium	- Age > 90% of the life expectancy - Minor infiltration - 2 x patch repairs - 5 x minor defects	Medium	- <200 customers upstream - Low environmental impact - 5.8m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended. 42m of this line was unable to be assessed due to patch liners restricting the diameter. Undertake assessment of this line to determine the condition
61	AS1-A05	3.03	Very Low	- Main was constructed in 2016 - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 4)	Monitor as recommended
62	AS02-AS01	8.25	Very Low	- Main was constructed in 2016 - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 4)	Monitor as recommended
63	AS03-AS02	25.65	Very Low	- Main was constructed in 2016 - No defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 4)	Monitor as recommended
64	A04-A05	79.22	Low	- Age > 90% of the life expectancy - 1 x minor defects	Medium	- <200 customers upstream - Low environmental impact - 6.1m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
65	N03-N02	60.51	Medium*	- Age > 90% of the life expectancy - 1 x joint with gushing infiltration - 1 x major defect (infiltration)	Medium	- <200 customers upstream - Low environmental impact - 0.9m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended. Install patch liner or dig up and repair joint to prevent infiltration
66	N02-N01	58.70	Medium	- Age > 90% of the life expectancy - Major infiltration - 1 x minor defect	Medium	- <200 customers upstream - Low environmental impact - 1.4m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended
67	R01-N03	77.27	Medium	- Age > 90% of the life expectancy - 1 x patch repair - 5 x minor defects	Low	- <10 customers upstream - Low environmental impact - 1.8m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
68	R02-R01	39.24	Medium*	- Age > 90% of the life expectancy - 1 x private junction with major obstruction (piece of pipe broken off) - 1 x minor, 1 x moderate, and 1 x major defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended. Clear junction of obstruction and assess private connection line to confirm condition
69	BB02-BB03	26.23	Very High	- Age > 90% of the life expectancy - Multiple points with major infiltration - 3 x patch repairs - 1 x minor and 5 x moderate defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the road pavement	Replace	Replacement of this line is recommended.
70	BB01-BB02	53.62	High	- Age > 90% of the life expectancy - Minor infiltration - 8 x patch repairs - 7 x minor, 1 x moderate, and 2 x major defects	Medium	- <200 customers upstream - Low environmental impact - 1.4m deep - Within the road pavement	Replace	Replacement of this line is recommended.
71	BB03-BB04	82.79	Medium	- Age > 90% of the life expectancy - 1 x junction with 25% obstruction - Minor root intrusion - 2 x patch repairs - 4 x minor and 2 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended

72	A08-BB01	13.67	Medium	- Age > 90% of the life expectancy - Ponding to 40% depth - 1 x minor defect	Medium	- <200 customers upstream - Low environmental impact - 3.5m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended
73	DE-BB01	45.53	Medium*	- Age > 90% of the life expectancy - Ponding to 25% depth - 1 x minor, 1 x moderate, and 1 x major defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the road pavement	Monitor (Cat 2)	Monitor as recommended. Major radial joint displacement at short PVC pipe replacement. Main should be exposed and repaired, or a patch liner installed
74	A09-A10	72.07	High	- Age > 90% of the life expectancy - Ponding to 25% depth - Major infiltration - 4 x minor and 3 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 4.1m deep - Within the road pavement	Replace	Replacement of this line is recommended
75	A08-A09	64.75	Very High	- Age > 90% of the life expectancy - Ponding to 40% depth - Major infiltration - 2 x patch repairs - 1 x moderate and 2 x major defects	Medium	- <200 customers upstream - Low environmental impact - 4.6m deep - Within the road pavement	Replace[1]	Replacement of this line is recommended
76	A11-A12	70.41	High	- Age > 90% of the life expectancy - Ponding to 40% depth - Moderate infiltration - 3 x minor and 3 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 3.7m deep - Within the road pavement	Replace	Replacement of this line is recommended
77	A10-A11	44.58	High	- Age > 90% of the life expectancy - Gushing infiltration - 2 x minor and 2 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 4.0m deep - Within the road pavement	Replace	Replacement of this line is recommended
78	BA01-CM01	42.82	Medium*	- Age > 90% of the life expectancy - Acute root intrusion - 1 x moderate defect	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended. Root intrusion at the end of line, not obstructing flow, clear roots and install a patch liner repair to prevent repeat intrusion.
79	BA01-BA02	41.54	Low	- Age > 90% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - 1.6m deep - Within the road pavement	Leave (Cat 3)	Monitor as recommended
80	BB02-BA01	73.73	High*	- Age > 90% of the life expectancy - 1 x junction with 50% obstruction - Acute root intrusion at a single joint - Minor infiltration - 2 x minor, 2 x moderate, 2 x major defects	Low	- <10 customers upstream - Low environmental impact - 1.6m deep - Within the road pavement and private property	Monitor (Cat 1)	Monitor as recommended. Clear junction of obstruction and clear joint of acute root intrusion and install patch liner repair to prevent repeat intrusion
81	A12-A13	73.86	High*	- Age > 90% of the life expectancy - Minor infiltration - 3 x minor, 2 x moderate, 1 x major defects	Medium	- <50 customers upstream - Low environmental impact - 3.1m deep - Within the road pavement	Replace	Replacement of this line is recommended. 1 x joint is radially displaced by 40mm.
82	Y01-Y02	70.56	Medium	- Age > 90% of the life expectancy - Minor infiltration - 3 x patch repairs - 2 x minor and 3 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.5m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
83	Z01-DE	21.62	Very High	- Age > 90% of the life expectancy - 1 x private junction broken and obstructed - 3 x major defects	Low	- <10 customers upstream - Low environmental impact - 1.1m deep - Within the road pavement	Replace	Replacement of this line is recommended

84	A12-Z01	80.55	High*	- Age > 90% of the life expectancy - 1 x private junction with major obstruction - 3 x minor, 2 x moderate, and 1 x major defects	Low	- <10 customers upstream - Low environmental impact - 1.8m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended. Clear junction of major obstruction (75%)
85	A10-BD01	65.06	Very High	- Age > 90% of the life expectancy - Major infiltration - 1 x minor and 9 x moderate defects	Medium	- <50 customers upstream - Low environmental impact - 3.4m deep - Within the road pavement	Replace	Replacement of this line is recommended
86	BE01-BD01	26.72	Medium	- Age > 90% of the life expectancy - No defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
87	BE01-DE	9.42	Medium	- Age > 90% of the life expectancy - 2 x private junctions with minor obstruction - No other defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
88	BD01-DE	30.27	Medium	- Age > 90% of the life expectancy - 1 x private junctions with minor obstruction - Ponding to 15% depth - 1 x minor and 1 x moderate defect	Low	- <10 customers upstream - Low environmental impact - 1.1m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
89	BD01-BD02	50.97	Medium	- Age > 90% of the life expectancy - 1 x private junctions with minor obstruction - 5 x minor defects	Low	- <10 customers upstream - Low environmental impact - 1.6m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
90	BD02-BD03	49.16	Medium	- Age > 90% of the life expectancy - 1 x private junctions with minor obstruction - 4 x minor defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
91	A15-A16	82.72	Medium	- Age > 90% of the life expectancy - 1 x private junction with minor obstruction - 3 x patch repairs - 5 x minor defects	Low	- <10 customers upstream - Low environmental impact - 0.9m deep - Within the road pavement	Monitor (Cat 2)	Monitor as recommended
92	A16-DE	25.12	Medium	- Age > 90% of the life expectancy - 1 x minor and 1 x moderate defect	Low	- <10 customers upstream - Low environmental impact - 0.9m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
93	UNV-A16	32.12	Medium	- Age > 90% of the life expectancy - 1 x patch repair	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Monitor (Cat 2)	Monitor as recommended
94	A15-CN01	62.23	Medium	- Age > 90% of the life expectancy - Ponding to 15% depth - 1 x patch repair - 1 x minor defect	Low	- <10 customers upstream - Low environmental impact - 1.3m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
95	BB02-BB03	77.73	Very High	- Age > 90% of the life expectancy - 1 x private junction with minor obstruction - 1 x private junction with longitudinal displacement (>20mm) - Gushing infiltration - 4 x patch repairs - 5 x minor and 7 x moderate defects	Low	- <10 customers upstream - Low environmental impact - 1.5m deep - Within private property and road pavement	Replace	Replacement of this line is recommended

96	DE-N03	21.07	Medium	- Age > 90% of the life expectancy - No defects	Very Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the verge	Leave (Cat 3)	Monitor as recommended
97	D02-E01	30.93	High	- Constructed in 2004 - 4 x minor and 3 x moderate defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Monitor (Cat 1)	Monitor as recommended
98	G01-E01	21.39	Very High	- Constructed in 2004 - Acute root intrusion (obstructed assessment) - 2 x moderate and 1 x major defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within the road pavement	Replace	Replacement of this line is recommended. Clearing of root intrusion must occur to facilitate CCTV prior to finalising scope
99	E01-E02	47.99	Very High	- Age > 90% of the life expectancy - Gushing infiltration - 5 x minor, 3 x moderate, and 1 x major defects	Medium	- <50 customers upstream - Low environmental impact - 6.4m deep - Within the verge	Replace	Replacement of this line is recommended
100	A03-B01	72.44	Very High	- Age > 90% of the life expectancy - 1 x junction with 40% obstruction - Ponding to 10% depth - Gushing infiltration - 1 x minor, 1 x moderate, and 2 x major defects	Medium	- <200 customers upstream - Low environmental impact - 4.4m deep - Within the road pavement	Replace	Replacement of this line is recommended
101	A03-A04	68.44	Medium	- Age > 90% of the life expectancy - Ponding to 50% depth - 1 x minor and 1 x moderate defects	Medium	- <200 customers upstream - Low environmental impact - 6.2m deep - Within the road pavement	Monitor (Cat 1)	Monitor as recommended
102	A04-DE	26.72	Medium	- Age > 90% of the life expectancy - 2 x junctions with minor root intrusion - 2 x minor defects	Low	- <10 customers upstream - Low environmental impact - 1.2m deep - Within private property	Monitor (Cat 2)	Monitor as recommended
103	A02-A03	64.64	Medium	- Age > 90% of the life expectancy - Ponding to 60% depth - 8 x minor defects	Medium	- <200 customers upstream - Low environmental impact - 5.9m deep - Within the verge	Monitor (Cat 1)	Monitor as recommended
104	N01-A02	71.04	High*	- Age > 90% of the life expectancy - Ponding to 50% depth - Major infiltration - 3 x patch repairs - 8 x minor and 3 x moderate defects	Very Low	- <50 customers upstream - Low environmental impact - 2.1m deep - Within the verge	Monitor (Cat 2)	Monitor as recommended. Piece of plastic is caught in a pipe joint resulting in an obstruction. This obstruction is to be removed from the main.
105	A01-A02	40.28	Medium	- Age > 90% of the life expectancy - Ponding to 50% depth - No defects	Medium	- <200 customers upstream - Low environmental impact - 6.5m deep - Within the verge	Monitor (Cat 1)	Monitor as recommended. 35m of the assessment was not undertaking due to high flow levels which could not be cleared due to third party works. Reassess this main
106	EAA01-E02	13.65	Medium	- Constructed in 2004 - Ponding to 25% depth - Minor infiltration - 4 x minor defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Monitor (Cat 2)	Monitor as recommended
107	EAA02-EAA01	15.51	Medium	- Age > 30% of the life expectancy - 2 x moderate defects	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Monitor (Cat 2)	Monitor as recommended

108	EAA03-EAA02	5.85	Low	- Age > 30% of the life expectancy - 1 x minor defect	Low	- <10 customers upstream - Low environmental impact - Depth unknown - Within private property	Leave (Cat 3)	Monitor as recommended
109	E02-E03	78.66	Very High	- Age > 90% of the life expectancy - 1 x private junction with minor obstruction - Ponding to 30% depth - 2 x minor, 7 x moderate, and 1 x major defects	Medium	- <50 customers upstream - Low environmental impact - 6.3m deep - Within the road pavement and verge	Replace	Replacement of this line is recommended

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#	Pipe Section	Decision Outcome	Capital Works Delivery Period					Pipe Age at Next Assessment (yrs.)
			2019	2023	2027	2031	2035	
1	EA04-EA05	Replace	Immediate					37
2	EA03-EA04	Monitor (Cat 1)		Assess				41
3	EA02-EA03	Monitor (Cat 2)			Assess			45
4	EA01-EA02	Monitor (Cat 2)			Assess			45
5	EA01-EA01/End	Monitor (Cat 2)			Assess			45
6	E18-EA01	Monitor (Cat 2)	Patch liner		Assess			45
7	E14-E16	Leave (Cat 3)				Assess		67
8	E13-E14	Monitor (Cat 2)			Assess			63
9	E17-E18	Monitor (Cat 1)		Assess				59
10	K01 -E08	Leave (Cat 3)				Assess		67
11	K01-K02	Replace	Immediate					55
12	E08-E09	Monitor (Cat 2)			Assess			59
13	E09-E10	Replace	Immediate					55
14	K02-K03	Monitor (Cat 2)			Assess			63
15	E10-L01	Monitor (Cat 2)	Patch liner		Assess			63
16	L01-DE	Leave (Cat 3)				Assess		67
17	E10-E11	Monitor (Cat 2)			Assess			63
18	E07-E08	Monitor (Cat 1)	Re-assess	Assess				59
19	E06-E07	Monitor (Cat 2)			Assess			67
20	J01-J02	Monitor (Cat 2)			Assess			63
21	E06-J01	Monitor (Cat 2)			Assess			63
22	E05-E06	Monitor (Cat 1)	Clean main Path liner	Assess				63
23	E05-DE	Leave (Cat 4)					Assess	71
24	E04-E05	Monitor (Cat 1)		Assess				59
25	E03-E04	Replace	Immediate					55
26	N04-N05	Monitor (Cat 1)		Assess				59

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27	N05-N06	Leave (Cat 3)	2 x Patch liner			Assess		67
28	N06-T01	Leave (Cat 4)					Assess	71
29	N06-S01	Leave (Cat 3)				Assess		67
30	UNV-S01	Monitor (Cat 1)		Assess				59
31	DE-UNV	Leave (Cat 4)					Assess	31
32	N06-NO7	Monitor (Cat 1)		Assess				59
33	B01-B02	Monitor (Cat 2)			Assess			45
34	B01-BC01	Leave (Cat 4)					Assess	18
35	UNV-B02	Leave (Cat 4)					Assess	53
36	B02-B03	Leave (Cat 3)				Assess		49
37	B03-DEA	Leave (Cat 3)	2 x Clear junction			Assess		49
38	SPS4010-GB01	Leave (Cat 4)					Assess	49
39	GB01-DE	Leave (Cat 3)	Patch liner			Assess		45
40	GB01-GC01	Leave (Cat 4)					Assess	39
41	GC01-GC02	Leave (Cat 4)					Assess	39
42	GC02-GC03	Leave (Cat 4)					Assess	19
43	GC03-DE	Leave (Cat 4)					Assess	19
44	N07-U01	Monitor (Cat 2)			Assess			63
45	N07-NO8	Replace	Immediate					55
46	N03-NO4	Leave (Cat 3)	Clear obstruction			Assess		67
47	N01-P01	Leave (Cat 3)				Assess		67
48	DE-P01	Leave (Cat 4)					Assess	71
49	E17-E16	Replace	Immediate					55
50	E11-E12	Monitor (Cat 1)	Clear junction	Assess				63
51	E12-E13	Replace	Immediate					55
52	A10-W01	Replace	Immediate					55
53	W01-W02	Monitor (Cat 1)		Assess				59
54	W01-X01	Leave (Cat 3)				Assess		67
55	A07-A08	Monitor (Cat 1)		Assess				59
56	A07-BK01	Monitor (Cat 2)	Clear junction		Assess			63

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57	A07-V01	Monitor (Cat 1)	Clear junction Line junction	Assess				59
58	V01-V02	Monitor (Cat 2)			Assess			63
59	A06-A07	Monitor (Cat 1)		Assess				59
60	A05-A06	Monitor (Cat 1)	Re-assess	Assess				59
61	AS1-A05	Leave (Cat 4)					Assess	19
62	AS02-AS01	Leave (Cat 4)					Assess	19
63	AS03-AS02	Leave (Cat 4)					Assess	19
64	A04-A05	Monitor (Cat 2)			Assess			63
65	N03-N02	Monitor (Cat 1)	Patch liner	Assess				59
66	N02-N01	Monitor (Cat 1)		Assess				59
67	R01-N03	Monitor (Cat 2)			Assess			63
68	R02-R01	Monitor (Cat 2)	Clear and assess junction		Assess			63
69	BB02-BB03	Replace	Immediate					59
70	BB01-BB02	Replace	Immediate					55
71	BB03-BB04	Monitor (Cat 2)			Assess			63
72	A08-BB01	Monitor (Cat 1)		Assess				59
73	DE-BB01	Monitor (Cat 2)	Patch liner		Assess			63
74	A09-A10	Replace	Immediate					55
75	A08-A09	Replace	Immediate					55
76	A11-A12	Replace	Immediate					55
77	A10-A11	Replace	Immediate					55
78	BA01-CM01	Monitor (Cat 2)	Patch liner		Assess			63
79	BA01-BA02	Leave (Cat 3)				Assess		67
80	BB02-BA01	Monitor (Cat 1)	Clear junction Patch liner	Assess				59
81	A12-A13	Replace	Immediate					55
82	Y01-Y02	Monitor (Cat 2)			Assess			63
83	Z01-DE	Replace	Immediate					55
84	A12-Z01	Monitor (Cat 1)	Clear junction	Assess				59

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85	A10-BD01	Replace	Immediate					55
86	BE01-BD01	Monitor (Cat 2)			Assess			63
87	BE01-DE	Monitor (Cat 2)			Assess			63
88	BD01-DE	Monitor (Cat 2)			Assess			63
89	BD01-BD02	Monitor (Cat 2)			Assess			63
90	BD02-BD03	Monitor (Cat 2)			Assess			63
91	A15-A16	Monitor (Cat 2)			Assess			63
92	A16-DE	Monitor (Cat 2)			Assess			63
93	UNV-A16	Monitor (Cat 2)			Assess			63
94	A15-CN01	Monitor (Cat 2)			Assess			63
95	BB02-BB03	Replace	Immediate					55
96	DE-N03	Leave (Cat 3)				Assess		67
97	D02-E01	Monitor (Cat 1)		Assess				19
98	G01-E01	Replace	Immediate					15
99	E01-E02	Replace	Immediate					55
100	A03-B01	Replace	Immediate					55
101	A03-A04	Monitor (Cat 1)		Assess				59
102	A04-DE	Monitor (Cat 2)			Assess			63
103	A02-A03	Monitor (Cat 1)		Assess				63
104	N01-A02	Monitor (Cat 2)	Clear obstruction		Assess			63
105	A01-A02	Monitor (Cat 1)	Re-assess	Assess				63
106	EAA01-E02	Monitor (Cat 2)			Assess			23
107	EAA02-EAA01	Monitor (Cat 2)			Assess			28
108	EAA03-EAA02	Leave (Cat 3)				Assess		32
109	E02-E03	Replace	Immediate					55

5. CONCLUSIONS AND RECOMMENDATIONS

Willow & Sparrow Pty Ltd have assessed the CCTV footage and completed the decision tree and risk/replacement matrix for the relevant sewer gravity mains within Catchment 4001 in Mullumbimby, NSW. Of the 123 sewer mains within the catchment, the assessment of 109 were undertaken, the remaining mains were not assessed due to issues associated with buried MHs and SPS works that were underway at the time resulting in the surcharging of mains within the vicinity of SPS4001. It is recommended that the 14 mains that were not assessed during the first pass of the catchment be undertaken in FY19/20.

With regards to the 109 mains that were assessed, 22 are recommended for immediate replacement in addition to another 22 mains that are recommended for immediate minor rectification works such as clearing blockages, clearing junctions, installing patch liners, and re-assessing mains in which the assessment was incomplete. The 87 mains that are not recommended for immediate replacement are recommended for re-assessment as per Table 115.

Two feasible methodologies have been identified for the mains that are recommended for immediate replacement, these include structural lining with a Cured in Place Pipe (CIPP) or similar, and the removal and replacement of the existing gravity sewer main via open trench excavation. The relevant mains and the associated conceptual construction cost estimates for each replacement methodology are listed below in Table 116. The recommended methodology is highlighted green with associated justification. A detailed breakdown of the construction cost estimate for each main can be found in **Attachment 1**.

The scope for the mains that are recommended for future assessment subject to immediate minor rectification works being undertaken are listed below in Table 117 with the associated conceptual construction cost estimates. The associated rates for each item can be found in **Attachment 2**. These rates have been applied to each main as applicable to fulfil the scope.

It is recommended that the scope identified in both Tables 116 and 117 (replacement and minor rectification works) be prepared for tender and completed in FY19/20 at a total estimated cost of **$358,991.00** (±20%) (excl GST).

Table 116 | Commercial Comparison of Rectification Options

#	Line	Length (m)	# of Junctions	Depth (m)	Groundwater	Primary Location	Conceptual Cost Estimate ($)		Justification for Proposed Methodology and Key Scope Notes
							Open Trench Replacement	Structural Lining	
1	EA04-EA05	35.89	-	1.6m		Roadway	$28,788.50	$10,444.00	More economical | Lower community Impact | ≥60 year life Remove existing patch liners
11	K01-K02	25.34	-	2.3m		Verge	$14,396.00	$6,248.00	More economical | Lower community Impact | ≥60 year life Remove root intrusion
13	E09-E10	45.98	1	3.4m		Verge	$32,835.72	$13,056.80	More economical | Lower community Impact | ≥60 year life Remove existing patch liners & root intrusion from junction
25	E03-E04	63.97	1-Closed	6.1m	Yes	Verge	$152,321.30	$13,935.20	More economical | Lower community Impact | ≥60 year life
45	N07-NO8	58.9	3	1.3m		Verge	$25,114.00	$18,124.00	More economical | Lower community Impact | ≥60 year life Remove extensive root intrusion from the main and the junction
49	E17-E16	62.73	1	Assume 1.5m		Private property	$59,665.90	$14,536.80	More economical | Lower community Impact | ≥60 year life Remove existing patch liners
51	E12-E13	83.11	-	2.7m	Yes	Roadway	$76,750.45	$16,497.60	More economical | Lower community Impact | ≥60 year life Remove root intrusion
52	A10-W01	39.55	2	2.0m		Roadway	$31,668.25	$13,528.00	More economical | Lower community Impact | ≥60 year life Remove existing patch liner
69	BB02-BB03	26.23	3	Assume 1.5m	Yes	Roadway	$25,734.65	$13,396.80	More economical | Lower community Impact | ≥60 year life Remove existing patch liners
70	BB01-BB02	53.62	2	1.4m		Roadway	$34,697.10	$18,779.20	More economical | Lower community Impact | ≥60 year life Remove existing patch liners
74	A09-A10	72.07	1	4.1m	Yes	Roadway	$113,671.75	$16,231.20	More economical | Lower community Impact | ≥60 year life
75	A08-A09	64.75	-	4.6m	Yes	Roadway	$105,668.75	$13,560.00	More economical | Lower community Impact | ≥60 year life Remove existing patch liners
76	A11-A12	70.41	-	3.7m		Roadway	$59,193.95	$14,465.60	More economical | Lower community Impact | ≥60 year life
77	A10-A11	44.58	-	4.0m	Yes	Roadway	$74,994.50	$10,332.80	More economical | Lower community Impact | ≥60 year life
81	A12-A13	73.86	1	3.1m		Roadway	$61,746.70	$16,517.60	More economical | Lower community Impact | ≥60 year life
83	Z01-DE	21.62	2	1.1m		Roadway	$17,137.10	$9,659.20	More economical | Lower community Impact | ≥60 year life
85	A10-BD01	65.06	-	3.4m	Yes	Roadway	$72,010.70	$13,609.60	More economical | Lower community Impact | ≥60 year life
95	BB02-BB03	77.73	9	1.5m	Yes	Roadway	$52,167.15	$31,136.80	More economical | Lower community Impact | ≥60 year life Remove existing patch liners
98	G01-E01	21.39	-	Assume 1.5m		Roadway	$19,532.45	$7,122.40	More economical | Lower community Impact | ≥60 year life Buried upstream MH to be located and uncovered and remove extensive root intrusion
99	E01-E02	47.99	-	6.4m	Yes	Verge	$120,085.25	$10,878.40	More economical | Lower community Impact | ≥60 year life
100	A03-B01	72.44	3	4.4m	Yes	Roadway	$125,051.00	$21,290.40	More economical | Lower community Impact | ≥60 year life Clear obstruction from the junction
109	E02-E03	78.66	1	6.3m	Yes	Roadway	$195,823.50	$17,285.60	More economical | Lower community Impact | ≥60 year life
TOTAL		1,205.88m	30				$ 1,499,054.67	$320,636.00	

*Allows for thrust boring of new main as an existing private structure is above the existing alignment, hence open trench replacement is not a viable option.

Table 117 | Scope of Minor Rectification Works

#	Line	Issue	Required Works	Location	Conceptual Cost Estimate ($)
6	E18-EA01	Root intrusion at joint and cracking of main	Install structural patch liner	53.40m from EA01	$1,400.00
15	E10-L01	Significant radial displacement ≤20mm at 8 O'clock due to PVC section replacement	Install structural patch liner	3.84m from L01	$1,400.00
18	E07-E08	Patch liner obstructing flow and inspection	Re-assess (CCTV) - 22.00m	Entire main	$515.00
22	E05-E06	- line was cleaned 3 times with sediment still being present in the line - Significant cracking/breaking in pipe wall	- Clean main – 43.91m - Install structural patch liner	- Entire main - 23.67m from E06	$2,260.00
27	N05-N06	- Root intrusion with obstruction between 5-20% from 3-5 O'clock - Root intrusion with obstruction between 5-20% from 2-6 O'clock and crack width of 6mm	- Remove root intrusion - 2 x Install structural patch liner	- 10.18m from N06 - 30.56m from N06	$3,300.00
37	B03-DEA	- Private junction open in good condition at 9 O'clock, junction is 75% blocked - Private junction open in good condition at 9 O'clock, junction is 50% blocked	2 x Clear junction of obstruction and install structural liner	- 3.97m from DE - 6.14m from DE	$6,200.00
39	GB01-DE	Large hole through the pipe wall at 12 O'clock	Install structural patch liner	12.90m from DE	$1,400.00
46	N03-NO4	Assessment abandoned due to blockage (unable to locate downstream MH)	Locate buried MH Clear main of obstruction	38.24m from N04	$1,080.00
50	E11-E12	Private junction open in good condition at 9 O'clock, junction obstructed ≤50% by root intrusion	Clear junction of obstruction and install structural liner	45.44m from E12	$3,200.00
56	A07-BK01	Private junction open in good condition at 9 O'clock. Root intrusion blocking flow by 25%	Clear junction of obstruction and install structural liner	20.96m from Bk01	$3,200.00
57	A07-V01	Private junction open in good condition at 3 O'clock. Pipe break at 12 O'clock	- Clear junction of obstruction - Install structural junction patch liner	69.31m from V01	$1,850.00
60	A05-A06	Patch liner indicating poor condition of pipe and obstructing inspection	Re-assess (CCTV) – 71.00m	Entire main	$1,365.00
65	N03-N02	Infiltration gushing though pipe joint at 4 O'clock	Install structural patch liner	36.08m from N03	$1,400.00
68	R02-R01	Private junction open in good condition at 3 O'clock, large piece of pipe obstructing flow <50%	Clear obstruction in junction and assess private connection line Reline private connection line if necessary*	15.59m from R02	$1,050.00 $3,200.00*
73	DE-BB01	Significant radial joint displacement >20mm at 6 O'clock likely resulting in substantial infiltration	Install structural patch liner	14.91m from DE	$1,400.00
78	BA01-CM01	Root intrusion with obstruction between 5-20% at 6 O'clock. Roots initially obstructed assessment and had to be cut	- Cut roots - Install structural patch liner	42.26m from CM01	$2,145.00
80	BB02-BA01	- Root intrusion with obstruction between 20-50% from 12-5 O'clock - Private junction open in good condition at 9 O'clock. Large obstruction 20-50% from 3-9 O'clock	- Clear obstruction and install structural patch liner - Clear junction of obstruction	- 33.56m from BB02 - 33.93m from BB02	$2,760.00
84	A12-Z01	Private junction open in poor condition at 3 O'clock, major obstruction 75%	Clear junction of obstruction	19.89m from Z01	$350.00 Confirm if junction is live
104	N01-A02	Obstruction of 5-20% due to piece of plastic being wedged in pipe joint from 6-8 O'clock	Clear obstruction from main	43.75m from N01	$1,265.00
105	A01-A02	Assessment terminated due to obstruction which is resulting in ponding to a depth of 40%	Re-assess (CCTV)	Entire main	$815.00
				TOTAL	**$38,355.00**

ATTACHMENT 1 – CONCEPTUAL CONSTRUCTION COST ESTIMATES FOR COMPLETE RECTIFICATION OF MAINS

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - EA04-EA05

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 3,000.00	$ 3,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 3,200.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	35.9	$ 50.00	$ 1,795.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ 1,795.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 1.5-2.5m deep	m	35.9	$ 240.00	$ 8,616.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 8,616.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2	53.9	$ 150.00	$ 8,077.50
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ 8,077.50**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day	2	$ 1,000.00	$ 2,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 6,000.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ 1,100.00**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 3,200.00
2	Removal and Disposal	$ 1,795.00
3	Supply, Delivery, Excavation and Installation	$ 8,616.00
4	Site Restoration	$ 8,077.50
5	Other	$ 6,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		**$ 28,788.50**

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - EA04-EA05

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ -**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	35.9	$ 160.00	$ 5,744.00
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
3.03	Remove existing patch liners	each	3	$ 500.00	$ 1,500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 7,244.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ -**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 1,000.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ -**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 7,244.00
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		**$ 10,444.00**

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - K01-K02

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 3,000.00	$ 3,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 3,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	25.3	$ 50.00	$ 1,265.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 1,265.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 1.5-2.5m deep	m	25.3	$ 240.00	$ 6,072.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 6,072.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²	38	$ 20.00	$ 759.00
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 759.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	1	$ 2,000.00	$ 2,000.00
5.02	Traffic Control	Day		$ 1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 2,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 3,200.00
2	Removal and Disposal	$ 1,265.00
3	Supply, Delivery, Excavation and Installation	$ 6,072.00
4	Site Restoration	$ 759.00
5	Other	$ 2,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 14,396.00

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - K01-K02

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	25.3	$ 160.00	$ 4,048.00
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,800.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 4,048.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day		$1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 4,048.00
4	Site Restoration	$ -
5	Other	$ -
6	As-constructed Survey Drawings	$ -
Total amount		$ 6,248.00

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - E09-E10

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 4,000.00	$ 4,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 4,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	45.98	$ 50.00	$ 2,299.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 2,299.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 2.5-4m deep	m	45.98	$ 324.00	$ 14,897.52
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	1	$ 500.00	$ 500.00
3.03	Clear private junction of obstruction and reline	Lump	1	$ 2,000.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 17,397.52

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2	91.96	$ 20.00	$ 1,839.20
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 1,839.20

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	3	$ 2,000.00	$ 6,000.00
5.02	Traffic Control	Day		$ 1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 6,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 4,200.00
2	Removal and Disposal	$ 2,299.00
3	Supply, Delivery, Excavation and Installation	$ 17,397.52
4	Site Restoration	$ 1,839.20
5	Other	$ 6,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 32,835.72

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - E09-E10

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	45.98	$ 160.00	$ 7,356.80
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	1	$1,500.00	$ 1,500.00
3.03	Clear private junction of obstruction and reline	Lump	1	$2,000.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 10,856.80

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day		$1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 10,856.80
4	Site Restoration	$ -
5	Other	$ -
6	As-constructed Survey Drawings	$ -
Total amount		$ 13,056.80

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - E03-E04

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 8,000.00	$ 8,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 8,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	63.97	$ 50.00	$ 3,198.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,198.50

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe >6m deep	m	63.97	$ 1,200.00	$ 76,764.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	1	$ 500.00	$ 500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 77,264.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²	127.9	$ 20.00	$ 2,558.80
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 2,558.80

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	6	$ 2,000.00	$ 12,000.00
5.02	Traffic Control	Day	6	$ 1,000.00	$ 6,000.00
5.03	Groundwater management	Day	6	$ 7,000.00	$ 42,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 60,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (ex GST)
1	Preliminary Works	$ 8,200.00
2	Removal and Disposal	$ 3,198.50
3	Supply, Delivery, Excavation and Installation	$ 77,264.00
4	Site Restoration	$ 2,558.80
5	Other	$ 60,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 152,321.30

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - E03-E04

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	63.97	$ 160.00	$ 10,236.20
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	1	$1,500.00	$ 1,500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 11,736.20

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day		$1,000.00	$ -
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (ex GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 11,736.20
4	Site Restoration	$ -
5	Other	$ -
6	As-constructed Survey Drawings	$ -
Total amount		$ 13,936.20

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - N07-NO8

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 3,000.00	$ 3,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 3,200.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	58.9	$ 50.00	$ 2,945.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 2,945.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe <1.5m	m	58.9	$ 180.00	$ 10,602.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	3	$ 500.00	$ 1,500.00
3.03	Clear private junction of obstruction and reline	Lump	1	$ 2,000.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 14,102.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2	88.4	$ 20.00	$ 1,767.00
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 1,767.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5:	Other				
5.01	Flow Control	Day	1	$ 2,000.00	$ 2,000.00
5.02	Traffic Control	Day		$ 1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 2,000.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 3,200.00
2	Removal and Disposal	$ 2,945.00
3	Supply, Delivery, Excavation and Installation	$ 14,102.00
4	Site Restoration	$ 1,767.00
5	Other	$ 2,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 25,114.00

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - N07-NO8

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	58.9	$ 160.00	$ 9,424.00
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	3	$1,500.00	$ 4,500.00
3.03	Clear private junction of obstruction and reline	Lump	1	$2,000.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 15,924.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day		$1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ -
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 15,924.00
4	Site Restoration	$ -
5	Other	$ -
6	As-constructed Survey Drawings	$ -
Total amount		$ 18,124.00

Schedule of Quantities and Prices
Open Excavation Construction Cost Estimate - E17-E16

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1		$ -
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,000.00
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	62.73	$ 50.00	$ 3,136.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,136.50
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 DIEL pipe 1.5m assumed depth via thrust boring	m	62.73	$ 750.00	$ 47,047.50
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	1	$ 500.00	$ 500.00
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 47,547.50
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²	94.1	$ 20.00	$ 1,881.80
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 1,881.80
Section 5:	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day		$ 1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 4,000.00
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,000.00
2	Removal and Disposal	$ 3,136.50
3	Supply, Delivery, Excavation and Installation	$ 47,547.50
4	Site Restoration	$ 1,881.80
5	Other	$ 4,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 59,665.80

Schedule of Quantities and Prices
Structural Lining Construction Cost Estimate - E17-E16

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ -	$ -
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,000.00
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	62.73	$ 160.00	$ 10,036.80
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	1	$1,500.00	$ 1,500.00
3.03	Remove existing patch liners	each	2	$ 500.00	$ 1,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 12,536.80
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day		$1,000.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ -
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,000.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 12,536.80
4	Site Restoration	$ -
5	Other	$ -
6	As-constructed Survey Drawings	$ -
Total amount		$ 14,536.80

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - E12-E13

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 4,000.00	$ 4,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 4,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	83.11	$ 50.00	$ 4,155.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 4,155.50
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 2.5-4.0m deep	m	83.11	$ 320.00	$ 26,595.20
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 26,595.20
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	124.67	$ 150.00	$ 18,699.75
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 18,699.75
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
5.03	Groundwater management	Day	4	$ 2,500.00	$ 10,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 22,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 4,200.00
2	Removal and Disposal	$ 4,155.50
3	Supply, Delivery, Excavation and Installation	$ 26,595.20
4	Site Restoration	$ 18,699.75
5	Other	$ 22,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 76,750.45

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - E12-E13

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	83.11	$ 160.00	$ 13,297.60
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 13,297.60
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 13,297.60
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 16,497.60

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A10-W01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 3,000.00	$ 3,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 3,200.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	39.55	$ 50.00	$ 1,977.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ 1,977.50**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 1.5-2.5m deep	m	39.55	$ 240.00	$ 9,492.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	2	$ 500.00	$ 1,000.00
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 10,492.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2	59.33	$ 150.00	$ 8,898.75
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ 8,898.75**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day	2	$ 1,000.00	$ 2,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 6,000.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ 1,100.00**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 3,200.00
2	Removal and Disposal	$ 1,977.50
3	Supply, Delivery, Excavation and Installation	$ 10,492.00
4	Site Restoration	$ 8,898.75
5	Other	$ 6,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		**$ 31,668.25**

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A10-W01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ -**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	39.55	$ 160.00	$ 6,328.00
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	2	$1,500.00	$ 3,000.00
3.03	Remove existing patch liners	each	2	$ 500.00	$ 1,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 10,328.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ -**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 1,000.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ -**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 10,328.00
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		**$ 13,528.00**

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - BB02-BB03

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	26.23	$ 50.00	$ 1,311.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 1,311.50

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe <1.5 deep	m	26.23	$ 180.00	$ 4,721.40
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	3	$ 500.00	$ 1,500.00
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 6,221.40

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	39.35	$ 150.00	$ 5,901.75
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 5,901.75

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day	2	$ 1,000.00	$ 2,000.00
5.03	Groundwater management	Day	2	$ 1,500.00	$ 3,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 9,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (ex GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ 1,311.50
3	Supply, Delivery, Excavation and Installation	$ 6,221.40
4	Site Restoration	$ 5,901.75
5	Other	$ 9,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 25,734.65

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - BB02-BB03

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	26.23	$ 160.00	$ 4,196.80
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	3	$1,500.00	$ 4,500.00
3.03	Remove existing patch liners	each	3	$ 500.00	$ 1,500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 10,196.80

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (ex GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 10,196.80
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 13,396.80

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - BB01-BB02

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	53.62	$ 50.00	$ 2,681.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ 2,681.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe <1.5m deep	m	53.62	$ 180.00	$ 9,651.60
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	2	$ 500.00	$ 1,000.00
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 10,651.60**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²	80.43	$ 150.00	$ 12,064.50
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ 12,064.50**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day	2	$ 1,000.00	$ 2,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 6,000.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ 1,100.00**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ 2,681.00
3	Supply, Delivery, Excavation and Installation	$ 10,651.60
4	Site Restoration	$ 12,064.50
5	Other	$ 6,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		**$ 34,697.10**

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - BB01-BB02

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ -**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	53.62	$ 160.00	$ 8,579.20
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	2	$1,500.00	$ 3,000.00
3.03	Remove existing patch liners	each	8	$ 500.00	$ 4,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 15,579.20**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ -**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 1,000.00**

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ -**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 15,579.20
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		**$ 18,779.20**

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A09-A10

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 6,000.00	$ 6,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 6,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	72.07	$ 50.00	$ 3,603.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,603.50

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 4.0-6.0m deep	m	72.07	$ 750.00	$ 54,052.50
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	1	$ 500.00	$ 500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 54,552.50

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²	108.1	$ 150.00	$ 16,215.75
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 16,215.75

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
5.03	Groundwater management	Day	4	$ 5,000.00	$ 20,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 32,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 6,200.00
2	Removal and Disposal	$ 3,603.50
3	Supply, Delivery, Excavation and Installation	$ 54,552.50
4	Site Restoration	$ 16,215.75
5	Other	$ 32,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 113,671.75

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A09-A10

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	72.07	$ 160.00	$ 11,531.20
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	1	$1,500.00	$ 1,500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 13,031.20

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 13,031.20
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 16,231.20

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A08-A09

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 6,000.00	$ 6,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 6,200.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	64.75	$ 50.00	$ 3,237.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,237.50
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 4.0-6.0m deep	m	64.75	$ 750.00	$ 48,562.50
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 48,562.50
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2	97.13	$ 150.00	$ 14,568.75
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 14,568.75
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5:	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
5.03	Groundwater management	Day	4	$ 5,000.00	$ 20,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 32,000.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 6,200.00
2	Removal and Disposal	$ 3,237.50
3	Supply, Delivery, Excavation and Installation	$ 48,562.50
4	Site Restoration	$ 14,568.75
5	Other	$ 32,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 105,668.75

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A08-A09

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	64.75	$ 160.00	$ 10,360.00
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
3.03	Remove existing patch liners	each	2	$ 500.00	$ 1,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 10,360.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 10,360.00
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 13,560.00

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A11-A12

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 4,000.00	$ 4,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 4,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	70.41	$ 50.00	$ 3,520.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,520.50
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 2.5-4.0m deep	m	70.41	$ 320.00	$ 22,531.20
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 22,531.20
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	105.62	$ 150.00	$ 15,842.25
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 15,842.25
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 12,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 4,200.00
2	Removal and Disposal	$ 3,520.50
3	Supply, Delivery, Excavation and Installation	$ 22,531.20
4	Site Restoration	$ 15,842.25
5	Other	$ 12,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 59,193.95

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A11-A12

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	70.41	$ 160.00	$ 11,265.60
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 11,265.60
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 11,265.60
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 14,465.60

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A10-A11

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 4,000.00	$ 4,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 4,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	44.58	$ 50.00	$ 2,229.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 2,229.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 4.0-6.0m deep	m	44.58	$ 750.00	$ 33,435.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 33,435.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	66.87	$ 150.00	$ 10,030.50
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 10,030.50
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	3	$ 2,000.00	$ 6,000.00
5.02	Traffic Control	Day	3	$ 1,000.00	$ 3,000.00
5.03	Groundwater management	Day	3	$ 5,000.00	$ 15,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 24,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 4,200.00
2	Removal and Disposal	$ 2,229.00
3	Supply, Delivery, Excavation and Installation	$ 33,435.00
4	Site Restoration	$ 10,030.50
5	Other	$ 24,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 74,994.50

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A10-A11

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	44.58	$ 160.00	$ 7,132.80
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 7,132.80
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 7,132.80
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 10,332.80

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A12-A13

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 4,000.00	$ 4,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 4,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	73.86	$ 50.00	$ 3,693.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,693.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 2.5-4.0m deep	m	73.86	$ 320.00	$ 23,635.20
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	1	$ 500.00	$ 500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 24,135.20
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	110.8	$ 150.00	$ 16,618.50
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 16,618.50
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 12,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 4,200.00
2	Removal and Disposal	$ 3,693.00
3	Supply, Delivery, Excavation and Installation	$ 24,135.20
4	Site Restoration	$ 16,618.50
5	Other	$ 12,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 61,746.70

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A12-A13

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	73.86	$ 160.00	$ 11,817.60
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	1	$1,500.00	$ 1,500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 13,317.60
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 13,317.60
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 16,517.60

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - Z01-DE

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	21.6	$ 50.00	$ 1,081.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ 1,081.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe <1.5m deep	m	21.6	$ 180.00	$ 3,891.60
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	2	$ 500.00	$ 1,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 4,891.60**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m^2	32.4	$ 150.00	$ 4,864.50
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ 4,864.50**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5:	Other				
5.01	Flow Control	Day	1	$ 2,000.00	$ 2,000.00
5.02	Traffic Control	Day	1	$ 1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 3,000.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ 1,100.00**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ 1,081.00
3	Supply, Delivery, Excavation and Installation	$ 4,891.60
4	Site Restoration	$ 4,864.50
5	Other	$ 3,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		**$ 17,137.10**

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - Z01-DE

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ -**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	21.62	$ 160.00	$ 3,459.20
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	2	$1,500.00	$ 3,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 6,459.20**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4	Site Restoration				
4.01	Reinstate road pavement	m^2		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m^2		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ -**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 1,000.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ -**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 6,459.20
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		**$ 9,659.20**

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A10-BD01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 4,000.00	$ 4,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 4,200.00**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	65.06	$ 50.00	$ 3,253.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ 3,253.00**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 2.5-4.0m deep	m	65.06	$ 320.00	$ 20,819.20
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 20,819.20**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	97.59	$ 150.00	$ 14,638.50
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ 14,638.50**
Section 5:	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
5.03	Groundwater management	Day	4	$ 4,000.00	$ 16,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 28,000.00**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ 1,100.00**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 4,200.00
2	Removal and Disposal	$ 3,253.00
3	Supply, Delivery, Excavation and Installation	$ 20,819.20
4	Site Restoration	$ 14,638.50
5	Other	$ 28,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		**$ 72,010.70**

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A10-BD01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ -**
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	65.06	$ 160.00	$ 10,409.60
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 10,409.60**
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ -**
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 1,000.00**
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ -**

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 10,409.60
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		**$ 13,609.60**

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - BB02-BB03

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	77.73	$ 50.00	$ 3,886.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,886.50

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe <1.5m deep	m	77.73	$ 180.00	$ 13,991.40
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	9	$ 500.00	$ 4,500.00
3.03	Remove existing patch liners	each		$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 18,491.40

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	116.6	$ 150.00	$ 17,489.25
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 17,489.25

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day	2	$ 1,000.00	$ 2,000.00
5.03	Groundwater management	Day	2	$ 1,500.00	$ 3,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 9,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ 3,886.50
3	Supply, Delivery, Excavation and Installation	$ 18,491.40
4	Site Restoration	$ 17,489.25
5	Other	$ 9,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 52,167.15

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - BB02-BB03

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	77.73	$ 160.00	$ 12,436.80
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	9	$1,500.00	$ 13,500.00
3.03	Remove existing patch liners	each	4	$ 500.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 27,936.80

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 27,936.80
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 31,136.80

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - G01-E01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main 1.5m assumed depth	m	21.39	$ 50.00	$ 1,069.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 1,069.50

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe	m	21.39	$ 180.00	$ 3,850.20
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 3,850.20

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²	32.09	$ 150.00	$ 4,812.75
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 4,812.75

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day	2	$ 2,000.00	$ 4,000.00
5.02	Traffic Control	Day	2	$ 1,000.00	$ 2,000.00
5.03	Locate and uncover MH	Lump	1	$ 500.00	$ 500.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 6,500.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ 1,069.50
3	Supply, Delivery, Excavation and Installation	$ 3,850.20
4	Site Restoration	$ 4,812.75
5	Other	$ 6,500.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 19,532.45

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - G01-E01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	21.39	$ 160.00	$ 3,422.40
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 3,422.40

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Locate and uncover MH	Lump	1	$ 500.00	$ 500.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,500.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 3,422.40
4	Site Restoration	$ -
5	Other	$ 1,500.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 7,122.40

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - E01-E02

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 8,000.00	$ 8,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 8,200.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	47.99	$ 50.00	$ 2,399.50
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ 2,399.50**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe >6.0m deep	m	47.99	$ 1,200.00	$ 57,588.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	0	$ 500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 57,588.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²	71.99	$ 150.00	$ 10,797.75
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ 10,797.75**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5	Other				
5.01	Flow Control	Day	4	$ 2,000.00	$ 8,000.00
5.02	Traffic Control	Day	4	$ 1,000.00	$ 4,000.00
5.03	Groundwater management	Day	4	$ 7,000.00	$ 28,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 40,000.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ 1,100.00**

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 8,200.00
2	Removal and Disposal	$ 2,399.50
3	Supply, Delivery, Excavation and Installation	$ 57,588.00
4	Site Restoration	$ 10,797.75
5	Other	$ 40,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		**$ 120,085.25**

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - E01-E02

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					**$ 2,200.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					**$ -**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	47.99	$ 160.00	$ 7,678.40
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	0	$1,500.00	$ -
Sub-total amount for Section 3 (To be carried forward to the Summary)					**$ 7,678.40**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					**$ -**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					**$ 1,000.00**
Pay Item	**Brief Description**	**Unit**	**Qty**	**Unit Rate ($ excl GST)**	**Price (excl GST) (Qty x Unit Rate)**
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					**$ -**

Summary of Schedule of Rates

Section	Description	Amount (excl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 7,678.40
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		**$ 10,878.40**

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - A03-B01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 6,000.00	$ 6,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 6,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	72.44	$ 50.00	$ 3,622.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,622.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe 4.0-6.0m deep	m	72.44	$ 750.00	$ 54,330.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	3	$ 500.00	$ 1,500.00
3.03	Clear private junction of obstruction and reline	Lump	1	$ 2,000.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 57,830.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	108.7	$ 150.00	$ 16,299.00
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 16,299.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	5	$ 2,000.00	$ 10,000.00
5.02	Traffic Control	Day	5	$ 1,000.00	$ 5,000.00
5.03	Groundwater management	Day	5	$ 5,000.00	$ 25,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 40,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 6,200.00
2	Removal and Disposal	$ 3,622.00
3	Supply, Delivery, Excavation and Installation	$ 57,830.00
4	Site Restoration	$ 16,299.00
5	Other	$ 40,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 125,051.00

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - A03-B01

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	72.44	$ 160.00	$ 11,590.40
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	3	$1,500.00	$ 4,500.00
3.03	Clear private junction of obstruction and reline	Lump	1	$2,000.00	$ 2,000.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 18,090.40

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (exl GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 18,090.40
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 21,290.40

Schedule of Quantities and Prices

Open Excavation Construction Cost Estimate - E02-E03

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1:	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$ 8,000.00	$ 8,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 8,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2:	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m	78.66	$ 50.00	$ 3,933.00
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ 3,933.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3:	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, installation, connection to existing maintenance structures, and backfill of DN150 PVC pipe >6.0m deep	m	78.66	$ 1,200.00	$ 94,392.00
3.02	Supply, delivery, installation, and connection of DN150x150 property junctions to existing private service lines	each	1	$ 500.00	$ 500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 94,892.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4:	Site Restoration				
4.01	Reinstate road pavement	m²	118	$ 150.00	$ 17,698.50
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ 17,698.50
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5:	Other				
5.01	Flow Control	Day	7	$ 2,000.00	$ 14,000.00
5.02	Traffic Control	Day	7	$ 1,000.00	$ 7,000.00
5.03	Groundwater management	Day	7	$ 7,000.00	$ 49,000.00
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 70,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6:	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item	1	$ 1,100.00	$ 1,100.00
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ 1,100.00

Summary of Schedule of Rates

Section	Description	Amount (ex GST)
1	Preliminary Works	$ 8,200.00
2	Removal and Disposal	$ 3,933.00
3	Supply, Delivery, Excavation and Installation	$ 94,892.00
4	Site Restoration	$ 17,698.50
5	Other	$ 70,000.00
6	As-constructed Survey Drawings	$ 1,100.00
Total amount		$ 195,823.50

Schedule of Quantities and Prices

Structural Lining Construction Cost Estimate - E02-E03

Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 1	Preliminary Works				
1.01	Site establishment and disestablishment and all preliminary works including CEMP and all required approvals	Item	1	$2,000.00	$ 2,000.00
1.02	Preparation of Traffic management Plan	Item	1	$ 200.00	$ 200.00
Sub-total amount for Section 1 (To be carried forward to the Summary)					$ 2,200.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 2	Removal and Disposal				
2.01	Excavation, disconnection, removal and appropriate disposal of existing DN150 VC gravity sewer main	m		$ 50.00	$ -
Sub-total amount for Section 2 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 3	Supply, Delivery, Excavation and Installation				
3.01	Supply, delivery, cleaning, and installation of structural liner	m	78.66	$ 160.00	$ 12,585.60
3.02	Supply, delivery, and installation of DN150x150 property junction liners	each	1	$1,500.00	$ 1,500.00
Sub-total amount for Section 3 (To be carried forward to the Summary)					$ 14,085.60
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 4	Site Restoration				
4.01	Reinstate road pavement	m²		$ 150.00	$ -
4.02	Reinstate verge and median with top soil	m²		$ 20.00	$ -
Sub-total amount for Section 4 (To be carried forward to the Summary)					$ -
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 5	Other				
5.01	Flow Control	Day		$2,000.00	$ -
5.02	Traffic Control	Day	1	$1,000.00	$ 1,000.00
5.03	Groundwater management	Day		$1,500.00	$ -
Sub-total amount for Section 5 (To be carried forward to the Summary)					$ 1,000.00
Pay Item	Brief Description	Unit	Qty	Unit Rate ($ excl GST)	Price (excl GST) (Qty x Unit Rate)
Section 6	As-constructed Survey Drawings				
6.01	As-constructed survey and drawings	Item		$1,100.00	$ -
Sub-total amount for Section 6 (To be carried forward to the Summary)					$ -

Summary of Schedule of Rates

Section	Description	Amount (ex GST)
1	Preliminary Works	$ 2,200.00
2	Removal and Disposal	$ -
3	Supply, Delivery, Excavation and Installation	$ 14,085.60
4	Site Restoration	$ -
5	Other	$ 1,000.00
6	As-constructed Survey Drawings	$ -
Total amount		$ 17,285.60

ATTACHMENT 2 – CONCEPTUAL CONSTRUCTION COST RATES FOR MINOR RECTIFICATION WORKS

Rates for Minor Rectification Works Items		
Brief Description	**Unit**	**Unit Rate ($ excl GST)**
Site establishment / disestablishment and all preliminary works including CEMP and all required approvals	Item	$ 200.00
Preparation of Traffic management Plan	Item	$ 100.00
Supply, Delivery, Excavation and Installation of structural liner	m	$ 160.00
Supply, Delivery, Excavation and Installation of structural liner in private connection	m	$ 300.00
Supply, Delivery, and Installation of Patch Liner	Each	$ 1,200.00
Traffic Control	hr	$ 125.00
Supply, Delivery, Clean and CCTV	m	$ 15.00
Location Services	hr	$ 120.00

END OF REPORT

Willow+ Sparrow

Mullumbimby (4001)

Gravity Sewer Maintenance Hole

Condition Assessment

Prepared for: Byron Shire Council

DOCUMENT CONTROL

Revision number	Description	Prepared	Reviewed	Issued	Issue date
0	Final Report	JV	MC	MC	7/10/19

Document title: Mullumbimby – 4001 Gravity Sewer Maintenance Hole Condition Assessment

Document number: BSC_4001SMHCA

Author: Julian Vivoli, *BEng*

Client name: Byron Shire Council

Client's representative: Dean Baluch

Approved for use by:

Name: Michael Chamberlain **Signature:** **Date:** 7th October 2019

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Contents

1. INTRODUCTION

Willow & Sparrow Pty Ltd has been engaged by Byron Shire Council (BSC) to prepare a Condition Assessment report for the sewerage catchment upstream of Sewer Pump Station (SPS) 4001 in Mullumbimby, NSW.

1.1 Project background

Byron Shire Council has identified peaking factors of approximately 8 x ADWF within this portion of the Mullumbimby sewerage catchment. This is a clear indication that this portion of the network is subject to the adverse impacts of inflow and infiltration (I&I). Council wishes to undertake a prudent process to confirm the actual condition of the gravity sewer maintenance holes (MH), determine which MHs require rehabilitation or replacement, and to then procure the rehabilitation or replacement of the selected MHs.

Due to the uncertainty as to which MHs are to be replaced, it is anticipated that the project be delivered in two stages, with a hold point at the completion of stage 1. This hold point will enable Council to review this Condition Assessment report and determine which MHs will be carried forward into the rehabilitation/replace phase of the project in FY19/20.

The two stages of work are:

- Stage 1 – Condition Assessment of each MH, and
- Stage 2 – Procurement and delivery of the MH rectification works

1.2 Scope

This Condition Assessment report provides a record of the findings of the condition assessments that were based on visual inspections, and water and smoke testing. The report also provides recommendations for rectification works and a re-assessment schedule to maintain the integrity and function of the network.

1.3 Site description

This Condition Assessment report has been prepared for the gravity sewer catchment as shown in Figure 1. The Mullumbimby catchment upstream of 4001 comprises a gravity sewer system that services hundreds of residential properties in addition to the Mullumbimby CBD. The MHs encompassed by the blue hatch in Figure 1 are the mains that have been addressed in this Condition Assessment report.

Figure 1 | Gravity sewer catchment 4001 – Mullumbimby, NSW, Source: Byron Shire Council GeoCortex 2019

2. MAINTENANCE HOLE CONDITION ASSESSMENT RECORDS – 4001 CATCHMENT

2.1 EA/4 – Azalea Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	1800
Defects	
Inflow	Major inflow evident through MH lid
Liner	MH liner is delaminating at the base of the MH

2.2 EA/3 – Azalea Street

Attributes	
Location	Asphalt footpath
Diameter	1200
Depth	1900
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and has exposed aggregate throughout

2.3 EA/5 – Azalea Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	1200
Defects	
Inflow	Major inflow evident through MH lid and surround
Benching	Benching doesn't exist

2.4 EA/1 – Azalea Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	1900
Defects	
Inflow	Major inflow evident through MH lid and surround which is also offset 30%
Chamber	MH chamber is unlined and has minor exposed aggregate throughout

2.5 EA/2 – Azalea Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	1700
Lid	Raised 400mm above surface level
Defects	
Inflow	None
Chamber	Chamber subject to minor root intrusion
Liner	Liner subject to partial delamination

2.6 E/18 – Azalea Street

Attributes	
Location	Vegetation adjacent to creek
Diameter	1200
Depth	1200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.7 E/16 – Jubilee Avenue

Attributes	
Location	Concrete footpath
Diameter	1200
Depth	1700
Defects	
Inflow	None
Chamber	MH chamber is unlined and has exposed aggregate throughout

2.8 E/14 – Jubilee Avenue

Attributes	
Location	Concrete footpath
Diameter	1200
Depth	2200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.9 E/13 – Jubilee Avenue



Attributes	
Location	Concrete footpath
Diameter	1200
Depth	2700
Defects	
Inflow	None visible, though cracking exists around concrete surround
Liner	Liner subject to partial delamination

2.10 K/1 – Jubilee Avenue



Attributes	
Location	Grassed verge
Diameter	1200
Depth	2400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.11 E/8 – Byron Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	4200
Defects	
Inflow	Major inflow evident through MH converter slab
Liner	Liner subject to partial delamination and collapse immediately beneath the converter slab which is through to soil

2.12 E/7 – Byron Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	4100
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.13 E/9 – Byron Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	3800
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.14 E/17 – Azalea Street


No internal picture available

Attributes	
Location	Grassed verge
Diameter	1200
Depth	1300
Defects – based on recorded assessment	
Inflow	None
Liner	Liner subject to partial delamination

2.15 K/2 – Jubilee Avenue



Attributes	
Location	Concrete footpath
Diameter	1200
Depth	2000
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.16 E/10 - Byron Street



Attributes	
Location	Asphalt driveway
Diameter	1200
Depth	4300
Defects	
Inflow	None
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.17 UNV - Byron Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	1300
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.18 E/5 – Small Lane



Attributes	
Location	Unsealed road pavement
Diameter	1200
Depth	4500
Defects	
Inflow	None
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.19 E/6 – Small Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	1600
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.20 J/1 – Small Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	1600
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.21 E/4 – Myokum Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	5400
Defects	
Inflow	None
Liner	MH liner is subject to major delamination

2.22 K/3 – Jubilee Avenue

Attributes	
Location	Concrete footpath
Diameter	1200 x 1200
Depth	1000
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and in good condition

2.23 E/12 – Jubilee Avenue



Attributes	
Location	Grassed park
Diameter	1200
Depth	3100
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.24 J/2 – Small Lane



Attributes	
Location	Private property
Diameter	1000 x 1000
Depth	1300
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.25 GA/1 – Myokum Street



Attributes	
Location	Private property
Diameter	1200
Depth	800
Defects	
Inflow	None
Liner	Liner subject to partial delamination
Other	Material build-up in chamber obstructing flow channel

2.26 E/3 – Myokum Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	6600
Defects	
Inflow	None
Liner	Completely delaminated. Chamber is effectively unlined

2.27 N/4 – Whian Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	3300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.28 N/5 – Whian Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	2800
Defects	
Inflow	None
Liner	Liner subject to partial delamination
Chamber	Subject to minor root intrusion

2.29 N/6 – Whian Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	2100
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.30 T/1 – Whian Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	2000
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.31 S/1 – Jubilee Avenue



Attributes	
Location	Grassed verge
Diameter	1000 x 1000
Depth	1300
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.32 UNV – Jubilee Avenue



Attributes	
Location	Private property
Diameter	1200
Depth	1000
Lid	Raised 150mm
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.33 B/1 – Station Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	2900
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.34 B/2 – Station Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	2400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.35 B/3 – Station Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	1400
Defects	
Inflow	None
Liner	Liner subject to delamination

2.36 GB/1 – Station Street



Attributes	
Location	Private property
Diameter	1200
Depth	2200
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.37 GC/1 – Station Street

Attributes	
Location	Private property
Diameter	1200
Depth	2000
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition
Other	Minor root intrusion evident

2.38 GC/2 – Station Street

Attributes	
Location	Private property
Diameter	1200
Depth	1300
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition
Other	Minor root intrusion evident

2.39 BC/1 – Station Street



Attributes	
Location	Grassed verge
Diameter	1200
Depth	1600
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.40 N/7 – River Terrace



Attributes	
Location	Grassed verge
Diameter	1200
Depth	1700
Defects	
Inflow	None
Liner	Liner subject to partial delamination, blocking flow path

2.41 N/8 – River Terrace

Attributes	
Location	Grassed verge
Diameter	1000 x 1000
Depth	1300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.42 U/1 – Dalley Street

Attributes	
Location	Asphalt driveway
Diameter	1000 x 1000
Depth	1000
Defects	
Inflow	None
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.43 P/1 – Fern Street

Attributes	
Location	Grassed verge
Diameter	1000 x 1000
Depth	1100
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.44 N/1 – Fern Street

Attributes	
Location	Unsealed roadway
Diameter	1200
Depth	4300
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.45 A/10 – Studal Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	4100
Defects	
Inflow	None
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.46 W/1 – Studal Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	2000
Defects	
Inflow	None
Liner	Liner subject to partial delamination

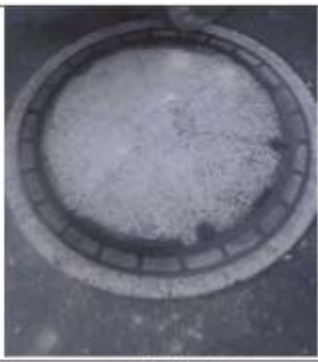
2.47 W/2 – Studal Lane

Attributes	
Location	Road pavement
Diameter	1200
Depth	1500
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined and minor traces of aggregate are visible

2.48 X/1 – Stuart Street

Attributes	
Location	Road pavement
Diameter	1000 x 1000
Depth	1200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.49 V/1 – Station Street


Attributes	
Location	Road pavement
Diameter	1200
Depth	1800
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.50 V/2 – Station Street



Attributes	
Location	Road pavement
Diameter	1000 x 1000
Depth	1200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.51 A/8 – Burringbar Street



Attributes	
Location	Road pavement
Diameter	1200
Depth	4400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.52 A/7 – McGoughans Lane

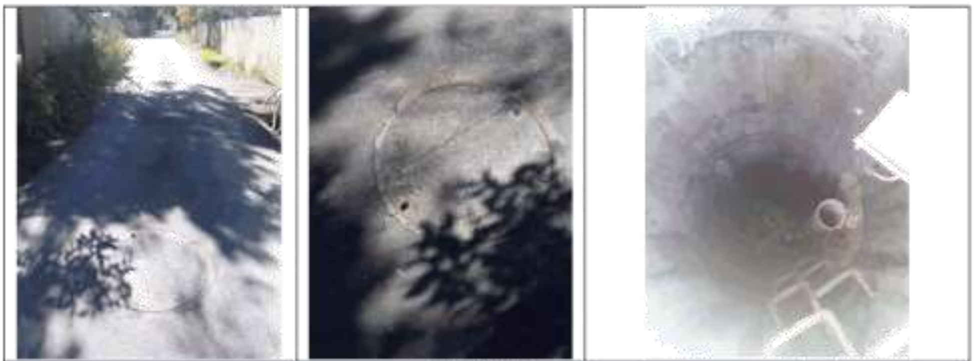


Attributes	
Location	Road pavement
Diameter	1200
Depth	5300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.53 A/6 – McGoughans Lane

Attributes	
Location	Unsealed road pavement
Diameter	1200
Depth	5600
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.54 A/5 – McGoughans Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	5900
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.55 AS/1 – McGoughans Lane



Attributes	
Location	Private property
Diameter	1200
Depth	1200
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.56 AS/2 – McGoughans Lane



Attributes	
Location	Private property
Diameter	1200
Depth	1400
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition
Lid and Surround	Lid and surround offset by 30%

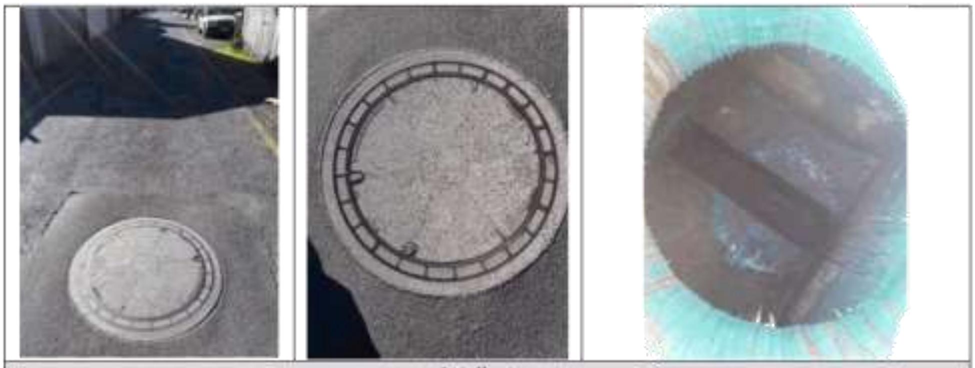
2.57 N/2 – Studal Lane

Attributes	
Location	Unsealed road pavement
Diameter	1200
Depth	4200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.58 R/1 – Studal Lane

Attributes	
Location	Road pavement
Diameter	1200
Depth	1600
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.59 R/2 – Studal Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	1300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.60 CN/1 – Brunswick Terrace

Attributes	
Location	Grassed verge
Diameter	1200 x 1200
Depth	1000
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.61 BB/1 – Burringbar Street



Attributes	
Location	Road pavement
Diameter	1200
Depth	3900
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.62 BB/2 – McGoughans Lane

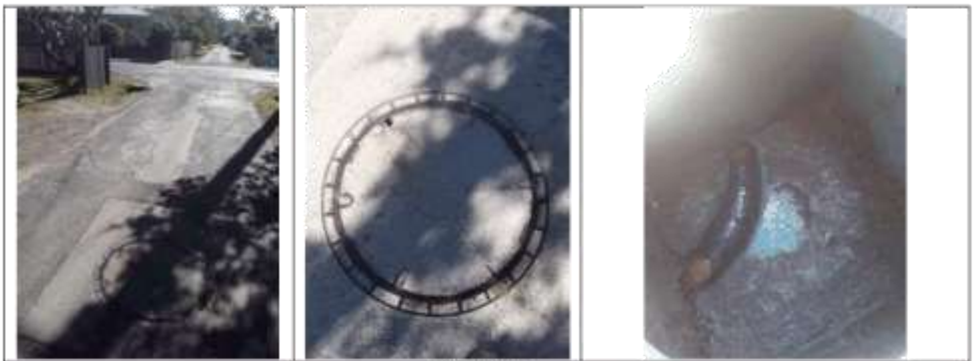


Attributes	
Location	Road pavement
Diameter	1200
Depth	3300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.63 BB/3 – McGoughans Lane

Attributes	
Location	Road pavement
Diameter	1200
Depth	2600
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.64 BB/4 – McGoughans Lane



Attributes	
Location	Road pavement
Diameter	1200 x 1200
Depth	1300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.65 A/9 – Burringbar Street

Attributes	
Location	Concrete footpath
Diameter	1200
Depth	4400
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.66 A/11 – Burringbar Street

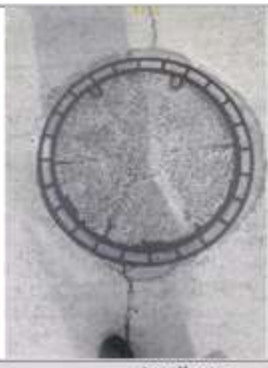
Attributes	
Location	Concrete footpath
Diameter	1200
Depth	4000
Defects	
Inflow	None
Chamber	MH chamber is unlined and in good condition

2.67 A/12 – Burringbar Street



Attributes	
Location	Road pavement
Diameter	1200
Depth	3400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.68 BA/1 – Azalea Street


Attributes	
Location	Road pavement
Diameter	1200
Depth	2200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.69 BA/2 – Station Street



Attributes	
Location	Road pavement
Diameter	1000 x 1000
Depth	1500
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.70 CM/1 – Argyle Street



Attributes	
Location	Road pavement
Diameter	1000 x 1000
Depth	1000
Defects	
Inflow	None
Liner	Liner subject to partial delamination
Chamber	Subject to minor root intrusion

2.71 A/13 – Jubilee Avenue



Attributes	
Location	Concrete footpath
Diameter	1200
Depth	2600
Defects	
Inflow	Major inflow evident through MH lid
Chamber	MH chamber is unlined with exposed aggregate throughout

2.72 A/14 – Jubilee Avenue


Attributes	
Location	Grassed verge
Diameter	1200
Depth	1800
Defects	
Inflow	None
Liner	Liner subject to partial delamination

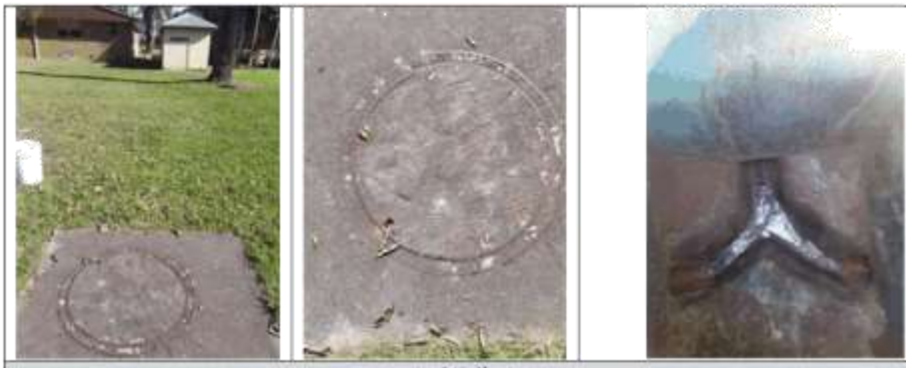
2.73 A/15 – Riley Lane

Attributes	
Location	Road pavement
Diameter	1200 x 1200
Depth	1300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.74 Y/1 – Cenotaph Lane

Attributes	
Location	Grassed verge
Diameter	1200
Depth	1900
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.75 Y/2 – Cenotaph Lane

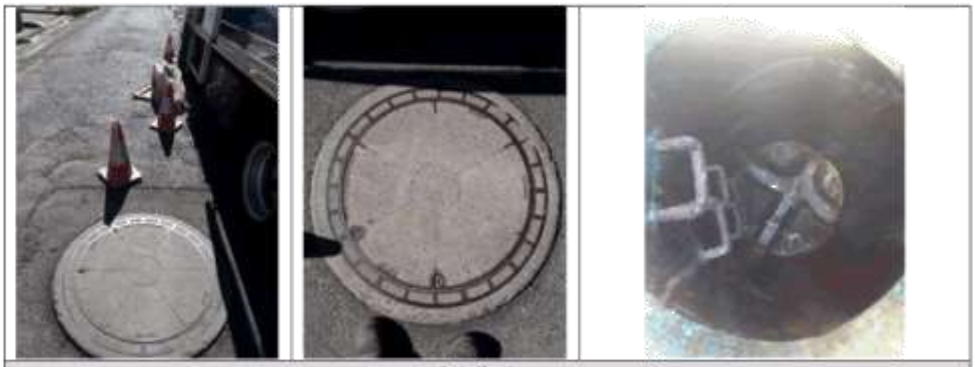


Attributes	
Location	Grassed verge
Diameter	1200 x 1200
Depth	1400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.76 Z/1 – River Terrace

Attributes	
Location	Grassed verge
Diameter	1000 x 1000
Depth	1400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.77 BD/1 – Studal Lane



Attributes	
Location	Road pavement
Diameter	1200
Depth	2800
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.78 BD/3 – Studal Lane

Attributes	
Location	Road pavement
Diameter	1200 x 1200
Depth	1300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.79 BD/2 – Studal Lane

Attributes	
Location	Road pavement
Diameter	1200
Depth	2100
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.80 A/16 – Riley Lane

Attributes	
Location	Unsealed road pavement
Diameter	1000 x 1000
Depth	1300
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.81 N/3 – Whian Street

Attributes	
Location	Unsealed road pavement
Diameter	1200
Depth	3600
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.82 E/2 – Stuart Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	6900
Defects	
Inflow	None
Chamber	MH chamber is unlined with exposed aggregate throughout

2.83 E/1 – Stuart Street

Attributes	
Location	Grassed verge
Diameter	1200
Depth	7000
Defects	
Inflow	None
Chamber	MH chamber is unlined with exposed aggregate throughout

2.84 A/1 – Stuart Street

Attributes	
Location	Concrete SPS 4001 driveway
Diameter	1200
Depth	7200
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.85 A/3 – Fern Street

Attributes	
Location	Road pavement
Diameter	1200
Depth	6250
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.86 A/4 – McGoughans Lane

Attributes	
Location	Road pavement
Diameter	1200
Depth	6400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.87 A/2 – Fern Street



Attributes	
Location	Road pavement
Diameter	1200
Depth	6700
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.88 EAA/1 – Stuart Street



Attributes	
Location	Private property
Diameter	1200
Depth	1950
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.89 EAA/2 – Stuart Street

Attributes	
Location	Private property
Diameter	1200
Depth	1400
Defects	
Inflow	None
Liner	Liner subject to partial delamination

2.90 Maintenance holes that could not be located

MH ID - Street	GC/3 – Station Street	BE/1 – Stuart Street	E/11 – Jubilee Avenue
			

3. DETERMINATION OF RISK AND RECOMMENDATIONS

As MH's are isolated structures with a similar and predominantly low potential consequence of failure, it is recommended that their ongoing management doesn't consider the consequence of their failure in their risk determination. The overall condition score should solely be considered as the risk of failure.

With the above being considered, overall condition scores have been assigned to each of the assessed MHs (1 being as new, and 5 requiring immediate rectification). The recommended assessment schedule has been developed off the assigned overall condition scores. Typically, each integer aligns with an additional 4 year period in which the MH is to be assessed e.g. a MH with a risk score of 3 will be assessed in 8 years where as a MH with a risk score of 2 will be assessed in 12 years.

Table 1 below provides a summary of the information presented in the report, recommends an overall condition score (risk of failure), and proposes rectification works and the timing for re-assessment.

4. SUMMARY OF FINDINGS

Table 1 | Summary / Decision Table

#	Attribute Information						Summary of Findings						Decision Outcome	Capital Works Delivery Period				
	MH ID	Street	Location	Diameter	Depth	Shape	Lid Condition	Step Iron	Chamber / liner	I&I Score	Batch	Overall Condition Score		2019	2023	2027	2031	2035
1	EA/4	Azalea Street	Grassed verge	1200	1800	Circular	1	2	5	5	265793	3	Remove and replace MH lid and surround and existing MH liner and monitor as recommended	Immediate		Monitor (Cat 2)		
2	EA/3	Azalea Street	Footpath	1200	1900	Circular	2	3	5	5	265794	3	Remove and replace MH lid and surround and existing MH liner and monitor as recommended	Immediate		Monitor (Cat 2)		
3	EA/5	Azalea Street	Grassed verge	1200	1200	Circular			5	5	265795	5	Remove and replace MH	Immediate				
4	EA/1	Azalea Street	Grassed verge	1200	1900	Circular	2	2	4	5	265796	3	Remove and replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
5	EA/2	Azalea Street	Grassed verge	1200	1700	Circular	1	1	3	1	265797	4	Monitor as recommended		Monitor (Cat 1)			
6	E/18	Azalea Street	Grassed verge	1200	1200	Circular	1	1	1	0	265803	3	Monitor as recommended			Monitor (Cat 2)		
7	E/16	Jubilee Avenue	Footpath	1200	1700	Circular	2	3	3	0	265839	3	Install MH liner and monitor as recommended	Immediate		Monitor (Cat 2)		
8	E/14	Jubilee Avenue	Footpath	1200	2200	Circular	1	1	3	1	265841	3	Monitor as recommended			Monitor (Cat 2)		
9	E/13	Jubilee Avenue	Footpath	1200	2700	Circular	3	2	3	2	265842	3	Monitor as recommended			Monitor (Cat 2)		
10	k1	Jubilee Avenue	Grassed verge	1200	2400	Circular	1	1	3	1	265850	3	Monitor as recommended			Monitor (Cat 2)		
11	E/8	Byron Street	Grassed verge	1200	4200	Circular	1	1	3	5	265851	3	Remove and replace MH lid and surround, rectify defect beneath converter slab and remove and replace MH liner. Monitor as recommended	Immediate		Monitor (Cat 2)		
12	E/7	Byron Street	Private - Residential	1200	4100	Circular	1	1	3	1	265853	3	Monitor as recommended			Monitor (Cat 2)		
13	E/9	Byron Street	Grassed verge	1200	3800	Circular	3	1	3	1	265854	3	Monitor as recommended			Monitor (Cat 2)		
14	E/17	Azalea Street	Vegetation adjacent to creek	1200	1300	Circular	3	1	1	0	265862	3	Monitor as recommended			Monitor (Cat 2)		
15	K/2	Jubilee Avenue	Footpath	1200	2000	Circular	1	1	3	1	265889	3	Monitor as recommended			Monitor (Cat 2)		

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16	E/10	Byron Street	Other	1200	4300	Circular	1	2	1	0	265890	3	Monitor as recommended			Monitor (Cat 2)		
17	Unverified	Byron Street	Grassed verge	1200 x 1200	1300	Rectangular	3		3	5	265891	3	Replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
18	E/5	Small Lane	Road pavement	1200	4500	Circular	1	2	3	1	265894	3	Monitor as recommended			Monitor (Cat 2)		
19	E/6	Small Lane	Road pavement	1200	1600	Circular			2	1	265895	2	Monitor as recommended				Leave (Cat 3)	
20	J/1	Small Lane	Road pavement	1200	1600	Circular	1		1	0	265896	2	Monitor as recommended				Leave (Cat 3)	
21	E/4	Myokum Street	Grassed verge	1200	5400	Circular	1	2	5	1	265898	4	Remove intruding roots and remove and replace existing liner and monitor as recommended	Immediate	Monitor (Cat 1)			
22	K/3	Jubilee Avenue	Footpath	1200 x 1200	1000	Rectangular	3		1	5	265947	3	Remove and replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
23	E/12	Jubilee Avenue	Grassed verge	1200	3100	Circular	1		3	1	266040	3	Monitor as recommended			Monitor (Cat 2)		
24	J/2	Small Lane	Private - Residential	1000 x 1000	1300	Rectangular	2		1	0	266042	3	Monitor as recommended			Monitor (Cat 2)		
25	GA/1	Myokum Street	Private - Residential	1200	800	Circular	1		3	1	266075	3	Remove build-up in channel and monitor as recommended	Immediate		Monitor (Cat 2)		
26	E/3	Myokum Street	Grassed verge	1200	6600	Circular	1	2	5	1	266077	3	Remove and replace MH liner and monitor as recommended	Immediate		Monitor (Cat 2)		
27	N/4	Whian Street	Grassed verge	1200	3300	Circular	1	1	3	1	266135	3	Monitor as recommended			Monitor (Cat 2)		
28	N/5	Whian Street	Footpath	1200	2800	Circular	1	1	1	0	266142	4	Monitor as recommended		Monitor (Cat 1)			
29	N/6	Whian Street	Grassed verge	1200	2100	Circular	1	1	3	1	266144	3	Monitor as recommended			Monitor (Cat 2)		
30	T/1	Whian Street	Grassed verge	1200	2000	Circular	1	1	3	1	266145	3	Monitor as recommended			Monitor (Cat 2)		
31	S/1	Jubilee Avenue	Grassed verge	1000 x 1000	1300	Rectangular	2		3	5	266153	3	Remove and replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
32	Unverified	Jubilee Avenue	Private - Residential	1200	1000	Circular	1		1	0	266163	2	Monitor as recommended				Leave (Cat 3)	
33	B/1	Station Street	Grassed verge	1200	2900	Circular	1	1	3	1	266174	3	Monitor as recommended			Monitor (Cat 2)		
34	B/2	Station Street	Grassed verge	1200	2400	Circular	1	1	3	1	266176	3	Monitor as recommended			Monitor (Cat 2)		
35	B/3	Station Street	Private - Residential	1200 x 1200	1400	Rectangular	1		5	1	266177	4	Monitor as recommended		Monitor (Cat 1)			
36	GB/1	Station Street	Private - Residential	1200	2200	Circular	1	1	2	1	266178	2	Monitor as recommended				Leave (Cat 3)	

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37	GC/1	Station Street	Private - Residential	1200	2000	Circular	1	1	1	0	266179	3	Monitor as recommended			Monitor (Cat 2)		
38	GC/2	Station Street	Private - Residential	1200	1300	Circular	1	1	1	0	266180	2	Monitor as recommended				Leave (Cat 3)	
39	BC/1	Station Street	Grassed verge	1200	1600	Circular	1		1	1	266217	1	Monitor as recommended					Leave (Cat 4)
40	N/7	River Terrace	Grassed verge	1200	1700	Circular	1	1	4	1	266219	3	Monitor as recommended			Monitor (Cat 2)		
41	N/8	River Terrace	Footpath	1000 x 1000	1300	Rectangular	1		1	0	266221	3	Monitor as recommended			Monitor (Cat 2)		
42	U/1	Dalley Street	Other	1200	1000	Circular	2		1	0	266223	3	Monitor as recommended			Monitor (Cat 2)		
43	P/1	Fern Street	Footpath	1000 x 1000	1100	Rectangular	1		3	5	266225	3	Remove and replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
44	N/1	Fern Street	Other	1200	4300	Circular	2	2	3	5	266226	3	Remove and replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
45	A/10	Studal Lane	Road pavement	1200	4100	Circular	1	1	1	0	266261	3	Monitor as recommended			Monitor (Cat 2)		
46	W/1	Studal Lane	Road pavement	1200	2000	Circular	1	1	3	1	266262	3	Monitor as recommended			Monitor (Cat 2)		
47	W/2	Studal Lane	Road pavement	1200 x 1200	1500	Rectangular	4		4	5	266265	3	Remove and replace MH lid and surround and monitor as recommended	Immediate		Monitor (Cat 2)		
48	X/1	Stuart Street	Private - Residential	1000 x 1000	1200	Rectangular	1		1	0	266267	3	Monitor as recommended			Monitor (Cat 2)		
49	v/1	Station Street	Road pavement	1200	1800	Circular	1	2	3	1	266270	3	Monitor as recommended			Monitor (Cat 2)		
50	V/2	Station Street	Road pavement	1000 x 1000	1200	Rectangular	1		1	0	266271	3	Monitor as recommended			Monitor (Cat 2)		
51	A/8	Burringbar Street	Road pavement	1200	4400	Circular	1	1	1	0	266272	3	Monitor as recommended			Monitor (Cat 2)		
52	A/7	McGoughans Lane	Road pavement	1200	5300	Circular	1	1	3	1	266273	3	Monitor as recommended			Monitor (Cat 2)		
53	A/6	McGoughans Lane	Road pavement	1200	5600	Circular	1	1	3	1	266274	3	Monitor as recommended			Monitor (Cat 2)		
54	A/5	McGoughans Lane	Road pavement	1200	5900	Circular	1	1	1	0	266275	3	Monitor as recommended			Monitor (Cat 2)		
55	AS/1	McGoughans Lane	Private - Residential	1200	1200	Circular	1		1	0	266276	2	Monitor as recommended				Leave (Cat 3)	
56	AS/2	McGoughans Lane	Private - Residential	1200	1400	Circular	1		1	0	266277	2	Realign existing MH lid and surround and monitor as recommended	Immediate			Leave (Cat 3)	
57	N/2	Studal Lane	Road pavement	1200	4200	Circular	1	1	3	1	266279	3	Monitor as recommended			Monitor (Cat 2)		
58	R/1	Studal Lane	Road pavement	1200	1600	Circular	2	1	3	1	266301	3	Monitor as recommended			Monitor (Cat 2)		
59	R/2	Studal Lane	Road pavement	1200	1300	Circular	1		3	1	266302	3	Monitor as recommended			Monitor (Cat 2)		

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60	CN/1	Brunswick Terrace	Grassed verge	1200 x 1200	1000	Rectangular	1		1	0	266303	3	Monitor as recommended			Monitor (Cat 2)		
61	BB/1	Burringbar Street	Road pavement	1200	3900	Circular	1	1	1	0	266351	3	Monitor as recommended			Monitor (Cat 2)		
62	BB/2	McGoughans Lane	Road pavement	1200	3300	Circular	1	2	3	1	266352	3	Monitor as recommended			Monitor (Cat 2)		
63	BB/3	McGoughans Lane	Road pavement	1200	2600	Circular	2	2	3	1	266353	3	Monitor as recommended			Monitor (Cat 2)		
64	BB/4	McGoughans Lane	Road pavement	1200 x 1200	1300	Rectangular	2		3	1	266354	3	Monitor as recommended			Monitor (Cat 2)		
65	A/9	Burringbar Street	Footpath	1200	4400	Circular	1	1	1	0	266355	2	Monitor as recommended				Leave (Cat 3)	
66	A/11	Burringbar Street	Footpath	1200	4000	Circular	1	1	1	0	266356	2	Monitor as recommended				Leave (Cat 3)	
67	A/12	Burringbar Street	Road pavement	1200	3400	Circular	1	2	1	0	266418	3	Monitor as recommended			Monitor (Cat 2)		
68	BA/1	Azalea Street	Road pavement	1200	2200	Circular	1	2	1	0	266473	3	Monitor as recommended			Monitor (Cat 2)		
69	Ba/2	Station Street	Road pavement	1000 x 1000	1500	Rectangular	1		1	0	266481	3	Monitor as recommended			Monitor (Cat 2)		
70	CM/1	Argyle Street	Garden	1000 x 1000	1000	Rectangular	1		4	1	266482	4	Monitor as recommended		Monitor (Cat 1)			
71	A/13	Jubilee Avenue	Footpath	1200	2600	Circular	2	2	3	5	266497	3	Remove and replace MH lid and surround and install MH liner and monitor as recommended	Immediate		Monitor (Cat 2)		
72	A/14	Jubilee Avenue	Grassed verge	1200	1800	Circular	1	1	3	1	266501	3	Monitor as recommended			Monitor (Cat 2)		
73	A/15	Riley Lane	Road pavement	1200 x 1200	1300	Rectangular	1		3	1	266502	3	Monitor as recommended			Monitor (Cat 2)		
74	Y/1	Cenotaph Lane	Grassed verge	1200	1900	Circular	1	1	3	1	266503	3	Monitor as recommended			Monitor (Cat 2)		
75	Y/2	Cenotaph Lane	Grassed verge	1200 x 1200	1400	Rectangular	2	2	3	1	266504	3	Monitor as recommended			Monitor (Cat 2)		
76	Z/1	River Terrace	Grassed verge	1000 x 1000	1400	Rectangular	1		3	1	266618	3	Monitor as recommended			Monitor (Cat 2)		
77	BD/1	Studal Lane	Road pavement	1200	2800	Circular	1	4	4	1	266620	3	Remove and replace MH liner and monitor as recommended	Immediate		Monitor (Cat 2)		
78	BD/3	Studal Lane	Road pavement	1200 x 1200	1300	Rectangular	1		3	1	266621	3	Monitor as recommended			Monitor (Cat 2)		
79	BD/2	Studal Lane	Road pavement	1200	2100	Circular	1	2	3	1	266622	3	Monitor as recommended			Monitor (Cat 2)		
80	A/16	Riley Lane	Road pavement	1000 x 1000	1300	Rectangular	1		3	1	266645	3	Monitor as recommended			Monitor (Cat 2)		
81	N3	Whian Street	Road pavement	1200	3600	Circular	1	1	1	0	267349	3	Monitor as recommended			Monitor (Cat 2)		
82	E/2	Stuart Street	Grassed verge	1200	6900	Circular	1	1	4	1	267484	4	Install MH liner and monitor as recommended	Immediate	Monitor (Cat 1)			

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83	E/1	Stuart Street	Grassed verge	1200	7000	Circular	1	3	3	1	267485	4	Monitor as recommended		Monitor (Cat 1)			
84	A/1	Stuart Street	Council Land	1200	7200	Circular	1	1	3	1	267486	3	Monitor as recommended			Monitor (Cat 2)		
85	A/3	Fern Street	Road pavement	1200	6250	Circular	1	1	3	1	267691	3	Monitor as recommended			Monitor (Cat 2)		
86	A/4	McGoughans Lane	Road pavement	1200	6400	Circular	1	2	1	0	267697	3	Monitor as recommended			Monitor (Cat 2)		
87	A/2	Fern Street	Road pavement	1200	6700	Circular	1	1	3	1	267698	3	Monitor as recommended			Monitor (Cat 2)		
88	EAA/1	Stuart Street	Private - Residential	1200	1950	Circular	1		1	0	267780	3	Monitor as recommended			Monitor (Cat 2)		
89	EAA/2	Stuart Street	Private - Residential	1200	1400	Circular	1		1	0	267786	3	Monitor as recommended			Monitor (Cat 2)		
90	GC/3	Station Street	Private - Residential	Unknown					1	0	266181	0	Locate and uncover MH	Immediate				
90	BE/1	Stuart Street	Private - Residential	Unknown					1	0	266623	0	Locate and uncover MH	Immediate				
90	E/11	Jubilee Avenue	Private - Residential	Unknown					1	0	266041	0	Locate and uncover MH	Immediate				

5. CONCLUSIONS AND RECOMMENDATIONS

As part of this project, 92 gravity sewer maintenance holes (MHs) were assessed within the 4001 catchment in Mullumbimby, NSW.

Willow & Sparrow Pty Ltd have assessed the available condition assessment information and assigned overall condition scores (risk of failure) to each MH with justification provided in Table 1. Furthermore, rectification works have been recommended where deemed necessary to maintain the assets integrity and function as well as a re-assessment schedule.

Of the 92 MHs that formed the assessment scope, 3 could not be located, of the remaining 89 MHs that were assessed 20 have been recommended for some form of rectification works.

Conceptual construction cost estimates for the MHs recommended for rectification works are listed below in Table 2. A detailed breakdown of the construction cost estimate for each MH can be found in **Attachment 1**.

It is recommended that the scope identified in Table 2 be prepared for tender and completed in FY19/20 at a total estimated cost of **$50,030.00** (±20%) (excl GST).

Table 2 | Conceptual Construction Cost Estimate for Rectification Works

#	Line	Diameter (mm)	Depth (m)	Street	Primary Location	Required Rectification Works	Conceptual Construction Cost Estimate
1	EA/4	1200	1800	Azalea Street	Grassed verge	Remove and replace MH lid and surround and existing MH liner	$2,560.00
2	EA/3	1200	1900	Azalea Street	Asphalt footpath	Remove and replace MH lid and surround and Install MH liner	$2,530.00
3	EA/5	1200	1200	Azalea Street	Grassed verge	Remove and replace MH	$2,840.00
4	EA/1	1200	1900	Azalea Street	Grassed verge	Remove and replace MH lid and surround	$940.00
7	E/16	1200	1700	Jubilee Avenue	Grassed verge	Install MH liner	$1,430.00
11	E/8	1200	4200	Byron Street	Grassed verge	Remove and replace lid and surround, rectify defect beneath converter slab and remove and replace MH liner	$5,520.00
17	Unverified	1200 x 1200	1300	Byron Street	Grassed verge	Replace MH lid and surround	$940.00
21	E/4	1200	5400	Myokum Street	Grassed verge	Remove intruding roots and remove and replace existing liner	$6,110.00
22	K/3	1200 x 1200	1000	Jubilee Avenue	Concrete footpath	Remove and replace MH lid and surround	$1,200.00
25	GA/1	1200	800	Myokum Street	Private - Residential	Remove build-up in channel	$440.00
26	E/3	1200	6600	Myokum Street	Grassed verge	Remove and replace MH liner	$6,180.00
31	S/1	1000 x 1000	1300	Jubilee Avenue	Grassed verge	Remove and replace MH lid and surround	$940.00
43	P/1	1000 x 1000	1100	Fern Street	Grassed verge	Remove and replace MH lid and surround	$940.00
44	N/1	1200	4300	Fern Street	Unsealed roadway	Remove and replace MH lid and surround	$1,900.00
47	W/2	1200 x 1200	1500	Studal Lane	Road pavement	Remove and replace MH lid and surround	$2,000.00
56	AS/2	1200	1400	McGoughans Lane	Private - Residential	Realign existing MH lid and surround	$640.00
71	A/13	1200	2600	Jubilee Avenue	Concrete footpath	Remove and replace MH lid and surround and install MH liner	$3,020.00
77	BD/1	1200	2800	Studal Lane	Road pavement	Remove and replace MH liner	$3,820.00
82	E/2	1200	6900	Stuart Street	Grassed verge	Install MH liner	$5,030.00
90	GC/3			Station Street	Private - Residential	Locate and uncover MH	$350.00
90	BE/1			Stuart Street	Private - Residential	Locate and uncover MH	$350.00
90	E/11			Jubilee Avenue	Private - Residential	Locate and uncover MH	$350.00
						TOTAL	**$50,030.00**

ATTACHMENT 1 – CONCEPTUAL COST ESTIMATES FOR MAINTENANCE HOLE RECTIFICATION WORKS

Schedule of uantities and Prices

Rectification of Sewer MH - EA/4

M HP	G P			P ME P	P P f
	r r r				
	r d M d d			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P f
	d				
	d d				
	d d				
N P PM M P N M RM					D B
M HP	G P			P ME P	P P f
	r	d			
	d r d r r			M	d r d
	d r r r M		r		d
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r				
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P ME P	P P f
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		D E

Schedule of uantities and Prices

Rectification of Sewer MH - EA/3

M HP	G P			P ME P	P P f
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P f
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r d				
	d r d r r			M	d r d
	d r r r M		r		d
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r				
	r				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		D E

Schedule of uantities and Prices

Rectification of Sewer MH - EA/5

M HP	G P			P ME P	P p f
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M	P P N M				
M HP	G P			P ME P	P p f
	d				
	d d				
	d d				
	d d				
N P PM M	P N M RM				
M HP	G P			P ME P	P p f
	r	d			
	d r d r r			M	d r d
	d r r r M		r		d
	d r M				
N P PM M	P N M RM				
M HP	G P			P ME P	P p f
	r				
	r				
	r				
N P PM M	P N M RM				B
M HP	G P			P ME P	P p f
	r				
		r			
	r	r			
	i				
	r	r			
	r	r			
N P PM M	P N M RM				

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M	P	

Schedule of uantities and Prices						
Rectification of Sewer MH - EA/1						
M HP	G P			P MP E	P P f	
	r r r					
	d d r d M			d	r	r
	r r r					
N P PM M	P P N M					
M HP	G P			P MP E	P P f	
	d					
	d d					
	d d					
N P PM M	P N M RM					
M HP	G P			P MP E	P P f	
	r	d				
	d r d r r			M	d r	d
	d r r r M		r		d	
N P PM M	P N M RM				D B	
M HP	G P			P MP E	P P f	
	r					
	r					
	r					
N P PM M	P N M RM				B	
M HP	G P			P MP E	P P f	
	r					
		r				
	r	r				
	I					
	r	r				
	r	r				
N P PM M	P N M RM					
Summary of Schedule of Rates						
P	G				P	
	r r r					
	d					
	r d					
	r					
	r					
PM M	P				E B	

Schedule of uantities and Prices

Rectification of Sewer MH - E/16

M HP	G P			P MḄ	P	P f
	r r r					
	r d M d d			d	r	r
	r r r					
N P PM M	P P N M					
M HP	G P			P MḄ	P	P f
	d					
	d d					
	d d					
N P PM M	P N M RM					
M HP	G P			P MḄ	P	P f
	r	d				
	r r d r d			M	d r	d
	M d r r r		r		d	
N P PM M	P N M RM					E
M HP	G P			P MḄ	P	P f
	r					
	r					
	r					
N P PM M	P N M RM					B
M HP	G P			P MḄ	P	P f
	r					
		r				
	r	r				
	I					
	r	r				
	r	r				
N P PM M	P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M	P	

Schedule of uantities and Prices

Rectification of Sewer MH - E/8

M HP	G P			P ME P	P P t
	r r r				
	d d r d M			d	r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P t
	d				
	d d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P t
	r	d			
	d r d r r			M	d r
	d r r r M		r		d
	d r d				
N P PM M P N M RM					E
M HP	G P			P ME P	P P t
	r				
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P ME P	P P t
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		D D B

Schedule of uantities and Prices

Rectification of Sewer MH - Unverified

M HP	G P			P ME P	P P r
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P r
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P r
	r	d			
	d r d r r			M	d r d
	d r r r M		r		d
N P PM M P N M RM					D B
M HP	G P			P ME P	P P r
	r				
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P ME P	P P r
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		E B

Schedule of uantities and Prices

Rectification of Sewer MH - E/4

M HP	G P			P MEP	P P f
	r r r				
	d d r d M			d	r
	r r r				
N P PM M	P P N M				
M HP	G P			P MEP	P P f
	d				
	d d				
	d d				
N P PM M	P N M RM				
M HP	G P			P MEP	P P f
	r	d			
	d r d r r			M	d r
	d r r r M		r		d
N P PM M	P N M RM				
M HP	G P			P MEP	P P f
	r				
	r				
	r				
N P PM M	P N M RM				B
M HP	G P			P MEP	P P f
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M	P N M RM				

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M	P	

Schedule of uantities and Prices

Rectification of Sewer MH - K/3

M HP	G P			P ME P	P P t
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M	P P N M				
M HP	G P			P ME P	P P t
	d				
	d d				
	d d				
N P PM M	P N M RM				
M HP	G P			P ME P	P P t
	r	d			
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M	P N M RM				D B
M HP	G P			P ME P	P P t
	r				
	r				
N P PM M	P N M RM				
M HP	G P			P ME P	P P t
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M	P N M RM				

Summary of Schedule of Rates

P	G		P
	r r r		
	d		
	r	d	
	r		
	r		
PM M	P		

Schedule of uantities and Prices

Rectification of Sewer MH - GA/1

M HP	G P			P MP	P P f
r r r					
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P MP	P P f
d					
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P MP	P P f
r d					
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					
M HP	G P			P MP	P P f
r					
	r				
	r				
N P PM M P N M RM					
M HP	G P			P MP	P P f
r					
		r			
	r	r			
	l				
	r	r			
	r	r			
	r r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		B

Schedule of uantities and Prices

Rectification of Sewer MH - E/3

M HP	G P			P MEP	P P I
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P MEP	P P I
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P MEP	P P I
	r d				
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					
M HP	G P			P MEP	P P I
	r				
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P MEP	P P I
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		

Schedule of uantities and Prices

Rectification of Sewer MH - S/1

M HP	G P			P MI P	P P I
r r r					
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P MI P	P P I
d					
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P MI P	P P I
r d					
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					D B
M HP	G P			P MI P	P P I
r					
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P MI P	P P I
r					
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		E B

Schedule of uantities and Prices

Rectification of Sewer MH - P/1

M HP	G P			P ME P	P P r
r	r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P r
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P r
	r	d			
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					D B
M HP	G P			P ME P	P P r
	r				
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P ME P	P P r
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		E B

Schedule of uantities and Prices

Rectification of Sewer MH - N/1

M HP	G P			P ME P	P P r
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P r
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P r
	r d				
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					D B
M HP	G P			P ME P	P P r
	r				
	r				
N P PM M P N M RM					
M HP	G P			P ME P	P P r
	r				
		r			
	r	r			
	l				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		E B

Schedule of uantities and Prices					
Rectification of Sewer MH - W/2					
M HP	G P			P ME P	P P f
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P f
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r d				
	d r d r r			M	d r d
	d r r r M		r		d
N P PM M P N M RM					D B
M HP	G P			P ME P	P P f
	r				
	r				
	r				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r				
		r			
	r	r			
	l				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates		
P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		

Schedule of uantities and Prices

Rectification of Sewer MH - AS/2

M HP	G P			P ME P	P p r
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P p r
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P p r
	r	d			
	d r d r r			M	d r d
	d r r r M		r		d
N P PM M P N M RM					
M HP	G P			P ME P	P p r
	r				
	r				
	r				
N P PM M P N M RM					B
M HP	G P			P ME P	P p r
	r				
		r			
	r	r			
	l				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		B

Schedule of uantities and Prices

Rectification of Sewer MH - A/13

M HP	G P			P ME P	P P f
r r r					
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P f
d					
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
r d					
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					
M HP	G P			P ME P	P P f
r					
	r				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
r					
		r			
	r	r			
	l				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		

Schedule of uantities and Prices

Rectification of Sewer MH - BD/1

M HP	G P			P MEP	P P r
	r r r				
	d d r d M			d	r r
	r r r				
N P PM M	P P N M				
M HP	G P			P MEP	P P r
	d				
	d d				
	d d				
N P PM M	P N M RM				D B
M HP	G P			P MEP	P P r
	r d				
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M	P N M RM				E
M HP	G P			P MEP	P P r
	r				
	r				
	r				
N P PM M	P N M RM				
M HP	G P			P MEP	P P r
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M	P N M RM				

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M	P	

Schedule of uantities and Prices Rectification of Sewer MH - E/2					
M HP	G P			P ME P	P P f
r	r r				
	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P f
	d				
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r d				
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r				
	r				
	r				
N P PM M P N M RM					
M HP	G P			P ME P	P P f
	r				
		r			
	r	r			
	l				
	r	r			
	r	r			
N P PM M P N M RM					

Summary of Schedule of Rates		
P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		D E

Schedule of uantities and Prices

Rectification of Sewer MH - GC/3

M HP	G P			P ME P	P P r
r r r					
	r d M d d			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P r
d					
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P ME P	P P r
r d					
	r r d r d			M	d r d
	M d r r r			r	d
N P PM M P N M RM					
M HP	G P			P ME P	P P r
r					
	r				
	r				
N P PM M P N M RM					
M HP	G P			P ME P	P P r
r					
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M P N M RM					D B

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		D B

Schedule of uantities and Prices

Rectification of Sewer MH - E/11

M HP	G P			P MP E	P P f
r r r					
	r d M d d			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P MP E	P P f
d					
	d d				
	d d				
N P PM M P N M RM					
M HP	G P			P MP E	P P f
r d					
	d r d r r			M	d r d
	d r r r M			r	d
N P PM M P N M RM					
M HP	G P			P MP E	P P f
r					
	r				
	r				
N P PM M P N M RM					
M HP	G P			P MP E	P P f
r					
		r			
	r	r			
	l				
	r	r			
	r	r			
N P PM M P N M RM					D B

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M P		D B

Schedule of uantities and Prices

Rectification of Sewer MH - E/11

M HP	G P			P ME P	P P r
r	r r				
	d d r d M			d	r
	r r r				
N P PM M	P P N M				
M HP	G P			P ME P	P P r
	d				
	d d				
	d d				
N P PM M	P N M RM				
M HP	G P			P ME P	P P r
	r	d			
	d r d r r			M	d r
	d r r r M		r		d
N P PM M	P N M RM				
M HP	G P			P ME P	P P r
	r				
	r				
	r				
N P PM M	P N M RM				
M HP	G P			P ME P	P P r
	r				
		r			
	r	r			
	I				
	r	r			
	r	r			
N P PM M	P N M RM				D B

r

d

Summary of Schedule of Rates

P	G	P
	r r r	
	d	
	r d	
	r	
	r	
PM M	P	D B

END OF REPORT

Willow+ Sparrow

Mullumbimby – Stormwater Condition Assessment

Prepared for: Byron Shire Council

DOCUMENT CONTROL

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Contents

ABBREVIATIONS

BSC	Byron Shire Council
CCTV	Closed-Circuit Television
DN	Nominal Diameter
MH	Maintenance Hole
PP	Polypropylene
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe

1. INTRODUCTION

Willow & Sparrow Pty Ltd has been engaged by Byron Shire Council (BSC) to prepare a Condition Assessment report for the stormwater network in Mullumbimby, NSW.

1.1 Project background

To date, a water sensitive approach has not been considered through the management of the stormwater network in Mullumbimby. As a result of this in addition to degrading and insufficiently sized infrastructure, poor conveyance and isolated flooding occurs frequently during wet weather events. It has been identified that the sewer network within Mullumbimby is suffering from high rates of Inflow and Infiltration with a contributing factor being flood waters during wet weather events in which the potential for infiltration into the sewer system is increased.

Council wishes to undertake a prudent process to confirm the condition of the stormwater network, determine which mains require rehabilitation or replacement in order of priority, and to then procure the rehabilitation or replacement of the stormwater culverts deemed to be in poor condition. It is imperative that the proposed works align with the requirements of the Water Sensitive Urban Design (WSUD) strategy.

Due to the uncertainty as to which mains are to be replaced, it is anticipated that the project be delivered in two stages, with a hold point at the completion of stage 1. This hold point will enable Council to review this Condition Assessment report and determine which stormwater culverts will be carried forward into the rehab/replace phase of the project in FY19/20.

The two stages of work are:

- Stage 1 – Condition Assessment of each stormwater culvert, and
- Stage 2 – Procurement and delivery of the stormwater culvert rectification works

1.2 Scope

Willow & Sparrow Pty Ltd were provided with CCTV footage of the relevant sections of stormwater culverts by Interflow Pty Ltd. This Condition Assessment report provides a record of the findings of the visual CCTV inspections and a completed decision tree and risk matrix.

1.3 Site description

This Condition Assessment report has been prepared for the stormwater catchment as shown in Figure 1. This portion of the stormwater system aids with the transfer of stormwater from a catchment that consists of hundreds of residential properties in addition to the Mullumbimby CBD. The stormwater culverts encompassed by the blue hatch in Figure 1 are the culverts that have been addressed in this Condition Assessment report.

Figure 1 | Stormwater Catchment– Mullumbimby, NSW, Source: Byron Shire Council GeoCortex 2019

2. CCTV INSPECTION RECORDS – STORMWATER CATCHMENT

2.1 Tincogan Street | Line HWL-1273 / HWL-1272| D-MBY-UPC-1089 | (16.76m)

The entire culvert is comprised of DN375 RCP. The culvert and associated joints are in poor condition with breaking, radial displacement, and exposed reinforcement all identified. There are no junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 1 for a summary of findings.

Figure 2 |Pipe breaking, Chg7.14m

Figure 3 | Displacement, Chg 11.73m

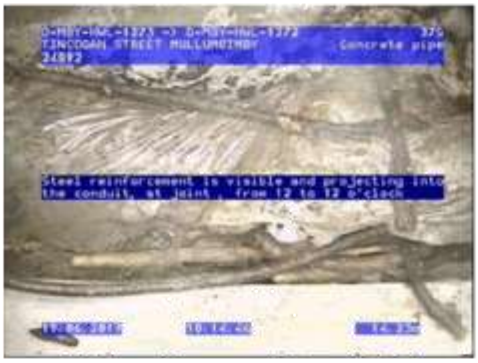

Figure 4 | Exposed reinforcement, Chg14.23m

Figure 5 | Exposed reinforcement, Chg14.23m

Table 1 | Line HWL-1273 / HWL-1272

Chainage (m)	Figure	Item	Observation
0 –16.76	-	Main	DN375 RCP
7.14	2	Breaking	Pipe breaking at 7 O'clock with exposed reinforcement
11.73	3	Displacement	Radial displacement of 10-20mm at 9 O'clock
14.23	4/5	Reinforcement	Exposed reinforcement from 12-12 O'clock

2.2 Tincogan Street | Line U/S / HWL-1273 | D-MBY-UPC-1091| (3.12m)

The entire culvert is comprised of DN225 RCP. The culvert and associated joints are in reasonable condition with only exposed aggregate and root intrusion identified. There are no junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 2 for a summary of findings.

Figure 6 |Exposed aggregate, Chg2.13m

Figure 7 | Root intrusion, Chg2.37m

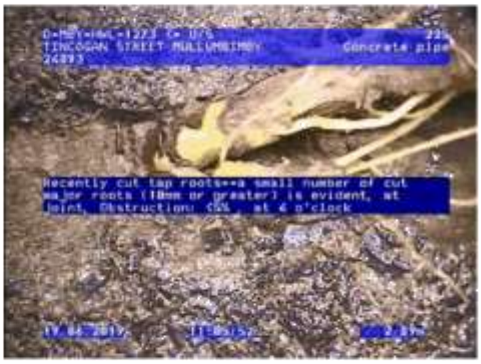

Figure 8 | Root intrusion, Chg2.89m

Figure 9 | Obstruction, Chg3.12m

Table 2 | Line U/S / HWL-1273

Chainage (m)	Figure	Item	Observation
0 –3.12	-	Main	DN225 RCP
2.13	6	Exposed aggregate	Exposed aggregate in the pipe wall from 7-5 O'clock
2.37	7	Roots	Root intrusion with obstruction of 5-20% from 4-6 O'clock
2.89	8	Roots	Major root 10mm wide – post cut
3.12	9	Obstruction	Material obstruction in the invert of the pipe

2.3 Brunswick Terrace | Line HWL-1274 / HWL-1275 | D-MBY-UPC-1092| (18.15m)

The entire culvert is comprised of DN450 RCP. The culvert and associated joints are in good condition with only minor joint displacement and root intrusion identified. There are no junctions on this culvert which was reportedly installed in 1940 (79 years).Refer to the below figures and Table 3 for a summary of findings.

Figure 10 |Displacement, Chg11.90m

Figure 11 | Root intrusion, Chg17.07m

Table 3 | Line HWL-1274 / HWL-1275			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –18.15	-	Main	DN450 RCP
11.90	10	Displacement	Radial joint displacement of 10-20mm at 6 O'clock
17.07	11	Roots	Root intrusion with obstruction of <5% at 6 O'clock

2.4 Brunswick Terrace | Line U/S / HWL-1274| D-MBY-UPC-1093 | (3.64m)

The entire culvert is comprised of a 600W x 400H RCBC. The culvert and associated joints are in reasonable condition but have been subject to corrosion with exposed aggregate and reinforcement evident throughout. There are no junctions on this culvert which was reportedly installed in 1940 (79 years).Refer to the below figures and Table 4 for a summary of findings.

Figure 12 |Exposed reinforcement, Chg0.39m

Figure 13 | Exposed aggregate, Chg0.39m

Table 4 | Line U/S / HWL-1274			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 3.64	-	Main	600W x 400H RCBC
0.39	12	Reinforcement	Exposed reinforcement at 12 O'clock
0.39	13	Aggregate	Exposed aggregate throughout the culvert

2.5 Burringbar Street | Line IPT-1276 / HWL-1277| D-MBY-UPI-1061| (25.92m)

The entire culvert is comprised of a DN375 RCP. The culvert and associated joints are in good condition apart from a single joint subject to isolated breaking. There are no junctions on this culvert which was reportedly installed in 1960 (59 years). Refer to the below figures and Table 5 for a summary of findings.

Figure 14 |Breaking, Chg12.10m

Figure 15 | General condition, Chg12.31m

Table 5 | Line IPT-1276 / HWL-1277

Chainage (m)	Figure	Item	Observation
0 –25.92	-	Main	DN375 RCP
12.10	14	Breaking	Pipe wall breaking at joint, length of break is 100mm at 5 O'clock
12.31	15	General condition	Typical pipe condition

2.6 Station Street | Line HWL-1224 / GIP-1522 | D-MBY-UPI-1309| (24.69m)

The entire culvert is comprised of a DN450 RCP. The culvert and associated joints are in reasonable condition with various minor defects identified such as cracking, infiltration, exposed reinforcement, and joint displacement. There are two junctions on this culvert which was reportedly installed in 1979 (40 years).Refer to the below figures and Table 6 for a summary of findings.

Figure 16 |Cracking, Chg8.67m

Figure 17 | Infiltration, Chg11.84m

Figure 18 | Junction, Chg12.11m

Figure 19 | Cracking, Chg 16.05m

Figure 20 |Infiltration, Chg18.56m

Figure 21 | Breaking, Chg19.76m

Figure 22 |Junction, Chg22.22m

Figure 23 | Soil visible, Chg23.44m

Table 6 | Line HWL-1224 / GIP-1522

Chainage (m)	Figure	Item	Observation
0 – 24.69	-	Main	DN450 RCP
8.67	16	Lifting eye seal	Cracking due to lifting eye seal 3mm wide from 11-1 O'clock
11.84	17	Lifting eye seal	Minor infiltration due to lifting eye seal from 11-1 O'clock
12.11	18	Junction	DN100 PVC junction open at 10 O'clock with reinforcement exposed connection
16.05	19	Lifting eye seal	Cracking due to lifting eye seal 3mm wide from 11-1 O'clock
18.56	20	Lifting eye seal	Minor infiltration due to lifting eye seal from 11-1 O'clock
19.76	21	Breaking	Pipe wall breaking at joint, length of break is 100mm at 6 O'clock
22.22	22	Junction	DN100 PVC junction open at 10 O'clock with reinforcement exposed connection
23.44	23	Lifting eye seal	Soil visible through lifting eye seal

2.7 Orchid Street | Line GIP-1522 / GIP-1223 | D-MBY-UPI-0983| (27.27m)

The entire culvert is comprised of a DN450 RCP. The culvert and associated joints are in reasonable condition with various minor defects identified such as cracking, infiltration, and breaking. There is a single junction on this culvert which was reportedly installed in 1975 (44 years).Refer to the below figures and Table 7 for a summary of findings.

Figure 24 |Infiltration, Chg6.02m

Figure 25 | Infiltration, Chg8.41m

Figure 26 | Lifting eye seal, Chg16.11m

Figure 27 | Junction, Chg 19.11m

Figure 28 | Breaking, Chg27.07m

Table 7 | Line GIP-1522 / GIP-1223

Chainage (m)	Figure	Item	Observation
0 – 27.27	-	Main	DN450 RCP
6.02	24	Lifting eye seal	Minor infiltration due to lifting eye seal from 11-1 O'clock
8.41	25	Lifting eye seal	Minor infiltration due to lifting eye seal from 11-1 O'clock
16.11	26	Lifting eye seal	Lifting eye seal with isolated breaking
19.11	27	Junction	DN100 PVC junction open at 2 O'clock
27.07	28	Breaking	Pipe wall breaking at connection to MH, length of break is 300mm from 7-9 O'clock

2.8 Orchid Street | Line GIP-1223 / GIP-6497 | D-MBY-UPI-0982 | (19.69m)

The entire culvert is comprised of a DN450 RCP. The culvert and associated joints are in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 1975 (44 years). Refer to the below figures and Table 8 for a summary of findings.

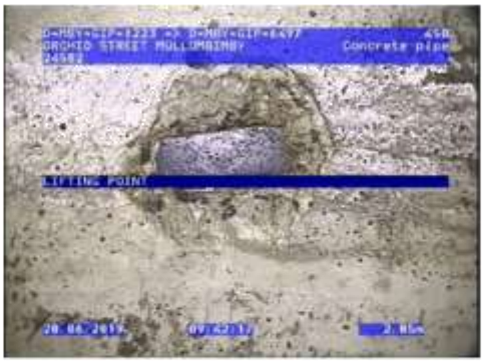

Figure 29 |Lifting eye seal, Chg2.05m

Figure 30 | General condition, Chg2.06m

Table 8 | Line GIP-1223 / GIP-6497

Chainage (m)	Figure	Item	Observation
0 –19.69	-	Main	DN450 RCP
2.05	29	Lifting eye seal	Lifting eye seal visible
2.06	30	General condition	Typical pipe condition

2.9 Orchid Street | Line GIP-6497 / GIP-1221| D-MBY-UPI-0982 | (15.09m)

The entire culvert is comprised of a DN450 RCP. The culvert and associated joints are in reasonable condition with only minor defects identified such as breaking, infiltration, and visible reinforcement. There are no junctions on this culvert which was reportedly installed in 1975 (44 years). Refer to the below figures and Table 9 for a summary of findings.

Figure 31 |Breaking, Chg7.35m

Figure 32 | Lifting eye seal, Chg8.79m

Figure 33 | Lifting eye seal, Chg11.23m

Figure 34 | Breaking, Chg 14.83m

Table 9 | Line GIP-6497 / GIP-1221

Chainage (m)	Figure	Item	Observation
0 – 15.09	-	Main	DN450 RCP
7.35	31	Breaking	Pipe wall breaking at joint, length of break is 100mm at 4 O'clock
8.79	32	Lifting eye seal	Lifting eye seal visible
11.23	33	Lifting eye seal	Lifting eye seal visible
14.83	34	Breaking	Pipe wall breaking at joint, length of break is 100mm at 4 O'clock

2.10 Orchid Street | Line FIP-1222 / GIP-1221 | D-MBY-UPI-0981| (19.33m)

The entire culvert is comprised of a DN375 RCP. The assessment was terminated after 8.31m due to significant root intrusion. Apart from the isolated root intrusion, the culvert and associated joints are in reasonable condition with only some exposed aggregate identified. There are no junctions on the section of this culvert that was assessed which was reportedly installed in 1996 (23 years).Refer to the below figures and Table 10 for a summary of findings.

Figure 35 |Lifting eye seal, Chg1.12m

Figure 36 | Exposed aggregate, Chg2.30m

Figure 37 | Significant root intrusion, Chg 8.31m

Table 10 | Line FIP-1222 / GIP-1221

Chainage (m)	Figure	Item	Observation
0 –8.31	-	Main	DN375 RCP
1.12	35	Lifting eye seal	Lifting eye seal visible
2.30	36	Aggregate	Isolated exposed aggregate in the pipe wall
8.31	37	Roots	Root intrusion with obstruction between 5-20% from 4-5 O'clock

2.11 Station Street | Line KIP-6496 / GIP-6497 | D-MBY-UPI-6416 | (14.54m)

The entire culvert is comprised of a DN225 PVC pipe. The culvert and associated joints are in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 2017 (2 years). Refer to the below figures and Table 11 for a summary of findings.

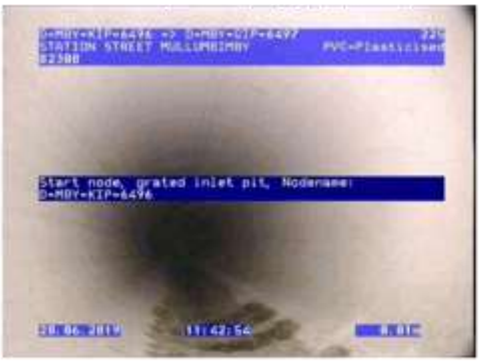

Figure 38 | General condition, Chg0.01m

Table 11 | Line KIP-6496 / GIP-6497			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –14.54	-	Main	DN225PVC
0.01	38	General Condition	Main in good condition

2.12 Station Street | Line KIP-6496 / GIP-6497 | D-MBY-UPI-6417 | (14.46m)

The entire culvert is comprised of a DN225 PVC pipe. The culvert and associated joints are in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 2017 (2 years). Refer to the below figures and Table 12 for a summary of findings.

Figure 39 | General condition, Chg0.00m

Table 12 | Line KIP-6496 / GIP-6497			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –14.46	-	Main	DN225 PVC
0.0	39	General Condition	Main in good condition

2.13 Burringbar Street | Line KIP-1300 / JPT-1297| D-MBY-UPI-0960| (8.41m)

The entire culvert is comprised of a DN375 RCP. The culvert and associated joints are in poor condition with identified defects including an isolated hole in the pipe wall, minor cracking, visible reinforcement, exposed aggregate, and slow ingress of infiltration. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 13 for a summary of findings.

Figure 40 |Hole, Chg0.55m

Figure 41 | Lifting eye seal, Chg 2.70m

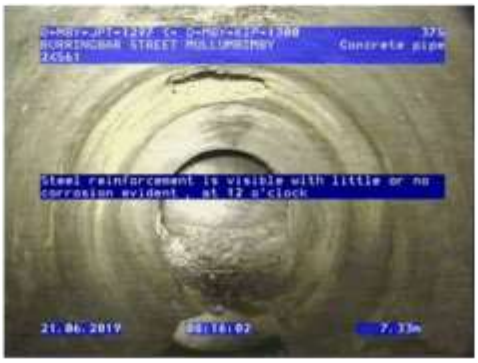

Figure 42 |Lifting eye seal, Chg7.33m

Figure 43 |Cracking, Chg7.49m

Figure 44 |Obstruction, Chg7.88m

Table 13 | Line KIP-1300 / JPT-1297			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 8.41	-	Main	DN375 RCP
0.55	40	Hole	Hole in pipe wall 100mm dia. From 2-3 O'clock
2.70	41	Lifting eye seal	Lifting eye seal visible
7.33	42	Lifting eye seal	Lifting eye seal visible
7.49	43	Cracking	Longitudinal cracking 2mm wide at 12 O'clock
7.88	44	Obstruction	Obstruction of 5-20% due to compacted material from 7-9 O'clock

2.14 Burringbar Street | Line KIP-1301 / JPT-1299 | D-MBY-UPI-0955 | (15.74m)

The entire culvert is comprised of a DN375 RCP. The culvert and associated joints are in poor condition with identified defects including an isolated hole in the pipe wall, minor cracking, and joint displacement. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 14 for a summary of findings.

Figure 45 |Lifting eye seal, Chg0.54m

Figure 46 | Loose rubber seal, Chg6.59m

Figure 47 |Displacement, Chg14.07m

Figure 48 |Hole, Chg14.85m

Table 14 | Line KIP-1301 / JPT-1299

Chainage (m)	Figure	Item	Observation
0 –15.74	-	Main	DN375 RCP
0.54	45	Lifting eye seal	Lifting eye seal visible
6.59	46	Loose seal	Rubber seal has become detached from joint allowing infiltration into the system
14.07	47	Displacement	Longitudinal joint displacement of 20-30mm
14.85	48	Hole	Hole in pipe wall 100mm dia. At 1 O'clock. Some points have extended right through

2.15 Burringbar Street | Line JPT-1302 / JPT-1299 | D-MBY-UPI-0951 | (19.76m)

The entire culvert is comprised of a DN525 RCP. The culvert and associated joints are in reasonable condition with identified defects including joint displacement and exposed reinforcement. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 15 for a summary of findings.

Figure 49 |Displacement, Chg1.57m

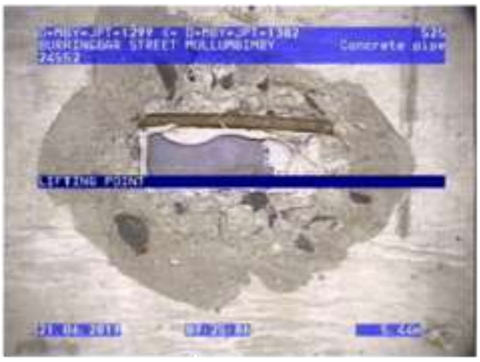

Figure 50 | Lifting eye seal, Chg5.44m

Figure 51 | Lifting eye seal, Chg12.88m

Table 15 | Line JPT-1302 / JPT-1299			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –19.76	-	Main	DN525 RCP
1.57	49	Displacement	Longitudinal joint displacement of 10-20mm
5.44	50	Reinforcement	Exposed reinforcement adjacent to existing lifting eye seal
12.88	51	Reinforcement	Exposed reinforcement adjacent to existing lifting eye seal

2.16 Burringbar Street | Line JPT-1299 / JPT-1297 | D-MBY-UPI-0950 | (64.11m)

The entire culvert is comprised of a DN525 RCP. The culvert and associated joints are in reasonable condition with identified defects including isolated exposed reinforcement and cracking and various points of minor seepage at lifting eye seals. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 16 for a summary of findings.

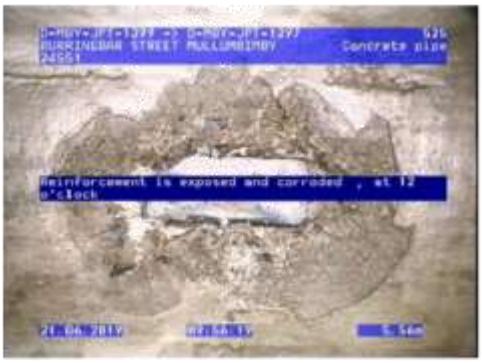

Figure 52 |Reinforcement, Chg5.56m

Figure 53 | Infiltration, Chg 10.48m

Figure 54 |Cracking, Chg63.81m

Table 16 | Line JPT-1299 / JPT-1297

Chainage (m)	Figure	Item	Observation
0 –64.11	-	Main	DN525 RCP
5.56	52	Displacement	Longitudinal joint displacement of 10-20mm
10.48	53	Infiltration	Signs of infiltration (wall staining) at numerous lifting eye seals throughout the alignment
63.81	54	Cracking	Circumferential cracking 2mm wide from 8-3 O'clock

2.17 Burringbar Street | Line JPT-1302 / JPT-1303 | D-MBY-UPI-0952 | (39.14m)

The entire culvert is comprised of a DN375 RCP. The culvert and associated joints are in good condition with identified defects including isolated exposed reinforcement. There are no junctions on this culvert which was reportedly installed in 1993 (26 years).Refer to the below figures and Table 17 for a summary of findings.

Figure 55 |Reinforcement, Chg11.87m

Figure 56 | Reinforcement, Chg31.68m

Table 17 | Line JPT-1302 / JPT-1303

Chainage (m)	Figure	Item	Observation
0 –39.14	-	Main	DN375 RCP
11.87	55	Reinforcement	Exposed reinforcement at pipe joint subject to corrosion
31.68	56	Reinforcement	Exposed reinforcement at pipe joint subject to corrosion

2.18 Burringbar Street | Line KIP-1499 / JPT-1303 | D-MBY-UPI-0956 | (16.10m)

The entire culvert is comprised of a DN375 RCP. The culvert and associated joints are in reasonable condition with identified defects including surface cracking, minor joint displacement, and isolated wall roughening. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 18 for a summary of findings.

Figure 57 |Cracking, Chg0.83m

Figure 58| Roughening, Chg9.41m

Figure 59 |Displacement, Chg14.42m

Table 18 | Line JPT-1302 / JPT-1303

Chainage (m)	Figure	Item	Observation
0 –16.10	-	Main	DN375 RCP
0.83	57	Cracking	Longitudinal surface cracking 1mm wide at 12 O'clock
9.41	58	Roughening	Roughening of the pipe wall from 11-12 O'clock
14.42	59	Displacement	Longitudinal joint displacement of 10-20mm

2.19 Burringbar Street | Line KIP-1304 / JPT-1303 | D-MBY-UPI-0953| (9.27m)

The entire culvert is comprised of a DN375 RCP. The culvert and associated joints are in reasonable condition with identified defects including surface cracking, minor joint displacement, and exposed reinforcement. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 19 for a summary of findings.

Figure 60 | Cracking, Chg2.02m

Figure 61 | Displacement, Chg4.58m

Figure 62 |Breaking, Chg7.03m

Table 19 | Line KIP-1304 / JPT-1303

Chainage (m)	Figure	Item	Observation
0 –9.27	-	Main	DN375 RCP
2.02	60	Cracking	Longitudinal surface cracking 1mm wide at 12 O'clock
4.58	61	Displacement	Longitudinal joint displacement of 10-20mm
7.03	62	Breaking	Pipe breaking at pipe joint resulting in exposure of reinforcement which is subject to corrosion

2.20 Fern Street | Line GIP-1221 / JPT-1220 | D-MBY-UPI-0980 | (52.50m)

The entire culvert is comprised of a DN450 RCP. The assessment was terminated after 29.42m due to rubble obstructing the assessment. The main is in particularly poor condition and appears to have somewhat collapsed at the invert. There are no junctions on the section of this culvert that was assessed which was reportedly installed in 1996 (23 years). Refer to the below figures and Table 20 for a summary of findings.

Figure 63 |Broken pipe, Chg8.33m

Figure 64| Root intrusion, Chg8.33m

Table 20 | Line GIP-1221 / JPT-1220

Chainage (m)	Figure	Item	Observation
0 –29.42	-	Main	DN450 RCP
8.33	63	Broken pipe	Pipe collapsed at the invert
8.33	64	Roots	Roots entering the pipe

2.21 Cedar Street | Line HWL-1232 / HWL-1233| D-MBY-UPC-0988| (6.30m)

The entire culvert is comprised of a DN225 RCP. The main is in particularly poor condition and appears to have been subject to corrosion of the pipe wall as the entire main is subject to exposed aggregate with isolated points subject to root intrusion and joint displacement. There are no junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 21 for a summary of findings.

Figure 65 |Exposed aggregate, Chg0.24m

Figure 66| Root intrusion, Chg0.96m

Figure 67 |Root intrusion, Chg1.63m

Figure 68 | Displacement, Chg5.39m

Table 21 | Line HWL-1232 / HWL-1233

Chainage (m)	Figure	Item	Observation
0 – 6.30	-	Main	DN225 RCP
0.24	65	Aggregate	Exposed aggregate throughout the entire culvert indicating corrosion
0.96	66	Roots	Root intrusion at joint obstruction <5% from 2-5 O'clock
1.63	67	Roots	Root intrusion at joint obstruction <5% from 7-9 O'clock
5.39	68	Displacement	Longitudinal joint displacement 10-20mm

2.22 Myokum Street | Line HWL-1225 / HWL-1226 | D-MBY-UPC-0984 | (25.52m)

The entire culvert is comprised of a DN300 RCP. The main is in particularly poor condition and is subject to defects such as exposed reinforcement, joint displacement, cracking, and breaking. There are no junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 22 for a summary of findings.

Figure 69 |Reinforcement, Chg0.81m

Figure 70 | Radial displacement,Chg1.66m

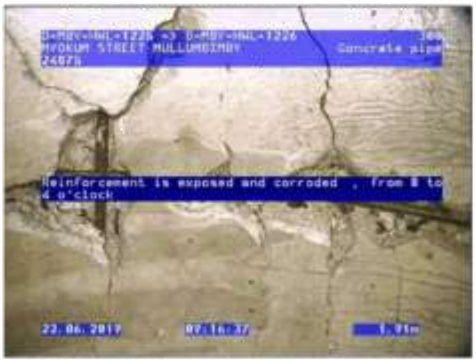

Figure 71 | Reinforcement, Chg1.91m

Figure 72 | Cracking, Chg 2.60m

Figure 73 | Break, Chg3.42m

Figure 74 | Break, Chg 4.90m

Table 22 | Line HWL-1225 / HWL-1226			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 5.45	-	Main	DN300 RCP
0.81	69	Reinforcement	Reinforcing steel exposed through major cracking from 12-12 O'clock
1.66	70	Displacement	Radial joint displacement >20mm at 9 O'clock
1.91	71	Reinforcement	Reinforcing steel exposed through major cracking from 8-4 O'clock
2.60	72	Cracking	Circumferential cracking 6mm wide from 12-12 O'clock
3.24	73	Break	Large break in obvert of pipe at joint which is also subject to radial displacement >50mm
4.90	74	Break	Large break in pipe from 12-12 O'clock at joint which is also subject to radial displacement >20mm

2.23 Byron Street | Line HWL-1231 / D/S Myokum| D-MBY-UPC-0987 | (23.06m)

The entire culvert is comprised of a DN300 RCP. The main is in particularly poor condition and is subject to defects such as exposed reinforcement, joint displacement, cracking, and breaking. There are no junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 23 for a summary of findings.

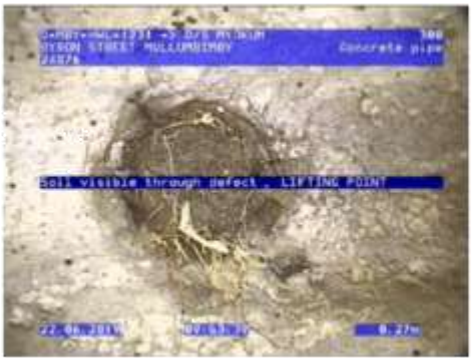

Figure 75 |Lifting eye seal, Chg0.27m

Figure 76| Displacement,Chg0.68m

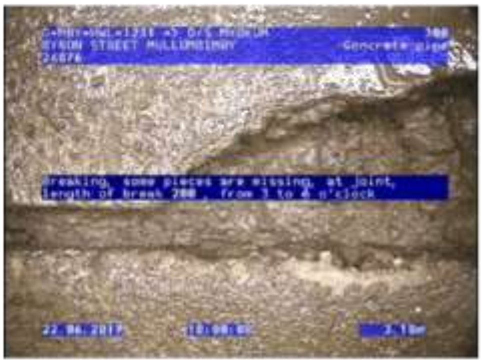

Figure 77 |Breaking, Chg3.18m

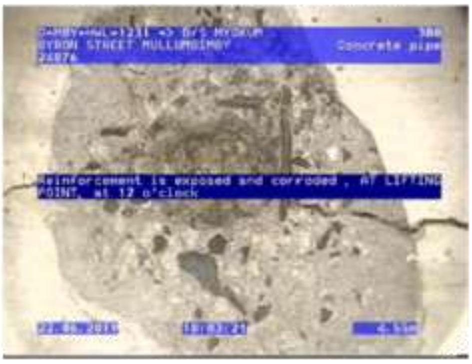

Figure 78| Lifting eye seal, Chg4.55m

Figure 79 |Cracking, Chg9.30m

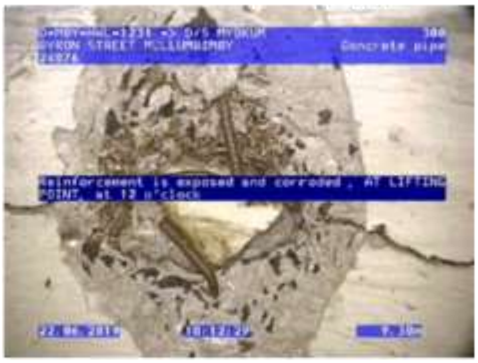

Figure 80| Lifting eye seal, Chg9.30m

Figure 81 | Breaking, Chg13.14m

Figure 82 | Displacement, Chg 15.63m

Figure 83 | Cracking, Chg16.82m

Figure 84 | Lifting eye seal, Chg 19.38m

Table 23 | Line HWL-1231 / D/S Myokum

Chainage (m)	Figure	Item	Observation
0 –23.06	-	Main	DN300 RCP
0.27	75	Lifting eye seal	Soil visible through lifting eye seal
0.68	76	Displacement	Longitudinal joint displacement of 10-20mm
3.18	77	Breaking	Pipe break at joint 200mm long from 3-6 O'clock
4.55	78	Lifting eye seal	Reinforcing steel is exposed at lifting eye seal which is also subject to cracking
9.30	79	Cracking	Circumferential cracking 5mm wide from 12-12 O'clock
9.30	80	Lifting eye seal	Reinforcing steel is exposed at lifting eye seal which is also subject to cracking
13.14	81	Breaking	Pipe break at joint 100mm long at 6 O'clock
15.63	82	Displacement	Longitudinal joint displacement of 10-20mm with exposed reinforcing steel
16.82	83	Cracking	Circumferential cracking 3mm wide from 12-12 O'clock
19.38	84	Lifting eye seal	Seepage of infiltration through lifting eye seal

2.24 Byron Street | Line HWL-1231 / D/S Myokum| D-MBY-UPC-0987 | (33.56m)

The entire culvert is comprised of a DN300 RCP. The assessment was terminated at 24.93m due to major tree roots obstructing the CCTV. The portion of the main that was assessed is in particularly poor condition and is subject to defects such as exposed reinforcement, joint displacement, cracking, breaking, and root intrusion. There are no junctions on the portion of this culvert that was assessed which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 24 for a summary of findings.

Figure 85 |Breaking, Chg1.59m

Figure 86 | Cracking,Chg3.91m

Figure 87 |Displacement, Chg5.02m

Figure 88 | Hole repair, Chg5.29m

Figure 89 | Cracking, Chg5.57m

Figure 90 | Breaking, Chg8.52m

Figure 91 |Root intrusion, Chg15.83m

Figure 92 | Root intrusion,Chg19.73m

Figure 93 |Ponding, Chg20.68m

Figure 94 | Root intrusion,Chg24.74m

Table 24 | Line HWL-1231 / D/S Myokum

Chainage (m)	Figure	Item	Observation
0 –24.93	-	Main	DN300 RCP
1.59	85	Breaking	Pipe break at joint 100mm long from 4-5 O'clock
3.91	86	Cracking	Circumferential cracking 20mm wide from 12-12 O'clock
5.02	87	Displacement	Radial joint displacement >20mm at 12 O'clock
5.29	88	Hole repair	Substantial hole 500x250mm externally repaired
5.57	89	Cracking	Circumferential cracking 20mm wide from 8-4 O'clock
8.52	90	Breaking	Pipe break 200mm long from 3-5 O'clock
15.83	91	Roots	Root intrusion with obstruction between 5-20% at 6 O'clock
19.73	92	Roots	Root intrusion with obstruction between 20-50% at 6 O'clock
20.68	93	Ponding	Ponding to a depth of 25% due to significant root obstruction downstream
24.74	94	Roots	Major root intrusion with obstruction between >75% from 12-12 O'clock

2.25 Orchid Street | Line JPT-1319 / IPT-1217| D-MBY-UPI-0976| (24.55m)

The entire culvert is comprised of a DN600 RCP. The assessment was terminated at 4.36m due to a conflicting pipe which has penetrated through the stormwater culvert obstructing the CCTV. The portion of the main that was assessed is in poor condition and is subject to cracking. There are no junctions on the portion of this culvert that was assessed which was reportedly installed in 1975 (44 years). Refer to the below figures and Table 25 for a summary of findings.

Figure 95 |Cracking, Chg0.08m

Figure 96 | Cracking,Chg1.79m

Figure 97 |Penetration, Chg3.75m

Figure 98 | Rubble, Chg24.55m - 1217

Table 25 | Line JPT-1319 / IPT-1217

Chainage (m)	Figure	Item	Observation
0 –4.36	-	Main	DN600 RCP
0.08	95	Cracking	Multiple cracking 3mm wide from 11-1 O'clock
1.79	96	Cracking	Longitudinal crack 6mm wide at 12 O'clock
3.75	97	Penetration	Culvert has been penetrated by a conduit ~DN150 which has significantly damaged the culvert and is obstructing the flow by 50%
24.55	98	Rubble	Major obstruction due to rubble of 50%

2.26 Fern Street | Line JPT-1220 / GIP-1219| D-MBY-UPI-0979| (>40.00m)

The entire culvert is comprised of a DN450 RCP. The assessment was terminated at 34.69m due to the track camera losing traction. The portion of the main that was assessed is in poor condition and is subject to defects such as cracking, displacement, breaking, and sediment build-up. There are no junctions on the portion of this culvert that was assessed which was reportedly installed in 1975 (44 years). Refer to the below figures and Table 26 for a summary of findings.

Figure 99 | Cracking, Chg5.13m

Figure 100| Breaking,Chg5.69m

Figure 101 |Sediment, Chg7.47m

Figure 102 | Cracking,Chg11.65m

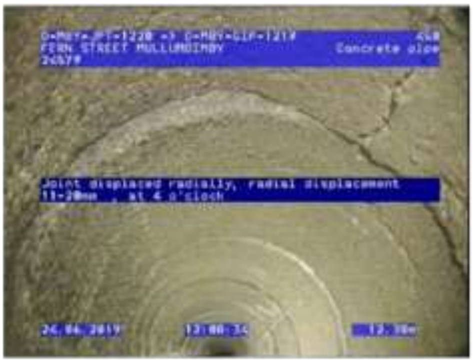

Figure 103 |Crushing, Chg12.38m

Figure 104 | Crushing,Chg14.92m

Figure 105 | Cracking, Chg18.08m

Figure 106 | Cracking,Chg19.41m

Figure 107 |Hole, Chg20.32m

Figure 108 | Cracking,Chg21.18m

Figure 109 |Breaking, Chg24.12m

Figure 110 | Cracking,Chg34.69m

Table 26 | Line JPT-1220 / GIP-1219

Chainage (m)	Figure	Item	Observation
0 –34.69	-	Main	DN450 RCP
5.13	99	Cracking	Longitudinal cracking 4mm wide at 12 O'clock
5.69	100	Breaking	Breaking of pipe wall 200mm long from 10-2 O'clock
7.47	101	Sediment	Build-up of sediment obstruction flow path 5-20% from 5-7 O'clock
11.65	102	Cracking	Longitudinal cracking 2mm wide at 12 O'clock

12.38	103	Crushing	Pipe wall exposed to external crushing forces is radially displacing the pipe 10-20mm from 11-1 O'clock
14.92	104	Crushing	Pipe wall exposed to external crushing forces is radially displacing the pipe 10-20mm at 4 O'clock
18.08	105	Cracking	Longitudinal cracking 5mm wide at 12 O'clock
19.41	106	Cracking	Longitudinal cracking 6mm wide at 12 O'clock
20.32	107	Hole	Hole 200mm dia from 10-2 O'clock with soil visible through the defect
21.18	108	Cracking	Multiple cracking 9mm wide from 12-12 O'clock
24.12	109	Breaking	Breaking of pipe wall 300mm long from 3-9 O'clock
34.69	110	Cracking	Multiple cracking 9mm wide from 12-12 O'clock

2.27 Fern Street | Line U/S / D/S| D-MBY-UPI-1255| (28.54m)

The entire culvert is comprised of a DN450 RCP. The main is in poor condition and is subject to defects such as cracking, displacement, breaking, root intrusion, and sediment build-up. There is a single junction on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 27 for a summary of findings.

Figure 111 |Roots, Chg0.01m

Figure 112| Cracking,Chg1.87m

Figure 113 |Displacement, Chg3.69m

Figure 114| Deformation,Chg4.11m

Figure 115 |Sediment, Chg5.82m

Figure 116| Connection,Chg6.75m

Figure 117 |Displacement, Chg9.85m

Figure 118| Cracking,Chg22.88m

Figure 119 |Reinforcement, Chg23.81m

Figure 120| Defective repair,Chg24.25m

Figure 121 | Defective repair, Chg24.25m

Table 27 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 –28.54	-	Main	DN450 RCP
0.01	111	Roots	Root intrusion inside circumferential crack obstruction <5% from 7-9 O'clock
1.87	112	Cracking	Multiple cracking width 6mm from 12-12 O'clock
3.69	113	Displacement	Radial joint displacement 5-10mm at 4 O'clock
4.11	114	Deformation	Pipe deformation due to external loading 5-10% over a 1m length at 12 O'clock

5.82	115	Sediment	Sediment in invert of pipe obstruction 5-20%
6.75	116	Junction	Junction pipe obstruction 5-20% at 10 O'clock
9.85	117	Displacement	Joint displaced radially 5-10mm with longitudinal cracking 4mm wide at 12 O'clock
22.88	118	Cracking	Longitudinal cracking 4mm wide at 12 O'clock
23.81	119	Reinforcement	Reinforcement is exposed and corroding from 10-2 O'clock
24.25	120/121	Defective repair	Hole in the pipe wall at 12 O'clock repaired with the use of a street sign which is now obstructing flow 5-20%

2.28 Burringbar Street | Line JPT-1288 / KIP/1542| D-MBY-UPI-1322| (6.85m)

The entire culvert is comprised of a DN450 RCP. The main is in reasonable condition and is subject to isolated radial displacement and root intrusion. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 28 for a summary of findings.

Figure 122 |Displacement, Chg4.30m

Figure 123| Root intrusion,Chg4.35m

Table 28 | Line JPT-1288 / KIP/1542

Chainage (m)	Figure	Item	Observation
0 –6.85	-	Main	DN450 RCP
4.30	122	Displacement	Radial joint displacement >20mm
4.35	123	Roots	Root intrusion obstruction at joint 5-20% from 5-7 O'clock

2.29 Burringbar Street | Line JPT-1285 / KIP/1284 | D-MBY-UPI-1067 | (27.03m)

The entire culvert is comprised of a DN300 RCP. The assessment was terminated at 1.43m due to root intrusion obstruction. The portion of the main that was assessed is in reasonable condition and is subject to isolated radial displacement and root intrusion. There are no junctions on the portion of this culvert that was assessed which was reportedly installed in 1984 (35 years).Refer to the below figures and Table 29 for a summary of findings.

Figure 124 | Displacement, Chg0.78m

Figure 125 | Root intrusion,Chg0.78m

Figure 126 | Breaking,Chg1.43m

Table 29 | Line JPT-1285 / KIP/1284

Chainage (m)	Figure	Item	Observation
0 – 1.43	-	Main	DN300 RCP
0.78	124	Displacement	Radial joint displacement >20mm
0.78	125	Roots	Root intrusion obstruction at joint 5-20% from 3-6 O'clock
1.43	126	Breaking	Pipe wall breaking at joint, length of break is 100mm between 12-1 O'clock

2.30 Burringbar Street | Line JPT-1288 / JPT-1292 | D-MBY-UPI-1075 | (88.95m)

The entire culvert is comprised of a DN750 RCP. The structural condition of the main is in good condition, however the culvert is subject to numerous points of infiltration (at every lifting eye seal) ranging from minor seepage to continuous flows. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 30 for a summary of findings.

Figure 127 | Displacement, Chg1.43m

Figure 128 | Cracking,Chg2.55m

Figure 129 | Infiltration, Chg9.91m

Figure 130 | Displacement,Chg28.41m

Figure 131 | Infiltration, Chg44.08m

Figure 132 | Root intrusion,Chg45.54m

Table 30 | Line JPT-1288 / JPT-1292

Chainage (m)	Figure	Item	Observation
0 – 88.95	-	Main	DN750 RCP
1.43	127	Displacement	Longitudinal joint displacement 20-30mm
2.55	128	Cracking	Circumferential cracking 2mm wide from 8-12 O'clock
9.91	129	Typical infiltration	Seepage of infiltration at lifting eye seal at various locations
28.41	130	Displacement	Longitudinal joint displacement 10-20mm
44.08	131	Typical infiltration	Continuous infiltration through lifting eye seal at various locations
45.54	132	Roots	Root intrusion obstruction <5% from 7-8 O'clock

2.31 River Terrace | Line HWL-1309 / HWL-1308 | D-MBY-UPI-0962 | (9.82m)

The entire culvert is comprised of a DN375 RCP. The main is in poor condition and is subject to defects such as cracking, breaking, and root intrusion. There are no junctions on this culvert which was reportedly installed in 1980 (39 years). Refer to the below figures and Table 31 for a summary of findings.

Figure 133 |Lifting eye seal, Chg0.94m

Figure 134| Breaking,Chg4.84m

Figure 135 |Lifting eye seal, Chg5.91m

Figure 136| Breaking,Chg7.25m

Figure 137 |Lifting eye seal, Chg8.56m

Figure 138| Breaking,Chg9.82m

Table 31 | Line HWL-1309 / HWL-1308			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –9.82	-	Main	DN375 RCP
0.94	133	Lifting eye seal	Soil is visible through deteriorated lifting eye seal
4.84	134	Breaking	Pipe break at joint, rubber ring visible from 11-12 O'clock
5.91	135	Lifting eye seal	Breaking of pipe wall 100mm long around lifting eye seal with reinforcement visible
7.25	136	Breaking	Pipe break at joint, rubber ring visible from 9-3 O'clock
8.56	137	Lifting eye seal	Breaking of pipe wall 100mm long around lifting eye seal with reinforcement visible
9.82	138	Breaking	Breaking of pipe wall at joint 200mm long from 8-4 O'clock

2.32 River Terrace | Line KIP-1308 / HWL-1307| D-MBY-UPI-0961| (16.84m)

The entire culvert is comprised of a DN375 RCP. The main is typically in reasonable condition and is subject to defects such as surface cracking, breaking, displacement, and root intrusion. There are no junctions on this culvert which was reportedly installed in 1980 (39 years). Refer to the below figures and Table 32 for a summary of findings.

Figure 139 |Breaking, Chg2.15m

Figure 140| Root intrusion,Chg9.60m

Figure 141 |Rubber ring, Chg11.70m

Figure 142| Displacement,Chg14.22m

Table 32 | Line KIP-1308 / HWL-1307

Chainage (m)	Figure	Item	Observation
0 –16.84	-	Main	DN375 RCP
2.15	139	Breaking	Pipe break at joint 100mm long from 11-1 O'clock
9.60	140	Root intrusion	Root intrusion at joint with obstruction of <5% from 4-5 O'clock
11.70	141	Rubber ring	Radial joint displacement of >20mm with rubber ring visible
14.22	142	Displacement	Radial joint displacement of 10-20mm

2.33 River Terrace | Line JPT-1310 / HWL-1312 | D-MBY-UPI-0965 | (2.47m)

The entire culvert is comprised of a DN300 RCP. The main is in poor condition and is subject to defects such as cracking, breaking, and displacement. There are no junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 33 for a summary of findings.

Figure 143 |Cracking, Chg0.11m

Figure 144| Displacement,Chg0.72m

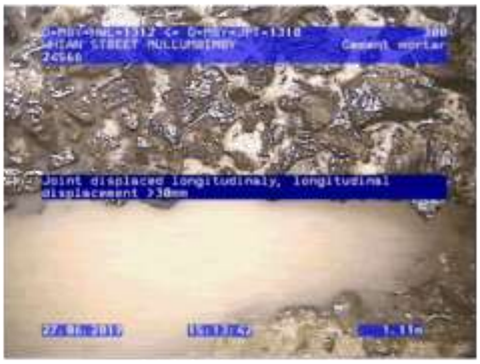

Figure 145 |Displacement, Chg1.11m

Figure 146| Cracking,Chg1.21m

Figure 147 | Breaking, Chg1.44m

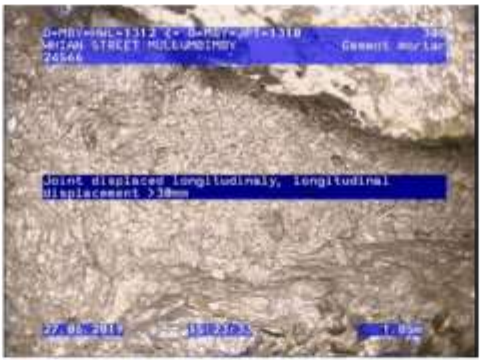

Figure 148 | Displacement, Chg 1.85m

Table 33 | Line JPT-1310 / HWL-1312			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 2.47	-	Main	DN300 RCP
0.11	143	Cracking	Circumferential cracking at joint 3mm wide from 12-12 O'clock
0.72	144	Displacement	Longitudinal joint displacement 20-30mm
1.11	145	Displacement	Longitudinal joint displacement >30mm
1.21	146	Cracking	Multiple cracking 4mm wide from 12-12 O'clock
1.44	147	Breaking	Pipe wall breaking 200 long from 2-6 O'clock
1.85	148	Displacement	Longitudinal joint displacement >30mm

2.34 River Terrace | Line KIP-1286 / JPT-1285 | D-MBY-UPI-1068 | (5.10m)

The entire culvert is comprised of a DN300 RCP. The main is in poor condition and is subject to defects such as cracking, breaking, and displacement. There is a single junction on this culvert which was reportedly installed in 1984 (35 years). Refer to the below figures and Table 34 for a summary of findings.

Figure 149 |Breaking, Chg4.11m

Figure 150 | Displacement,Chg4.11m

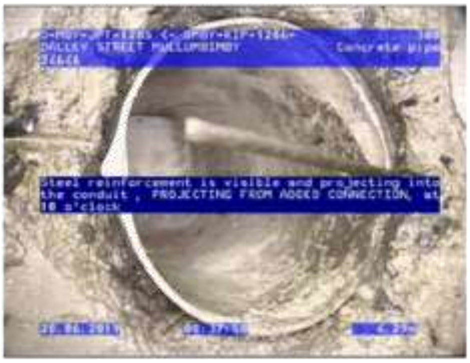

Figure 151 |Junction, Chg4.29m

Figure 152 | Breaking,Chg4.88m

Table 34 | Line KIP-1286 / JPT-1285

Chainage (m)	Figure	Item	Observation
0 –5.10	-	Main	DN300 RCP
4.11	149	Breaking	Pipe breaking at joint from 7-8 O'clock
4.11	150	Displacement	Radial joint displacement 10-20mm at 2 O'clock
4.29	151	Junction	Junction pipe with exposed reinforcing steel at 10 O'clock
4.88	152	Breaking	Pipe breaking with large section missing from 8-4 O'clock

2.35 Dalley Street | Line GIP-1287 / JPT-1285 | D-MBY-UPI-1069 | (2.08m)

The entire culvert is comprised of a DN300 RCP. The main is in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 1984 (35 years). Refer to the below figures and Table 35 for a summary of findings.

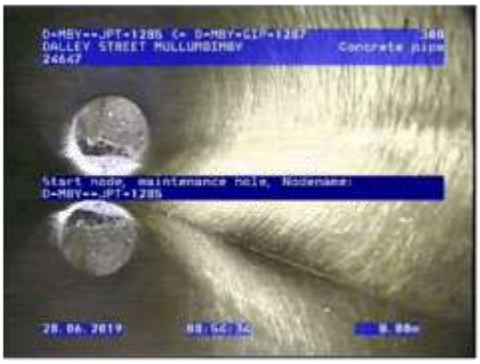

Figure 153 | Typical condition, Chg0.00m

Table 35 | Line GIP-1287 / JPT-1285			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –2.08	153	Typical condition	DN300 RCP with no defects identified

2.36 Dalley Street | Line KIP-1284 / D/S | D-MBY-UPI-1070 | (10.14m)

The entire culvert is comprised of a DN300 RCP. The main is in poor condition and is subject to defects such as cracking, breaking, and root intrusion. There is a single junction on this culvert which was reportedly installed in 1984 (35 years). Refer to the below figures and Table 36 for a summary of findings.

Figure 154 | Root intrusion, Chg0.36m

Figure 155 | Rubber ring,Chg0.36m

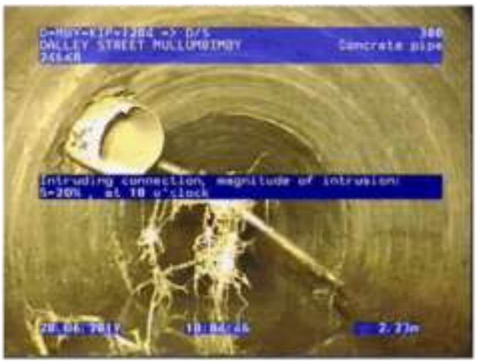

Figure 156 |Junction, Chg2.23m

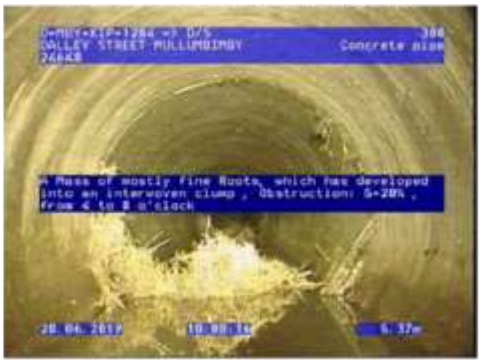

Figure 157 | Root intrusion,Chg5.37m

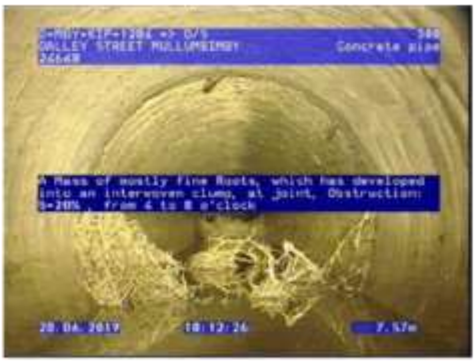

Figure 158 |Root intrusion, Chg7.57m

Figure 159 | Breaking,Chg7.57m

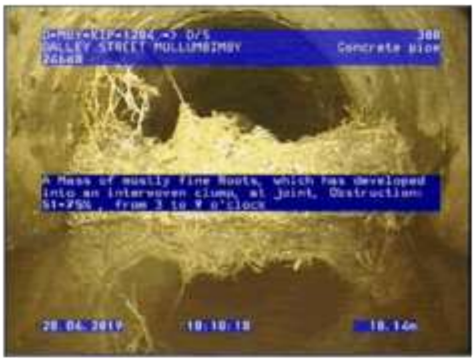

Figure 160 |Root intrusion, Chg10.14m

Table 36 | Line KIP-1284 / D/S

Chainage (m)	Figure	Item	Observation
0 – 10.14	-	Main	DN300 RCP
0.36	154	Root intrusion	Root intrusion obstruction 5-20% at 5 O'clock
0.36	155	Rubber ring	Rubber ring visible through displaced joint from 11-3 O'clock
2.23	156	Junction	Junction protruding through into flow path, obstruction 5-20% at 10 O'clock
5.37	157	Root intrusion	Root intrusion obstruction 5-20% from 4-8 O'clock
7.57	158	Root intrusion	Root intrusion obstruction 5-20% from 4-8 O'clock
7.57	159	Breaking	Pipe breaking at pipe joint 100mm long at 10 O'clock
10.14	160	Root intrusion	Root intrusion obstruction 50-75% from 3-9 O'clock

2.37 River Terrace | Line KIP-1281 / D/S | D-MBY-UPI-1064 | (3.70m)

The entire culvert is comprised of a DN375 RCP. The main is in poor condition and is subject to defects such as cracking and root intrusion. There are no junctions on this culvert which was reportedly installed in 1984 (35 years). Refer to the below figures and Table 37 for a summary of findings.

Figure 161 | Cracking, Chg1.13m

Figure 162 | Root intrusion,Chg1.49m

Table 37 | Line KIP-1281 / D/S

Chainage (m)	Figure	Item	Observation
0 – 3.70	-	Main	DN375 RCP
1.13	161	Cracking	Multiple cracking 4mm wide from 7-10 O'clock
1.49	162	Roots	Root intrusion through pipe joint (recently cut) likely obstruction 5-20% from 5-7 O'clock

2.38 Dalley Street | Line KIP-1293 / JPT-1292 | D-MBY-UPI-1076 | (12.49m)

The entire culvert is comprised of a DN450 RCP. The main is in reasonable condition and is subject to minor defects such as root intrusion and displacement. There are no junctions on this culvert which was reportedly installed in 1993 (26 years). Refer to the below figures and Table 38 for a summary of findings.

Figure 163 |Displacement, Chg0.35m

Figure 164 | Cracking,Chg3.90m

Figure 165 | Root intrusion, Chg10.13m

Table 38 | Line KIP-1293 / JPT-1292			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 12.49	-	Main	DN450 RCP
0.35	163	Displacement	Longitudinal joint displacement of 10-20mm
3.90	164	Cracking	Multiple cracking 1mm wide throughout
10.13	165	Roots	Root intrusion through pipe joint with obstruction <5% at 5 O'clock

2.39 Tincogan Street | Line U/S / GIP-5677 | D-MBY-UBC-1051 | (13.22m)

The entire culvert is comprised of a 470W x 300H RCBC. The main is in poor condition and is subject to defects such as sediment build up, displacement, and intruding junctions. There are two junctions on this culvert which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 39 for a summary of findings.

Figure 166 |Sediment, Chg1.43m

Figure 167| Junction, Chg 3.05m

Figure 168 | Displacement, Chg3.32m

Figure 169 | Displacement, Chg 4.55m

Figure 170 | Rubble, Chg7.96m

Figure 171 | Junction, Chg 12.21m

Table 39 | Line U/S / GIP-5677

Chainage (m)	Figure	Item	Observation
0 – 13.22	-	Main	470W x 300H RCBC
1.43	166	Sediment	Sediment build up upstream of protruding junction resulting in obstruction 5-20% from 3-5 O'clock
3.05	167	Junction	DN225 PVC open junction with sediment build up, obstruction 5-25% from 4-8 O'clock
3.32	168	Displacement	Radial joint displacement of 5-10mm at 9 O'clock
4.55	169	Displacement	Radial joint displacement of 10-20mm at 12 O'clock
7.96	170	Rubble	Large rock obstructing flow by 10-20% at 6 O'clock
12.21	171	Junction	Open junction 450W x 300H at 3 O'clock

2.40 Tincogan Street | Line GIP-4208 / GIP-4206| D-MBY-UBI-3667| (19.09m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition and is only subject to minor joint displacement. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 40 for a summary of findings.

Figure 172 |Rubber ring, Chg1.69m

Figure 173| Displacement,Chg16.64m

Table 40 | Line GIP-4208 / GIP-4206

Chainage (m)	Figure	Item	Observation
0 – 19.09	-	Main	DN375 RCP
1.69	172	Rubber ring	Rubber ring visible through displaced joint from 12-12 O'clock
16.64	173	Displacement	Longitudinal joint displacement of 10-20mm

2.41 Tincogan Street | Line GIP-4209 / GIP-4208 | D-MBY-UBI-3668 | (6.55m)

The entire culvert is comprised of a DN375 RCP. The main is in reasonable condition and is only subject to isolated breaking of the pipe wall. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 41 for a summary of findings.

Figure 174 | Breaking, Chg5.89m

Table 41 | Line GIP-4209 / GIP-4208

Chainage (m)	Figure	Item	Observation
0 – 6.55	-	Main	DN375 RCP
5.89	174	Breaking	Breaking of pipe wall, 400mm long from 12-12 O'clock

2.42 Tincogan Street | Line GIP-4209 / GIP-4206 | D-MBY-UPI-3666 | (6.56m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition and is only subject to isolated joint displacement. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 42 for a summary of findings.

Figure 175 | Displacement, Chg4.39m

Table 42 | Line GIP-4209 / GIP-4206			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 6.56	-	Main	DN375 RCP
4.39	175	Displacement	Longitudinal joint displacement of 10-20mm

2.43 Station Street | Line GIP-4206 / JPT-4212 | D-MBY-UPI-3670 | (12.29m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition and is only subject to isolated joint displacement. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 43 for a summary of findings.

Figure 176 | Displacement, Chg0.00m

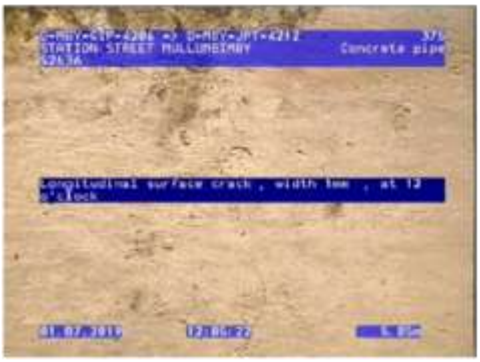

Figure 177 | Cracking, Chg5.85m

Table 43 | Line GIP-4206 / JPT-4212

Chainage (m)	Figure	Item	Observation
0 – 12.29	-	Main	DN375 RCP
0.00	176	Displacement	Longitudinal joint displacement of 10-20mm
5.85	177	Cracking	Surface cracking 1mm wide at 12 O'clock

2.44 McGoughans Lane | Line U/S / D/S | D-MBY-UBC-1050 | (11.78m)

The entire culvert is comprised of a 580W x 300H RCBC. The assessment was terminated at 11.78m due to equipment failure and reduced diameter. The portion of this main that was assessed is in poor condition and is subject to defects such as cracking, breaking, exposed reinforcement, and rubble. There are no junctions on the portion of this culvert that was assessed which was reportedly installed in 1940 (79 years). Refer to the below figures and Table 44 for a summary of findings.

Figure 178 |Breaking, Chg1.82m

Figure 179| Breaking,Chg2.84m

Figure 180 |Breaking, Chg4.86m

Figure 181| Breaking, Chg 5.85m

Figure 182 |Breaking, Chg6.46m

Figure 183| Breaking, Chg 7.12m

Figure 184 |Breaking, Chg9.46m

Figure 185 | Change of diameter,Chg10.70m

Table 44 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 – 11.78	-	Main	580W x 300H RCBC
1.82	178	Breaking	Breaking of culvert wall 600mm long at 12 O'clock
2.84	179	Breaking	Breaking of culvert wall 300mm long from 8-11 O'clock with rubble obstructing flow 5-20%
4.86	180	Breaking	Breaking of culvert wall 300mm long at 12 O'clock with reinforcing steel exposed
5.85	181	Breaking	Breaking of culvert wall at joint 400mm long at 12 O'clock
6.46	182	Breaking	Breaking of culvert wall 300mm long at 12 O'clock with reinforcing steel exposed
7.12	183	Breaking	Breaking of culvert wall 580mm long from 10-2 O'clock with reinforcing steel exposed
9.46	184	Breaking	Breaking of culvert wall 300mm long at 12 O'clock
10.70	185	Change of diameter	Reduction of culvert cross section, large step at joint obstructing flow by 50%

2.45 Station Street | Line JPT-4212 / KIP-4210 | D-MBY-UPI-3669 | (4.87m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition and is only subject to isolated surface cracking. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 45 for a summary of findings.

Figure 186 |Typical condition, Chg0.50m

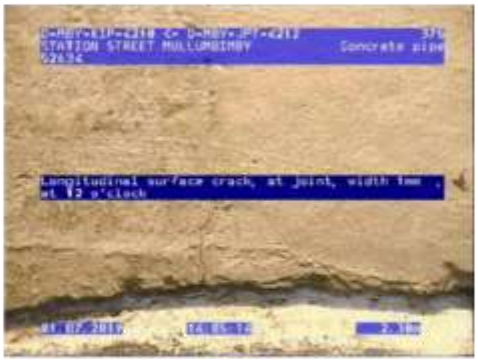

Figure 187 | Cracking, Chg2.30m

Table 45 | Line JPT-4212 / KIP-4210

Chainage (m)	Figure	Item	Observation
0 – 4.87	-	Main	DN375 RCP
0.00	186	Typical condition	Main is in good condition
2.30	187	Cracking	Surface cracking 1mm wide at 12 O'clock

2.46 Station Street | Line KIP-4223 / KIP-4210 | D-MBY-UPI-3680 | (49.35m)

The entire culvert is comprised of a DN600 RCP. The main is in good condition and is only subject to isolated surface cracking. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 46 for a summary of findings.

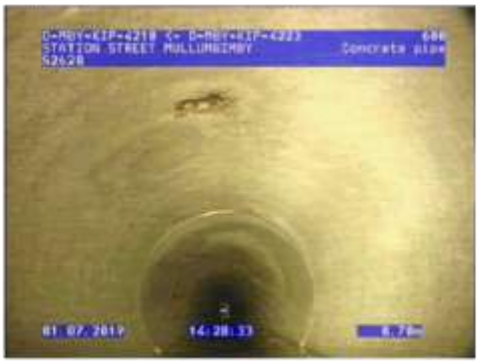

Figure 188 | Typical condition, Chg0.70m

Figure 189 | Cracking, Chg3.07m

Table 46 | Line KIP-4223 / KIP-4210

Chainage (m)	Figure	Item	Observation
0 – 49.35	-	Main	DN600 RCP
0.70	188	Typical condition	Main is in good condition
3.07	189	Cracking	Surface cracking 1mm wide at 12 O'clock

2.47 Station Street | Line KIP-4213 / JPT-4212 | D-MBY-UPI-3671 | (14.89m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 47 for a summary of findings.

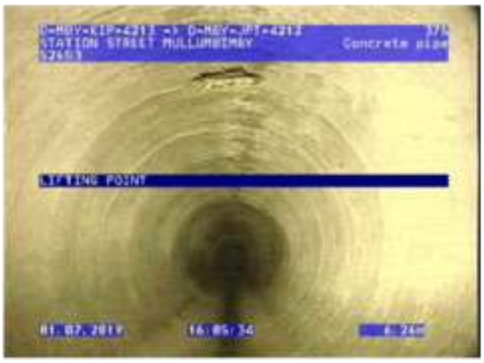

Figure 190 | Typical condition, Chg0.70m

Table 47 | Line KIP-4213 / JPT-4212

Chainage (m)	Figure	Item	Observation
0 – 14.89	-	Main	DN375 RCP
6.26	190	Typical condition	Main is in good condition

2.48 Station Street | Line KIP-4215 / JPT-4220 | D-MBY-UPI-3674 | (8.09m)

The entire culvert is comprised of a DN300 RCP. The main is in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 48 for a summary of findings.

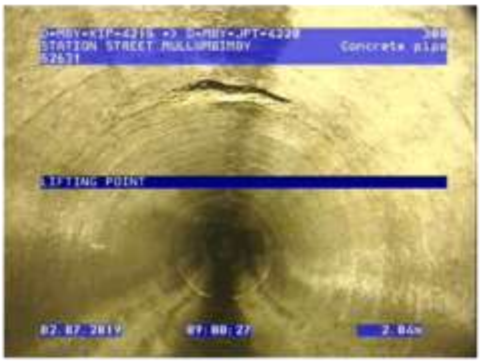

Figure 191 | Typical condition, Chg2.04m

Table 48 | Line KIP-4215 / JPT-4220			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 8.09	-	Main	DN300 RCP
2.04	191	Typical condition	Main is in good condition

2.49 Argyle Street | Line HWL-4218 / JPT-4216 | D-MBY-UPI-3675 | (5.64m)

The entire culvert is comprised of a DN450 RCP. The main is in good condition with a single displaced joint. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 49 for a summary of findings.

Figure 192 | Typical condition, Chg0.00m

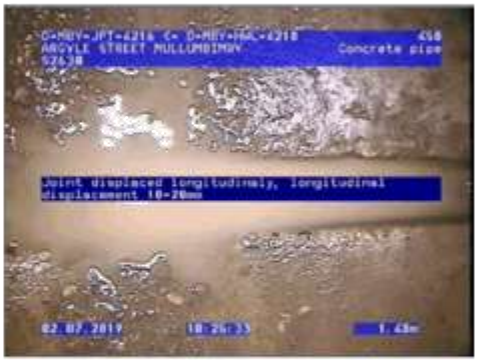

Figure 193 | Displacement, Chg1.48m

Table 49 | Line HWL-4218 / JPT-4216

Chainage (m)	Figure	Item	Observation
0 – 5.64	-	Main	DN450 RCP
0.00	192	Typical condition	Main is in good condition
1.48	193	Displacement	Longitudinal joint displacement 10-20mm

2.50 Station Street | Line JPT-4216 / JPT-4220| D-MBY-UPI-3675 | (3.89m)

The entire culvert is comprised of a DN450 RCP. The main is in good condition with a single displaced joint. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 50 for a summary of findings.

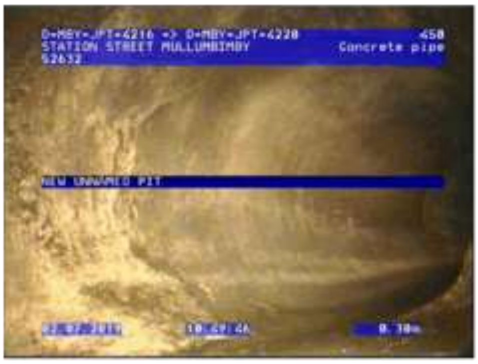

Figure 194 | Typical condition, Chg0.30m

Figure 195 | Displacement, Chg2.26m

Table 50| Line JPT-4216 / JPT-4220

Chainage (m)	Figure	Item	Observation
0 –3.89	-	Main	DN450 RCP
0.30	194	Typical condition	Main is in good condition
2.26	195	Displacement	Longitudinal joint displacement 10-20mm

2.51 Station Street | Line KIP-4210 / D/S KIP | D-MBY-UPI-3681 | (48.13m)

The entire culvert is comprised of a DN675 RCP. The main is in good condition with a single displaced joint. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 51 for a summary of findings.

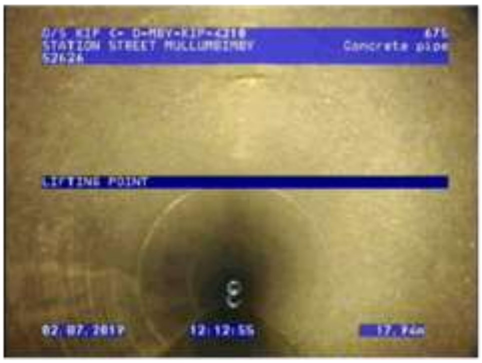

Figure 196 | Typical condition, Chg0.30m

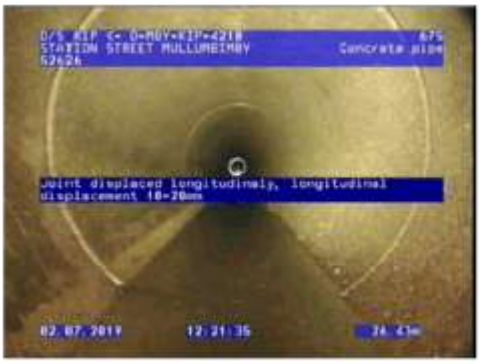

Figure 197 | Displacement, Chg2.26m

Table 51| Line KIP-4210 / D/S KIP

Chainage (m)	Figure	Item	Observation
0 – 3.89	-	Main	DN675 RCP
17.94	196	Typical condition	Main is in good condition
26.43	197	Displacement	Longitudinal joint displacement 10-20mm

2.52 Station Street | Line JPT-4221 / KIP-4223 | D-MBY-UPI-3681 | (6.68m)

The entire culvert is comprised of a DN675 RCP. The main is in good condition with no defects identified. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 52 for a summary of findings.

Figure 198 | Typical condition, Chg3.31m

Table 52 | Line JPT-4221 / KIP-4223

Chainage (m)	Figure	Item	Observation
0 – 6.68	-	Main	DN675 RCP
3.31	198	Typical condition	Main is in good condition

2.53 Station Street | Line JPT-4220 / JPT-4221 | D-MBY-UPI-3677 | (47.67m)

The entire culvert is comprised of a DN450 RCP. The main is in good condition with only a single joint subject to minor breaking. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 53 for a summary of findings.

Figure 199 | Typical condition, Chg16.33m

Figure 200 | Breaking, Chg47.06m

Table 53 | Line JPT-4220 / JPT-4221

Chainage (m)	Figure	Item	Observation
0 – 47.67	-	Main	DN450 RCP
16.33	199	Typical condition	Main is in good condition
47.06	200	Breaking	Breaking of pipe wall at joint 100mm long from 5-6 O'clock

2.54 Station Street | Line KIP-4222 / KIP-4223 | D-MBY-UPI-3679| (9.91m)

The entire culvert is comprised of a DN450 RCP. The main is in good condition with only minor joint displacement identified. There are no junctions on this culvert which was reportedly installed in 2011 (8 years). Refer to the below figures and Table 54 for a summary of findings.

Figure 201 |Displacement, Chg2.51m

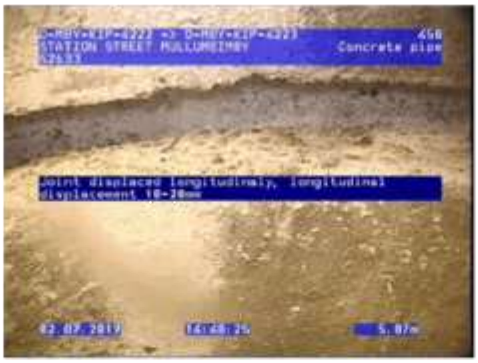

Figure 202 |Displacement, Chg5.07m

Table 54 | Line KIP-4222 / KIP-4223			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 9.91	-	Main	DN450 RCP
2.51	201	Displacement	Longitudinal joint displacement 10-20mm
5.07	202	Displacement	Longitudinal joint displacement 10-20mm

2.55 Stuart Street | Line HWL-1329 / D/S | D-MBY-UPC-1040 | (20.05m)

The entire culvert is comprised of a 610W x 300H RCBC. The main is in poor condition and is subject to defects such as cracking, breaking, and exposed reinforcement. There is a single junction on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 55 for a summary of findings.

Figure 203 |Junction, Chg1.94m

Figure 204| Breaking,Chg4.94m

Figure 205 |Cracking, Chg7.37m

Figure 206| Breaking,Chg9.96m

Figure 207 |Breaking, Chg16.18m

Figure 208| Rubble,Chg16.91m

Figure 209 |Cracking, Chg20.05m

Figure 210| Breaking,Chg20.05m

Table 55 | Line HWL-1329 / D/S

Chainage (m)	Figure	Item	Observation
0 – 20.05	-	Main	610W x 300H RCBC
1.94	203	Junction	Junction open DN225 at 9 O'clock, pipe breaking around connection
4.94	204	Breaking	Culvert wall breaking at joint 100mm long from 11-12 O'clock
7.37	205	Cracking	Cracking at joint 2mm wide from 10-12 O'clock
9.96	206	Breaking	Culvert wall breaking at joint 200mm long from 10-12 O'clock
16.18	207	Breaking	Culvert wall breaking at joint 500mm long from 9-3 O'clock
16.91	208	Rubble	Rocks and gravel obstructing flow <5% at 7 O'clock
20.05	209	Cracking	Cracking in culvert wall 4mm wide from 7-9 O'clock
20.05	210	Breaking	Breaking of culvert wall at joint 200mm long from 1-4 O'clock

2.56 Stuart Street | Line HWL-1330 / HWL-1329 | D-MBY-UPI-1041 | (3.06m)

The entire culvert is comprised of a DN300 RCP. The assessment was terminated at 3.06m due to an obstruction that could not be cleared due to the D/S end being beneath the road. The section of the culvert that was assessed is in poor condition with cracking, joint displacement, and major obstructions identified. There are no junctions on the section of this culvert that was assessed which was installed in 1940 (79 years). Refer to the below figures and Table 56 for a summary of findings.

Figure 211 |Cracking, Chg0.69m

Figure 212 |Displacement, Chg2.05m

Figure 213 | Displacement, Chg2.38m

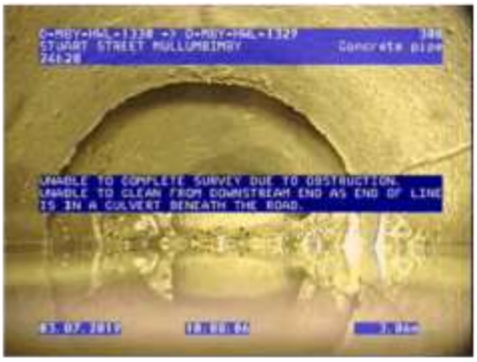

Figure 214 | Obstruction, Chg3.06m

Table 56 | Line HWL-1330 / HWL-1329

Chainage (m)	Figure	Item	Observation
0 – 3.06	-	Main	DN300 RCP
0.69	211	Cracking	Cracking of pipe wall 7mm wide from 12-12 O'clock
2.05	212	Displacement	Longitudinal joint displacement 10-20mm
2.38	213	Displacement	Radial joint displacement 10-20mm at 8 O'clock
3.06	214	Obstruction	Obstruction limiting assessment

2.57 Stuart Street | Line U/S / D/S | D-MBY-UBC-1052| (11.32m)

The entire culvert is comprised of a 450W x 300H RCBC. The culvert is in poor condition with cracking, joint displacement, breaking, and exposed reinforcement identified. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 57 for a summary of findings.

Figure 215 |Displacement, Chg1.00m

Figure 216 |Breaking, Chg1.00m

Figure 217 |Reinforcement, Chg2.77m

Figure 218 |Breaking, Chg3.83m

Figure 219 |Reinforcement, Chg5.04m

Figure 220 |Breaking, Chg6.20m

Figure 221 |Breaking, Chg8.76m

Figure 222 |Cross Section, Chg10.04m

Table 57 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 – 11.32	-	Main	450W x 300H RCBC
1.00	215	Displacement	Radial joint displacement 5-10mm at 9 O'clock
1.00	216	Breaking	Culvert wall breaking 100mm long at 11 O'clock
2.77	217	Reinforcement	Reinforcing steel exposed at culvert wall break 100mm long from 11-1 O'clock
3.83	218	Breaking	Culvert wall breaking 400mm long from 10-2 O'clock
5.04	219	Reinforcement	Reinforcing steel exposed at culvert joint break 100mm long at 6 O'clock
6.20	220	Breaking	Culvert wall breaking 200mm long from 10-12 O'clock
8.76	221	Breaking	Culvert wall breaking 100mm long from 10-2 O'clock
10.04	222	Cross Section	Change of cross-sectional area due to culvert increase in width

2.58 Tincogan Street | Line HWL-1324 / D/S | D-MBY-UBC-1039| (24.07m)

The entire culvert is comprised of a 450W x 300H RCBC. The assessment was terminated at 18.65m due to an obstruction beneath ponding flow. The culvert is typically in a reasonable condition with some surface cracking and joint displacement identified. There are no junctions on the section of this culvert that was assessed which was installed in 1940 (79 years). Refer to the below figures and Table 58 for a summary of findings.

Figure 223 |Aggregate, Chg0.44m

Figure 224 |Displacement, Chg1.29m

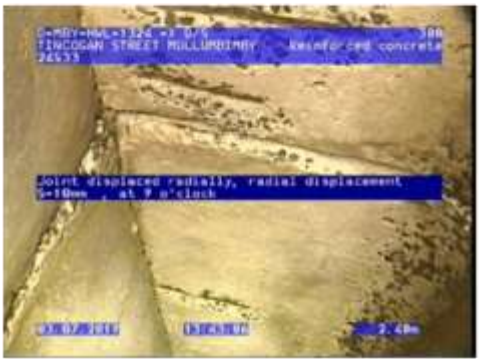

Figure 225 |Displacement, Chg2.40m

Figure 226 |Obstruction, Chg18.65m

Table 58 | Line HWL-1324 / D/S

Chainage (m)	Figure	Item	Observation
0 – 18.65	-	Main	450W x 300H RCBC
0.44	223	Aggregate	Aggregate in the concrete matrix is exposed from 12-12 O'clock
1.29	224	Displacement	Radial joint displacement 5-10mm at 6 O'clock
2.40	225	Displacement	Radial joint displacement 5-10mm at 9 O'clock
18.65	226	Obstruction	Assessment obstructed due to material beneath ponding flow

2.59 Dalley Street | Line U/S / KIP-1282 | D-MBY-UBI-1066 | (13.42m)

The entire culvert is comprised of a DN450 RCP. The culvert is typically in a reasonable condition with some defects such as root intrusion, joint displacement, and breaking. There are no junctions on this culvert which was installed in 1984 (35 years). Refer to the below figures and Table 59 for a summary of findings.

Figure 227 |Root intrusion, Chg1.92m

Figure 228 |Root intrusion, Chg9.53m

Figure 229 |Breaking, Chg11.89m

Figure 230 |Breaking, Chg13.24m

Table 59 | Line U/S / KIP-1282

Chainage (m)	Figure	Item	Observation
0 – 13.42	-	Main	DN450 RCP
1.92	227	Roots	Radial joint displacement of 10-20mm at 12 O'clock with major root intrusion (recently cut) obstruction <5%
9.53	228	Roots	Root intrusion through culvert joint (recently cut) obstruction <5% at 7 O'clock
11.89	229	Breaking	Breaking of culvert wall at joint 100mm long at 5 O'clock
13.24	230	Breaking	Breaking of culvert wall at connection to end structure 200mm long from 11-1 O'clock

2.60 Burringbar Street | Line KIP-1282 / D/S | D-MBY-UPI-1065 | (7.90m)

The entire culvert is comprised of a DN450 RCP. The assessment was terminated at 7.90m due to an item obstructing the assessment. The culvert is in poor condition with defects such as cracking, breaking, root intrusion, and joint displacement identified. There are no junctions on the section of this culvert that was assessed which was installed in 1984 (35 years). Refer to the below figures and Table 60 for a summary of findings.

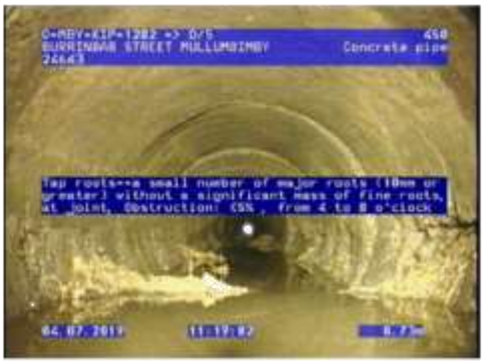

Figure 231 |Breaking, Chg0.73m

Figure 232 |Breaking, Chg1.16m

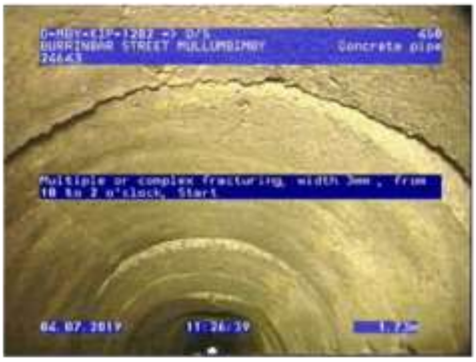

Figure 233 |Cracking, Chg1.73m

Figure 234 |Breaking, Chg1.93m

Figure 235 |Crushing, Chg3.20m

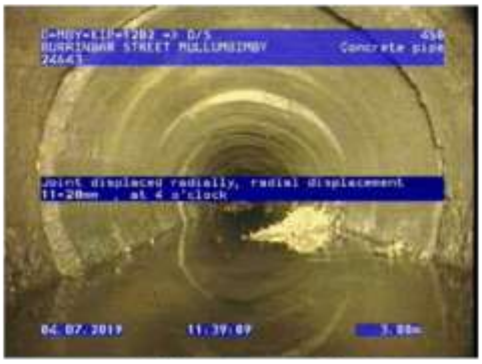

Figure 236 |Displacement, Chg3.88m

Figure 237 |Root intrusion, Chg4.69m

Figure 238 |Crushing, Chg5.30m

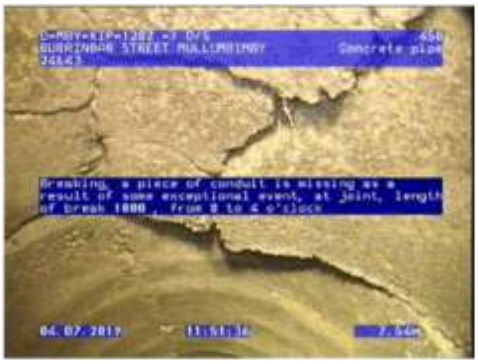

Figure 239 |Breaking, Chg7.54m

Figure 240 | Obstruction, Chg7.90m

Table 60 | Line KIP-1282 / D/S

Chainage (m)	Figure	Item	Observation
0 – 7.90	-	Main	DN450 RCP
0.73	231	Breaking	Culvert wall subject to root intrusion obstruction <5% and breaking from 3-9 O'clock
1.16	232	Breaking	Culvert wall breaking 300mm long from 3-5 O'clock
1.73	233	Cracking	Multiple cracking 3mm wide from 10-2 O'clock
1.93	234	Breaking	Culvert wall breaking, large chunks missing from 3-5 O'clock
3.20	235	Crushing	Culvert is horizontally deformed due to external crushing force for a 1m length at 12 O'clock
3.88	236	Displacement	Radial joint displacement 10-20mm at 2 O'clock
4.69	237	Roots	Root intrusion obstruction at joint <5% from 4-6 O'clock
5.30	238	Crushing	Culvert is horizontally deformed due to external crushing force for a 1m length at 12 O'clock
7.54	239	Breaking	Culvert is horizontally deformed due to external crushing force for a 1m length from 8-4 O'clock
7.90	240	Obstruction	Obstruction blocking assessment and flow 20-50%

2.61 Stuart Street | Line JPT-1305 / JPT-1297| D-MBY-UPI-0957| (112.36m)

The entire culvert is comprised of a DN450 RCP. The culvert is in a reasonable condition with defects such as cracking, exposed reinforcement, and joint displacement identified. There are no junctions on this culvert which was installed in 1993 (26 years). Refer to the below figures and Table 61 for a summary of findings.

Figure 241 |Sediment, Chg0.00m

Figure 242 |Reinforcement, Chg22.82m

Figure 243 |Reinforcement, Chg31.46m

Figure 244 |Reinforcement, Chg36.38m

Figure 245 |Reinforcement, Chg49.85m

Figure 246 | Displacement, Chg51.15m

Figure 247 |Cracking, Chg59.65m

Figure 248 | Displacement, Chg61.05m

Figure 249 |Reinforcement, Chg65.89m

Figure 250 | Displacement, Chg87.94m

Table 61 | Line JPT-1305 / JPT-1297

Chainage (m)	Figure	Item	Observation
0 – 112.36	-	Main	DN450 RCP
0.00	241	Sediment	Sediment in invert of culvert obstructing flow 5-20% at 6 O'clock
22.82	242	Reinforcement	Reinforcing steel exposed and corroding from 10-11 O'clock
31.46	243	Reinforcement	Reinforcing steel exposed and corroding at 2 O'clock
36.38	244	Reinforcement	Reinforcing steel exposed and corroding from 7-9 O'clock
49.85	245	Reinforcement	Reinforcing steel exposed and corroding from 8-12 O'clock
51.15	246	Displacement	Radial joint displacement 10-20mm at 10 O'clock
59.65	247	Cracking	Circumferential cracking 2mm wide from 5-7 O'clock
61.05	248	Displacement	Longitudinal joint displacement 10-20mm
65.89	249	Reinforcement	Reinforcing steel exposed and corroding from 12-1 O'clock
87.94	250	Displacement	Longitudinal joint displacement 10-20mm

2.62 Whian Street | Line U/S / D/S| D-MBY-UPI-0967| (3.29m)

The entire culvert is comprised of a DN225 PVC. The main is in good condition with only isolated root intrusion identified. There are no junctions on this culvert which was likely installed circa 2011 (8 years). Refer to the below figures and Table 62 for a summary of findings.

Figure 251 | Root intrusion, Chg1.37m

Table 62 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –3.29	-	Main	DN225 PVC
1.37	251	Roots	Root intrusion at joint obstructing flow <5% from 7-8 O'clock

2.63 McGoughans Lane | Line U/S / D/S | D-MBY-UPI-1317 | (3.29m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition with no defects identified. There are no junctions on this culvert which was likely installed circa 2011 (8 years). Refer to the below figures and Table 63 for a summary of findings.

Figure 252 | Typical condition, Chg3.31m

Table 63 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 3.29	-	Main	DN375 RCP
3.31	252	Condition	Culvert in good condition

2.64 McGoughans Lane | Line KIP-1280 / HWL-1278| D-MBY-UPI-1063| (6.42m)

The entire culvert is comprised of a DN450 RCP. The main is in a reasonable condition with minor defects such as root intrusion and breaking identified. There are no junctions on this culvert which was installed in 1984 (35 years). Refer to the below figures and Table 64 for a summary of findings.

Figure 253 | Breaking, Chg0.62m

Figure 254 | Root intrusion, Chg3.12m

Table 64 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 – 6.42	-	Main	DN450 RCP
0.62	253	Breaking	Culvert wall breaking 100mm long from 11-1 O'clock
3.12	254	Roots	Root intrusion at joint obstruction of 5-20% from 4-8 O'clock

2.65 River Terrace | Line U/S / HWL-1278 | D-MBY-UPI-1062| (15.89m)

The entire culvert is comprised of a DN600 RCP. The main is in a reasonable condition with minor defects such as root intrusion and joint displacement. There are no junctions on this culvert which was installed in 1984 (35 years). Refer to the below figures and Table 65 for a summary of findings.

Figure 255 |Root intrusion, Chg2.35m

Figure 256 | Root intrusion, Chg9.74m

Figure 257 |Root intrusion, Chg12.03m

Figure 258 |Displacement, Chg14.65m

Table 65 | Line U/S / HWL-1278

Chainage (m)	Figure	Item	Observation
0 – 15.89	-	Main	DN600 RCP
2.35	255	Roots	Root intrusion at joint obstruction of 5-20% from 4-8 O'clock
9.74	256	Roots	Root intrusion at joint obstruction of <5% from 3-4 O'clock
12.03	257	Roots	Root intrusion at joint obstruction of <5% from 4-5 O'clock
14.65	258	Displacement	Radial joint displacement 5-10mm at 6 O'clock

2.66 River Terrace | Line KIP-1282 / D/S | D-MBY-UPI-1065 | (21.25m) – refer to 2.60 for remaining assessment of this culvert

The entire culvert is comprised of a DN600 RCP that transitions to DN450 RCP at 7.70m. The assessment was terminated at 21.25m due to the inability to clean the culvert due to its poor condition and the root intrusion obstructing the assessment. The culvert is in poor condition with defects such as cracking, breaking, root intrusion, and joint displacement identified. There are three junctions on the section of this culvert that was assessed which was installed in 1984 (35 years). Refer to the below figures and Table 66 for a summary of findings.

Figure 259 |Root intrusion, Chg0.66m

Figure 260 |Hole repair, Chg7.36m

Figure 261 |Cross section, Chg7.70m

Figure 262 |Aggregate, Chg8.51m

Figure 263 |Cracking, Chg11.40m

Figure 264 |Root intrusion, Chg11.73m

Figure 265 |Displacement, Chg11.73m

Figure 266 |Unmarked MH, Chg12.57m

Figure 267 |Junction, Chg12.57m

Figure 268 |Root intrusion, Chg13.21m

Figure 269 | Cracking, Chg14.69m

Figure 270 | Hole, Chg15.23m

Figure 271 | Junction, Chg16.10m

Figure 272 | Junction, Chg19.38m

Table 66 | Line KIP-1282 / D/S

Chainage (m)	Figure	Item	Observation
0 – 21.25	-	Main	DN600/450 RCP
0.66	259	Roots	Root intrusion obstruction at joint <5% from 4-8 O'clock
7.36	260	Hole repair	Hole in culvert wall repaired externally with plastic lining
7.70	261	Cross section	Cross section of culvert reduced from DN600 to DN450
8.51	262	Aggregate	Exposed aggregate on the culvert wall from 12-12 O'clock
11.40	263	Cracking	Multiple surface cracking 1mm wide from 12-12 O'clock
11.73	264	Root intrusion	Root intrusion obstruction at joint <5% from 4-8 O'clock
11.73	265	Displacement	Radial joint displacement >20mm at 5 O'clock
12.57	266	Unmarked MH	Unmarked maintenance hole
12.57	267	Junction	DN300 junction in good condition at 3 O'clock
13.21	268	Root intrusion	Root intrusion obstruction at joint 5-20% from 4-6 O'clock
14.69	269	Cracking	Multiple cracking 3mm wide from 12-12 O'clock
15.23	270	Hole	Hole in culvert wall has extended right through to soil from 11-1 O'clock
16.10	271	Junction	DN150 defective junction, completely blocked
19.38	272	Junction	DN100 defective junction, completely blocked

2.67 Poplar Avenue | Line HWL-1423 / HWL-1422| D-MBY-UPC-1001| (9.48m)

The entire culvert is comprised of a DN450 RCP. The main is in poor condition with defects such as cracking, joint displacement, and a repaired hole. There are no junctions on this culvert which was installed in 1960 (59 years). Refer to the below figures and Table 67 for a summary of findings.

Figure 273 |Cracking, Chg0.60m

Figure 274 |Displacement, Chg2.02m

Figure 275 |Hole repair, Chg7.09m

Figure 276 |Cracking, Chg8.12m

Table 67 | Line HWL-1423 / HWL-1422

Chainage (m)	Figure	Item	Observation
0 –9.48	-	Main	DN450 RCP
0.60	273	Cracking	Cracking in culvert wall 2mm wide at 11 O'clock
2.02	274	Displacement	Longitudinal joint displacement 20-30mm
7.09	275	Hole repair	Hole repaired with sheet metal 300mm long from 11-1 O'clock
8.12	276	Cracking	Circumferential cracking 3mm wide from 7-5 O'clock

2.68 Poplar Avenue | Line HWL-1421 / JPT-1420| D-MBY-UPI-1000| (13.24m)

The entire culvert is comprised of a DN600 RCP. The main is in poor condition with defects such as joint displacement and holes. There is a single junction on this culvert which was installed in 1960 (59 years). Refer to the below figures and Table 68 for a summary of findings.

Figure 277 |Hole, Chg1.20m

Figure 278 | Displacement, Chg2.49m

Figure 279 |Displacement, Chg4.97m

Figure 280 |Displacement, Chg7.47m

Figure 281 | Displacement, Chg9.95m

Figure 282 | Junction, Chg13.24m

Table 68 | Line HWL-1421 / JPT-1420			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 13.24	-	Main	DN600 RCP
1.20	277	Hole	Hole through the culvert wall 100mm long from 4-8 O'clock
2.49	278	Displacement	Longitudinal joint displacement 20-30mm with partial breaking of the culvert wall
4.97	279	Displacement	Longitudinal joint displacement >30mm with a hole through the culvert wall from 4-8 O'clock
7.47	280	Displacement	Longitudinal joint displacement >30mm with a hole through the culvert wall from 4-8 O'clock
9.95	281	Displacement	Longitudinal joint displacement 10-20mm with obstruction 5-20% from fouling at joint
13.24	282	Junction	DN450 RCP junction open obstructing flow path 5-20% at 3 O'clock

2.69 Poplar Avenue | Line JPT-1420 / New Pit | D-MBY-UPI-0999 | (15.79m)

The entire culvert is comprised of a DN600 RCP. The main is in a reasonable condition with defects such as joint displacement being the primary concern. There are no junctions on this culvert which was installed in 1960 (59 years). Refer to the below figures and Table 69 for a summary of findings.

Figure 283 |Displacement, Chg3.65m

Figure 284 | Displacement, Chg6.15m

Figure 285 | Displacement, Chg6.47m

Figure 286 | Displacement, Chg8.26m

Figure 287 | Displacement, Chg10.83m

Table 69 | Line JPT-1420 / Unmarked			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 15.79	-	Main	DN600 RCP
3.65	283	Displacement	Longitudinal joint displacement >30mm
6.15	284	Displacement	Longitudinal joint displacement 20-30mm with partial breaking of the culvert wall
6.47	285	Displacement	Radial joint displacement >20mm at 6 O'clock
8.26	286	Displacement	Longitudinal joint displacement >30mm
10.83	287	Displacement	Longitudinal joint displacement 20-30mm

2.70 Poplar Avenue | Line New Pit / D/S Outfall | D-MBY-UPI-0999 | (19.70m)

The entire culvert is comprised of a DN600 RCP. The assessment was terminated at 19.70m due to an interwoven root ball that has formed where the pipe has reportedly collapsed. The culvert is in poor condition with defects such as cracking, breaking, root intrusion, joint displacement, and holes identified. There are no junctions on the section of this culvert that was assessed which was likely installed circa 1984 (35 years). Refer to the below figures and Table 70 for a summary of findings.

Figure 288 |Displacement, Chg2.83m

Figure 289 |Hole, Chg5.33m

Figure 290 |Hole, Chg7.71m

Figure 291 |Hole, Chg9.71m

Figure 292 |Hole, Chg12.71m

Figure 293 | Displacement, Chg12.71m

Figure 294 |Displacement, Chg15.28m

Figure 295 |Hole, Chg16.23m

Figure 296 |Hole, Chg17.63m

Figure 297 |Root intrusion, Chg19.70m

Table 70 | Line New Pit / D/S Outfall

Chainage (m)	Figure	Item	Observation
		Main	DN600 RCP
2.83	288	Displacement	Longitudinal joint displacement 20-30mm
5.33	289	Hole	Hole in culvert wall at joint through to soil from 7-10 O'clock
7.71	290	Hole	Hole in culvert wall at joint through to sky from 10-2 O'clock
9.71	291	Hole	Hole in culvert wall through to sky at 12 O'clock
12.71	292	Hole	Hole in culvert wall at joint through to sky at 12 O'clock
12.71	293	Displacement	Radial joint displacement 10-20mm at 12 O'clock
15.28	294	Displacement	Longitudinal joint displacement 10-20mm
16.23	295	Hole	Hole in culvert wall through to sky at 12 O'clock
17.63	296	Hole	Hole in culvert wall at joint through to sky from 8-11 O'clock with root intrusion obstruction 5-20%
19.70	297	Root intrusion	Significant root intrusion obstructing assessment and flow by 50-75%

2.71 Burringbar Street | Line KIP-1296 / JPT-1295 | D-MBY-UPI-0999| (7.42m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition with only minor isolated joint displacement identified. There are no junctions on this culvert which was likely installed circa 1993 (26 years). Refer to the below figures and Table 71 for a summary of findings.

Figure 298 |Typical condition, Chg3.27m

Figure 299 | Displacement, Chg7.09m

Table 71 | Line KIP-1296 / JPT-1295

Chainage (m)	Figure	Item	Observation
0 – 7.42	-	Main	DN375 RCP
3.27	298	Condition	Main is typically in good condition
7.09	299	Displacement	Radial joint displacement 10-20mm at 12 O'clock

2.72 Burringbar Street | Line JPT-1294 / JPT-1292 | D-MBY- UPI-1077 | (62.80m)

The entire culvert is comprised of a DN750 RCP. The main is typically in good condition with only some joint displacements identified. There are no junctions on this culvert which was likely installed circa 1993 (26 years). Refer to the below figures and Table 72 for a summary of findings.

Figure 300 |Displacement, Chg6.65m

Figure 301 | Displacement, Chg21.28m

Figure 302 |Displacement, Chg23.76m

Figure 303 |Rubber ring, Chg40.91m

Table 72 | Line JPT-1294 / JPT-1292

Chainage (m)	Figure	Item	Observation
0 –62.80	-	Main	DN750 RCP
6.65	300	Displacement	Longitudinal joint displacement 20-30mm
21.28	301	Displacement	Longitudinal joint displacement 20-30mm
23.76	302	Displacement	Longitudinal joint displacement 10-20mm
40.91	303	Rubber ring	Rubber ring has become dislodged from joint and is within the flow path from 11-2 O'clock

2.73 Burringbar Street | Line JPT-1295 / JPT-1294 | D-MBY-UPI-0948 | (30.85m)

The entire culvert is comprised of a DN750 RCP. The main is in good condition with only some joint displacements identified. There are no junctions on this culvert which was installed in 1993 (26 years). Refer to the below figures and Table 73 for a summary of findings.

Figure 304 | Displacement, Chg1.37m

Figure 305 | Displacement, Chg11.18m

Table 73 | Line JPT-1295 / JPT-1294

Chainage (m)	Figure	Item	Observation
0 – 30.85	-	Main	DN750 RCP
1.37	304	Displacement	Longitudinal joint displacement 20-30mm
11.18	305	Displacement	Longitudinal joint displacement 10-20mm

2.74 Left Bank Road | Line KIP-1239 / JPT-1238 | D-MBY-UPI-0993 | (0.56m)

The entire culvert is comprised of a DN375 RCP. The main is in good condition with only minor surface cracking identified. There are no junctions on this culvert which was installed in 1980 (39 years). Refer to the below figures and Table 74 for a summary of findings.

Figure 305 | General condition, Chg0.00m

Figure 306 | Cracking, Chg0.00m

Table 74 | Line KIP-1239 / JPT-1238

Chainage (m)	Figure	Item	Observation
0 – 0.56	-	Main	DN375 RCP
0.00	305	Condition	Culvert in good condition
0.00	306	Cracking	Longitudinal cracking 1mm wide at 11 O'clock

2.75 Left Bank Road | Line KIP-1237 / JPT-1238 | D-MBY-UPI-0992 | (15.80m)

The entire culvert is comprised of a DN450 RCP. The assessment was terminated at 8.69m due to a junction obstructing the assessment. The section of culvert that was assessed is in good condition with only minor root intrusion identified. There is a single junction on the portion of this culvert that was assessed which was installed in 1980 (39 years). Refer to the below figures and Table 75 for a summary of findings.

Figure 307 |Root intrusion, Chg2.43m

Figure 308 |Root intrusion, Chg4.94m

Figure 309 | Root intrusion, Chg7.47m

Figure 310 | Junction, Chg8.67m

Table 75 | Line KIP-1237 / JPT-1238

Chainage (m)	Figure	Item	Observation
0 – 8.69	-	Main	DN450 RCP
2.43	307	Roots	Root intrusion at joint with obstruction <5% from 8-4 O'clock
4.94	308	Roots	Root intrusion at joint with obstruction <5% from 8-4 O'clock
7.47	309	Roots	Root intrusion at joint with obstruction <5% from 8-4 O'clock
8.67	310	Junction	Obstruction of 5-20% from penetrating junction that is damage with a large longitudinal crack

2.76 Left Bank Road | Line U/S / JPT-1238 | D-MBY-UPI-0994 | (6.66m)

The entire culvert is comprised of a DN300 RCP. The culvert is in relatively poor condition with defects at the majority of joints such as displacements, root intrusion, and cracking. There are no junctions on this culvert which was installed in 1980 (39 years). Refer to the below figures and Table 76 for a summary of findings.

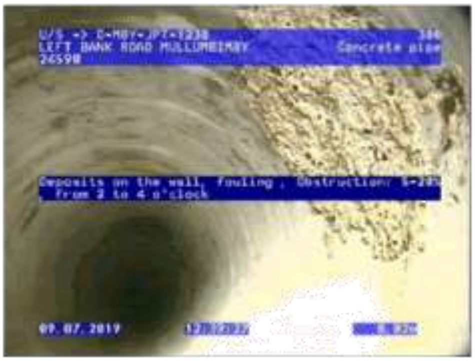

Figure 311 | Deposit, Chg0.02m

Figure 312 | Root intrusion, Chg1.09m

Figure 313 |Displacement, Chg2.92m

Figure 314 |Displacement, Chg4.72m

Figure 315 |Cracking, Chg6.44m

Table 76 | Line U/S / JPT-1238			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 6.66	-	Main	DN300 RCP
0.02	311	Deposit	Solid deposit attached to culvert wall with obstruction <5% from 2-4 O'clock
1.09	312	Roots	Root intrusion at joint with obstruction <5% from 8-4 O'clock
2.92	313	Displacement	Radial joint displacement 5-10mm at 6 O'clock
4.72	314	Displacement	Radial joint displacement 10-20mm at 12 O'clock
6.44	315	Cracking	Circumferential cracking 4mm wide from 8-4 o'clock

2.77 Jubilee Street | Line JPT-6461 / HWL-6462 | D-MBY-UPI-6393 | (37.02m)

The entire culvert is comprised of a DN375PP. The culvert is in good condition with no defects and just some minor angular deflections at joints. There are no junctions on this culvert which was installed in 2018 (1 year). Refer to the below figures and Table 77 for a summary of findings.

Figure 316 | Displacement, Chg25.77m

Table 77 | Line JPT-6461 / HWL-6462			
Chainage (m)	**Figure**	**Item**	**Observation**
0 –37.02	-	Main	DN375PP
25.77	316	Displacement	Angular displacement at joint

2.78 Jubilee Street | Line U/S / JPT-6461 | D-MBY-UPI-6392 | (0.99m)

The entire culvert is comprised of a DN375 PP. The culvert is in good condition with no defects identified. There are no junctions on this culvert which was installed in 2018 (1 year). Refer to the below figures and Table 78 for a summary of findings.

Figure 317 | Typical condition, Chg0.44m

Table 78 | Line /S / JPT-6461			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 0.99	-	Main	DN375 PP
0.44	317	Condition	Culvert in good condition, sticks and deleterious material in maintenance structure

2.79 Left Bank Road | Line JPT-1238 / HWL-1240 | D-MBY-UPI-0995 | (17.97m)

The entire culvert is comprised of a DN450 RCP. The culvert is in relatively poor condition with defects such as joint displacement, root intrusion, and breaking. There is a single junction within an unmarked MH on this culvert which was installed in 1980 (39 years). Refer to the below figures and Table 79 for a summary of findings.

Figure 318 |Root intrusion, Chg2.25m

Figure 319 |Unmarked MH, Chg2.94m

Figure 320 |Junction, Chg7.13m

Figure 321 |Breaking, Chg10.08m

Figure 322 | Displacement, Chg10.08m

Figure 323 |Breaking, Chg12.83m

Table 79 | Line JPT-1238 / HWL-1240			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 17.97	-	Main	DN450 RCP
2.25	318	Root intrusion	Root intrusion at joint with obstruction 5-20% from 3-5 O'clock
2.94	319	Unmarked MH	Unmarked maintenance structure identified
7.13	320	Junction	Junction entering into the maintenance structure with large sediment obstruction in junction line 5-20%
10.08	321	Breaking	Breaking of culvert wall at joint 100mm long from 10-2 O'clock
10.08	322	Displacement	Radial joint displacement 10-20mm at 6 O'clock
12.83	323	Breaking	Breaking of culvert wall at joint 100mm long from 4-5 O'clock

2.80 Tincogan Street | Line U/S / D/S | D-MBY-UPI-1090 | (4.85m)

The entire culvert is comprised of a DN225 RCP. The culvert is in very poor condition with breaking of the culvert wall evident throughout. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 80 for a summary of findings.

Figure 324 |Breaking, Chg0.00m

Figure 325 |Breaking, Chg4.46m

Table 80 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 –4.85	-	Main	DN225 RCP
0.00	324	Breaking	Culvert wall subject to significant breaking from 12-12 O'clock
4.46	325	Breaking	Culvert wall subject to significant breaking from 12-12 O'clock

2.81 Burringbar Street | Line U/S / D/S | D-MBY-UPC-1094 | (15.00m)

The entire culvert is comprised of a DN300 RCP. The assessment was terminated at 5.33m due to an obstruction occurring where the pipe diameter reduced from DN300 to DN225. The culvert is in very poor condition with breaking of the culvert wall, cracking, and joint displacement evident throughout. There are no junctions on the section of this culvert that was assessed which was likely installed circa 1940 (79 years). Refer to the below figures and Table 81 for a summary of findings.

Figure 326 | Breaking, Chg 0.23m

Figure 327 | Cracking, Chg 1.05m

Figure 328 | Displacement, Chg 2.09m

Figure 329 | Breaking, Chg 3.29m

Figure 330 | Deformation, Chg 3.69m

Figure 331 | Chane in diameter, Chg 5.13m

Table 81 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 – 5.33	-	Main	DN300 RCP
0.23	326	Breaking	Culvert wall subject to breaking 300mm long from 3-9 O'clock
1.05	327	Cracking	Longitudinal cracking 4mm wide at 12 O'clock
2.09	328	Displacement	Radial joint displacement >50mm at 4 O'clock
3.29	329	Breaking	Culvert wall subject to breaking 200mm long from 11-1 O'clock
3.69	330	Deformation	Culvert is horizontal deformed due to extensive breaking and external forces throughout
5.13	331	Diameter	Point repair in culvert undertaken with bricks as well as a reduction in diameter from DN300 to DN225

2.82 Stuart Street | Line HWL-1312 / D/S | D-MBY-UBC-0966 | (20.34m)

The entire culvert is comprised of a 600W x 375H RCBC. The culvert is in very poor condition with exposed aggregate, collapsed walls, root intrusion, and breaking. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 82 for a summary of findings.

Figure 332 | Aggregate, Chg 0.00m

Figure 333 | Collapse, Chg 2.24m

Figure 334 | Root intrusion, Chg 3.29m

Figure 335 | Root intrusion, Chg 10.59m

Figure 336 | Root intrusion, Chg 12.74m

Figure 337 | Breaking, Chg 14.71m

Table 82 | Line HWL-1312 / D/S			
Chainage (m)	Figure	Item	Observation
0 – 20.34	-	Main	600W x 375H RCBC
0.00	332	Aggregate	Culvert wall has exposed aggregate indicating deterioration throughout
2.24	333	Collapse	Culvert roof has collapsed for a 1000mm length
3.29	334	Roots	Root intrusion at joint with obstruction <5% at 5 O'clock
10.59	335	Roots	Root intrusion at joint with obstruction <5% at 5 O'clock
12.74	336	Roots	Root intrusion at joint with obstruction <5% at 5 O'clock
14.71	337	Breaking	Culvert roof subject to breaking 100mm long from 12-1 O'clock

2.83 Stuart Street | Line GIP-1315 / HWL-1523 | D-MBY-UPI-1311 | (9.21m)

The entire culvert is comprised of a DN300 RCP. The culvert is in poor condition with exposed aggregate, joint displacement, and obstructions identified. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 83 for a summary of findings.

Figure 338 | Rubble, Chg 0.00m

Figure 339 | Displacement, Chg 0.37m

Figure 340 | Cracking, Chg 1.14m

Figure 341 | Cracking, Chg 3.65m

Figure 342 | Displacement, Chg 4.15m

Figure 343 | Hole, Chg 6.78m

Table 83 | Line GIP-1315 / HWL-1523			
Chainage (m)	Figure	Item	Observation
0 – 9.21	-	Main	DN300 RCP
0.00	338	Rubble	Hard compacted material in the culvert invert obstructing flow 20-50% from 3-9 O'clock
0.37	339	Displacement	Radial joint displacement >50mm at 10 O'clock
1.14	340	Cracking	Longitudinal cracking 3mm wide at 2 O'clock and exposed aggregate
3.65	341	Cracking	Longitudinal cracking 2mm wide at 12 O'clock
4.15	342	Displacement	Radial joint displacement >20mm at 4 O'clock
6.78	343	Hole	Hole in culvert at joint 100mm long at 12 O'clock soil visible

2.84 Fern Street | Line KIP-1218 / D/S | D-MBY-UPI-0977 | (7.99m)

The entire culvert is comprised of a DN375/300 RCP. The culvert is in poor condition with exposed aggregate, joint displacement, and obstructions identified. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 84 for a summary of findings.

Figure 344 | Aggregate, Chg 0.00m

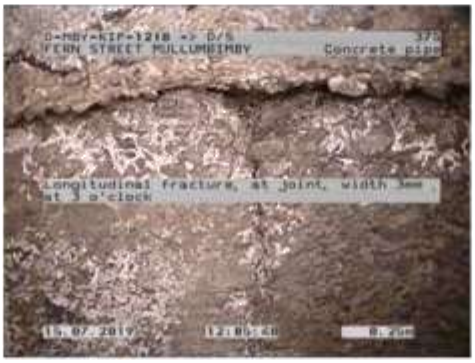

Figure 345 | Cracking, Chg 0.25m

Figure 346 | Displacement, Chg 0.75m

Figure 347 | Slip line, Chg 2.85m

Figure 348 | Displacement, Chg 3.93m

Figure 349 | Displacement, Chg 5.78m

Figure 350 | Breaking, Chg 6.40m

Table 84 | Line KIP-1218 / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 7.99	-	Main	DN375/300 RCP
0.00	344	Aggregate	Exposed aggregate on culvert wall throughout identifying deterioration
0.25	345	Cracking	Longitudinal cracking 3mm wide at 3 O'clock
0.75	346	Displacement	Radial joint displacement >20mm at 10 O'clock
2.85	347	Slip line	Culvert has had a smaller culvert (DN300) inserted inside of it resulting in a reduced flow capacity and large radial step
3.93	348	Displacement	Longitudinal joint displacement 20-30mm
5.78	349	Displacement	Longitudinal joint displacement 10-20mm
6.40	350	Breaking	Breaking of culvert wall 100mm long from 9-1 O'clock

2.85 Fern Street | Line KIP-1320 / JPT-1319 | D-MBY-UPI-0974 | (14.66m)

The entire culvert is comprised of a DN375 RCP. The culvert is in poor condition with exposed aggregate, joint displacement, and cracking identified. There is a single junction on this culvert which was installed in 1975 (44 years). Refer to the below figures and Table 85 for a summary of findings.

Figure 351 | Cracking, Chg 0.16m

Figure 352 | Displacement, Chg 1.84m

Figure 353 | Displacement, Chg 1.85m

Figure 354 | Displacement, Chg 2.49m

Figure 355 | Displacement, Chg 3.14m

Figure 356 | Displacement, Chg 5.69m

Figure 357 | Displacement, Chg 8.25m

Figure 358 | Junction, Chg 10.72m

Figure 359 | Cracking, Chg 13.26m

Figure 360 | Obstruction, Chg 14.52m

Table 85 | Line KIP-1218 / D/S

Chainage (m)	Figure	Item	Observation
0 – 14.66	-	Main	DN375 RCP
0.16	351	Cracking	Multiple cracking 3mm wide from 12-12 O'clock
1.84	352	Displacement	Longitudinal joint displacement >30mm
1.85	353	Displacement	Radial joint displacement 10-20mm at 6 O'clock
2.49	354	Displacement	Longitudinal joint displacement >30mm
3.14	355	Displacement	Longitudinal joint displacement >30mm
5.69	356	Displacement	Longitudinal joint displacement >30mm
8.25	357	Displacement	Longitudinal joint displacement >30mm
10.72	358	Junction	Junction DN300 open at 10 O'clock with wall breaking around penetration
13.26	359	Cracking	Circumferential cracking 3mm wide from 12-12 O'clock
14.52	360	Obstruction	Obstruction in maintenance structure due to sticks 5-20%

2.86 Burringbar Street | Line JPT-1297 / JPT-1295 | D-MBY-UPI-0949 | (21.47m)

The entire culvert is comprised of a DN750 RCP. The culvert is in good condition with only isolated joint displacement identified. There are no junctions on this culvert which was installed in 1993 (26 years). Refer to the below figures and Table 86 for a summary of findings.

Figure 361 | Sediment, Chg 0.00m

Figure 362 | Displacement, Chg 4.24m

Table 86 | Line JPT-1297 / JPT-1295

Chainage (m)	Figure	Item	Observation
0 – 21.47	-	Main	DN750 RCP
0.00	361	Sediment	Sediment build up with obstruction <5% from 5-7 O'clock
4.24	362	Displacement	Longitudinal joint displacement 10-20mm

2.87 Burringbar Street | Line JPT-1288 / GPT-5751 | D-MBY-UPI-1071 | (20.14m)

The entire culvert is comprised of a DN750 RCP. The culvert is in good condition with only isolated joint displacement identified. There are no junctions on this culvert which was installed in 1993 (26 years). Refer to the below figures and Table 87 for a summary of findings.

Figure 363 | Displacement, Chg 4.72m

Figure 364 | Displacement, Chg 17.12m

Figure 365 | Hole, Chg 19.96m

Table 87 | Line JPT-1288 / GPT-5751			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 20.14	-	Main	DN750 RCP
4.72	363	Displacement	Longitudinal joint displacement 10-20mm
17.12	364	Displacement	Longitudinal joint displacement 10-20mm
19.96	365	Hole	Hole through culvert wall to soil with exposed reinforcing steel at 12 O'clock

2.88 Orchid Place | Line U/S / KIP-1320 | D-MBY-UPI-0975 | (2.00m)

The entire culvert is comprised of a DN300 RCP. The culvert is in very poor condition with a pipe collapse at the downstream connection identified. There are no junctions on this culvert which was installed in 1975 (44 years). Refer to the below figures and Table 88 for a summary of findings.

Figure 366 | Sediment, Chg 0.00m

Figure 367 | Collapse, Chg 2.00m

Table 88 | Line U/S / KIP-1320

Chainage (m)	Figure	Item	Observation
0 – 2.00	-	Main	DN300 RCP
0.00	366	Sediment	Sediment build-up obstruction <5% at 6 O'clock
2.00	367	Collapse	Culvert has collapsed obstructing flow >90%

2.89 Whian Street | Line U/S / D/S | D-MBY-UPI-0968 | (4.14m)

The entire culvert is comprised of a DN300 RCP. The culvert appears to be in reasonable condition with only some cracking and root intrusion, however the entire culvert is 50% obstructed by compacted material (possibly concrete). There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 89 for a summary of findings.

Figure 368 | Obstruction, Chg 0.00m

Figure 369 | Cracking, Chg 0.48m

Figure 370 | Displacement, Chg 0.48m

Figure 371 | Cracking, Chg 2.36m

Figure 372 | root intrusion, Chg 3.92m

Table 89 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 4.14	-	Main	DN300 RCP
0.00	368	Obstruction	Culvert has a compacted material obstruction 50% from 3-9 O'clock
0.48	369	Cracking	Longitudinal cracking 3mm wide at 11 O'clock
0.48	370	Displacement	Radial joint displacement 10-20mm at 12 O'clock
2.36	371	Cracking	Multiple cracking at joint 3mm wide from 11-1 O'clock
3.92	372	Roots	Root intrusion obstruction 5-20% from 5-7 O'clock

2.90 Whian Street | Line U/S / JPT-1310 | D-MBY-UPI-0963 | (3.58m)

The entire culvert is comprised of a DN300 RCP. The culvert is in reasonable condition with only isolated exposed reinforcement and a single hole. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 90 for a summary of findings.

Figure 373 | Hole, Chg 1.19m

Figure 374 | Displacement, Chg 1.19m

Figure 375 | Reinforcement, Chg 1.98m

Table 90 | Line U/S / JPT-1310			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 3.58	-	Main	DN300 RCP
1.19	373	Hole	Hole in culvert wall through to soil 100mm long
1.19	374	Displacement	Radial joint displacement 5-10mm at 12 O'clock with minor sediment build-up
1.98	375	Reinforcement	Reinforcing steel exposed and corroding at 12 O'clock

2.91 Whian Street | Line JPT-1310 / D/S | D-MBY-UPI-0964 | (3.65m)

The entire culvert is comprised of a DN375 RCP. The culvert is in poor condition with various points subject to cracking. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 91 for a summary of findings.

Figure 373 | Cracking, Chg 0.45m

Figure 374 | Cracking, Chg 1.61m

Figure 375 | Cracking, Chg 2.69m

Table 91 | Line JPT-1310 / D/S

Chainage (m)	Figure	Item	Observation
0 – 3.65	-	Main	DN375 RCP
0.45	376	Cracking	Circumferential cracking 4mm wide from 8-4 O'clock
1.61	377	Cracking	Longitudinal surface cracking 1mm wide at 12 O'clock
2.69	378	Cracking	Circumferential cracking 4mm wide from 8-4 O'clock with reinforcing steel exposed

2.92 Dalley Street | Line HWL-1324 / D/S | N/A | (31.20m)

The entire culvert is comprised of a 450W x 300H RCBC. The culvert is in good condition with a few instances of minor joint displacement and an isolated instance of exposed reinforcement. There are no junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 92 for a summary of findings.

Figure 379 | Reinforcement, Chg 1.20m

Figure 380 | Displacement, Chg 7.47m

Figure 381 | Displacement, Chg 28.57m

Figure 382 | Displacement, Chg 29.92m

Table 92 | Line HWL-1324 / D/S

Chainage (m)	Figure	Item	Observation
0 – 31.20	-	Main	450W x 300H RCBC
1.20	379	Reinforcement	Reinforcing steel exposed and corroding at 11 O'clock
7.47	380	Displacement	Radial joint displacement 10-20mm at 6 O'clock
28.57	381	Displacement	Radial joint displacement 5-10mm at 6 O'clock
29.92	382	Displacement	Radial joint displacement 10-20mm at 12 O'clock

2.93 Argyle Street | Line KIP-1528 / D/S | D-MBY-UPI-3682 | (12.87m)

The entire culvert is comprised of a 1000W x 300H RCBC. The culvert is in good condition with a few instances of minor cracking and root intrusion. There are no junctions on this culvert which was installed in 1993 (26 years). Refer to the below figures and Table 93 for a summary of findings.

Figure 383 | Sediment, Chg 0.12m

Figure 384 | Reinforcement, Chg 4.40m

Figure 385 | rotated culverts, Chg 11.66m

Figure 386 | Obstruction, Chg 12.86m

Table 93 | Line KIP-1528 / D/S

Chainage (m)	Figure	Item	Observation
0 – 12.87	-	Main	1000W x 300H RCBC
0.12	383	Sediment	Sediment in the invert of the flow path obstructing flow <5% from 5-7 O'clock
4.40	384	Reinforcement	Reinforcing steel exposed and corroding from 8-10 O'clock
11.66	385	Rotated culverts	Two rotated culverts obstructing the flow path 50%
12.86	386	Obstruction	Mass of material that has entered the culvert through the grated inlet obstructing flow 20-50%

2.94 Studal Lane | Line U/S / D/S | D-MBY-UPI-0970 | (22.70m)

The entire culvert is comprised of a DN300 RCP. The culvert is in reasonable condition with defects such as cracking, breaking, and joint displacements identified. There are four junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and Table 94 for a summary of findings.

Figure 387 | Junction, Chg 0.18m

Figure 388 | Displacement, Chg 0.22m

Figure 389 | Cracking, Chg 1.42m

Figure 390 | Junction, Chg 3.03m

Figure 391 | Breaking, Chg 5.20m

Figure 392 | Junction, Chg 7.53m

Figure 393 | Junction, Chg 8.23m

Figure 394 | Breaking, Chg 10.15m

Figure 395 | Displacement, Chg 12.76m

Figure 396 | Displacement, Chg 15.15m

Figure 397 | Cracking, Chg 16.43m

Figure 398 | Cracking, Chg 21.44m

Table 94 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 – 22.70	-	Main	DN300 RCP
0.18	387	Junction	Junction 100mm open and in good condition protruding into flow path, obstruction 5-20% at 10 O'clock
0.22	388	Displacement	Radial joint displacement 10-20mm at 12 O'clock
1.42	389	Cracking	Circumferential cracking 7mm wide from 12-12 O'clock

3.03	390	Junction	Junction 100mm open and in good condition at 9 O'clock
5.20	391	Breaking	Culvert wall breaking at joint 100mm long from 11-1 O'clock
7.53	392	Junction	Junction 100mm open and in poor condition at 9 O'clock. Junction subject to deformation due to crushing
8.23	393	Junction	Junction 100mm open and in good condition protruding into flow path, obstruction 5-20% at 10 O'clock
10.15	394	Breaking	Culvert wall breaking at joint 100mm long at 6 O'clock
12.76	395	Displacement	Radial joint displacement 10-20mm at 12 O'clock
15.15	396	Displacement	Radial joint displacement 10-20mm at 6 O'clock
16.43	397	Cracking	Circumferential cracking 3mm wide from 12-12 O'clock
21.44	398	Cracking	Circumferential cracking 3mm wide from 12-12 O'clock

2.95 Studal Lane | Line JPT-1314 / D/S | D-MBY-UPI-1321 | (4.95m)

The entire culvert is comprised of a DN300 RCP. The culvert is in poor condition with defects such as cracking, breaking, and exposed reinforcement identified. There are no junctions on this culvert which was installed in 1979 (40 years). Refer to the below figures and Table 95 for a summary of findings.

Figure 399 | Reinforcement, Chg 0.00m

Figure 400 | Reinforcement, Chg 0.79m

Figure 401 | Reinforcement, Chg 1.46m

Figure 402 | Reinforcement, Chg 2.01m

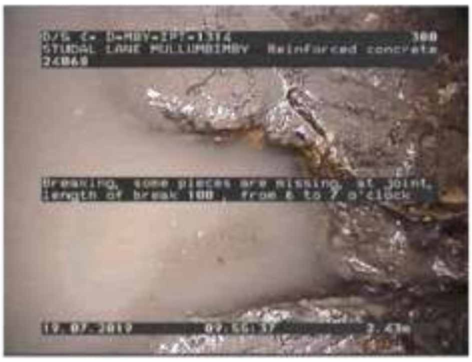

Figure 403 | Breaking, Chg 2.43m

Figure 404 | Cracking, Chg 3.79m

Figure 405 | Obstruction, Chg 4.23m

Table 95 | Line JPT-1314 / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 4.95	-	Main	DN300 RCP
0.00	399	Reinforcement	Culvert wall subject to breaking at joint with reinforcing steel exposed and corroding from 8-4 O'clock
0.79	400	Reinforcement	Culvert wall subject to breaking 100mm long with reinforcing steel exposed and corroding from 11-12 O'clock
1.46	401	Reinforcement	Culvert wall subject to breaking 100mm long with reinforcing steel exposed and corroding from 1-2 O'clock
2.01	402	Reinforcement	Culvert wall subject to breaking 100mm long with reinforcing steel exposed and corroding from 1-2 O'clock
2.43	403	Breaking	Culvert wall subject to breaking 100mm long from 6-7 O'clock
3.79	404	Cracking	Circumferential cracking 4mm wide from 12-12 O'clock
4.23	405	Obstruction	Deleterious material obstructing flow path 20-50% from 4-8 O'clock

2.96 Studal Lane | Line U/S / JPT-1314 | D-MBY-UPI-1321 | (30.20m)

The entire culvert is comprised of a DN300 RCP. The culvert is in a reasonable condition with defects such as cracking, breaking, and joint displacement identified. There are two junctions on this culvert which was installed in 1940 (79 years). refer to the below figures and table 96 for a summary of findings.

Figure 406 | Root intrusion, Chg 0.00m

Figure 407 | Displacement, Chg 2.42m

Figure 408 | Junction, Chg 8.44m

Figure 409 | Displacement, Chg 9.91m

Figure 410 | Junction, Chg 16.28m

Figure 411 | Displacement, Chg 17.01m

Figure 412 | Cracking, Chg 18.30m

Figure 413 | Breaking, Chg 24.58m

Figure 414 | Root intrusion, Chg 30.20m

Table 96 | Line JPT-1314 / D/S

Chainage (m)	Figure	Item	Observation
0 – 30.20	-	Main	DN300 RCP
0.00	406	Roots	Root intrusion obstructing flow by 20-50% from 5-7 O'clock
2.42	407	Displacement	Radial joint displacement >20mm at 12 O'clock
8.44	408	Junction	Junction 100mm in good condition intruding into flow path by 5-20% at 2 O'clock
9.91	409	Displacement	Radial joint displacement >20mm at 10 O'clock
16.28	410	Junction	Junction 100mm in good condition at 2 O'clock
17.01	411	Displacement	Longitudinal joint displacement 10-20mm
18.30	412	Cracking	Multiple cracking 2mm wide from 8-4 O'clock
24.58	413	Breaking	Culvert wall breaking at joint 200mm long from 10-2 O'clock
30.20	414	Roots	Root intrusion obstructing flow by 20-50% from 4-6 O'clock

2.97 McGoughans Lane | Line U/S / D/S | D-MBY-UBC-6474 | (4.82m)

The entire culvert is comprised of a 600W x 300H RCBC. The culvert is in good condition with no defects identified. There are no junctions on this culvert which was installed in 2018 (1 year). refer to the below figures and table 97 for a summary of findings.

Figure 415 | General condition, Chg 0.00m

Table 97 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 4.82	-	Main	600W x 300H RCBC
0.00	415	Condition	Culvert is in good condition

2.98 McGoughans Lane | Line HWL-1547 / HWL-1548 | D-MBY-UPI-425 | (7.26m)

The entire culvert is comprised of a DN375 RCP. The culvert is in good condition with no defects identified. There are no junctions on this culvert which was likely installed in the past 10 years. refer to the below figures and table 98 for a summary of findings.

Figure 416 | General condition, Chg 0.00m

Table 98 | Line U/S / D/S

Chainage (m)	Figure	Item	Observation
0 – 7.26	-	Main	DN375 RCP
0.00	416	Condition	Culvert is in good condition

2.99 Orchid Place | Line JPT-1319 / D/S | D-MBY-UPI-0973 | (1.87m)

The entire culvert is comprised of a DN375 RCP. The culvert is in good condition with no defects identified. There are no junctions on this culvert which was installed in 1975 (44 years). refer to the below figures and table 99 for a summary of findings.

Figure 417 | General condition, Chg 0.00m

Table 99 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 1.87	-	Main	DN375 RCP
0.00	417	Condition	Culvert is in good condition

2.100 Orchid Place | Line JPT-1319 / New Pit | D-MBY-UPI-0973 | (39.73m)

The entire culvert is comprised of a DN525 RCP. The culvert is in a reasonable condition with primary defects including root intrusion and joint displacement. There are two junctions on this culvert which was likely installed circa 1975 (44 years). refer to the below figures and table 100 for a summary of findings.

Figure 418 | Displacement, Chg 2.02m

Figure 419 | Displacement, Chg 4.44m

Figure 420 | Displacement, Chg 6.91m

Figure 421 | Junction, Chg 8.04m

Figure 422 | Root intrusion, Chg 14.53m

Figure 423 | Junction, Chg 14.71m

Figure 424 | Root intrusion, Chg 16.99m

Figure 425 | Root intrusion, Chg 24.50m

Figure 426 | Root intrusion, Chg 26.94m

Figure 427 | Displacement, Chg 29.38m

Table 100 | Line JPT-1319 / New Pit

Chainage (m)	Figure	Item	Observation
0 – 39.73	-	Main	DN525 RCP
2.02	418	Displacement	Longitudinal joint displacement 10-20mm
4.44	419	Displacement	Longitudinal joint displacement 10-20mm
6.91	420	Displacement	Longitudinal joint displacement 10-20mm
8.04	421	Junction	Junction 150mm closed in poor condition completely collapsed at 12 O'clock
14.53	422	Roots	Root intrusion obstructing flow <5% from 4-5 O'clock
14.71	423	Junction	Junction 150mm open in good condition at 12 O'clock
16.99	424	Roots	Root intrusion obstructing flow <5% at 4 O'clock
24.50	425	Roots	Root intrusion obstructing flow <5% from 4-5 O'clock
26.94	426	Roots	Root intrusion obstructing flow <5% from 7-8 O'clock
29.38	427	Displacement	Radial joint displacement 10-20mm

2.101 Studal Lane | Line U/S / D/S | D-MBY-UBC-1043 | (4.09m)

The entire culvert is comprised of a 450W x 225H RCBC. The culvert is in a reasonable condition with primary defects including joint displacement, and obstructions. There are no junctions on this culvert which was installed in 1940 (79 years). refer to the below figures and table 101 for a summary of findings.

Figure 428 | Displacement, Chg 3.01m

Figure 429 | Obstruction, Chg 3.47m

Figure 430 | Obstruction, Chg 4.09m

Table 101 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 4.09	-	Main	450W x 225H RCBC
3.01	428	Displacement	Longitudinal joint displacement 10-20mm
3.47	429	Obstruction	Compacted material (concrete) obstructing flow path 20-50%
4.09	430	Obstruction	Reduced culvert width obstructing flow path ~20%

2.102 Studal Lane | Line U/S / D/S | D-MBY-UBC-1042 | (4.31m)

The entire culvert is comprised of a 450W x 150H RCBC. The assessment was terminated at 4.31m due to an obstruction that could not be cleared due to no access from the D/S MH. The section of the culvert that was assessed is in poor condition with primary defects including joint displacement, and obstructions. There is a single junction on this culvert which was installed in 1940 (79 years). refer to the below figures and table 102 for a summary of findings.

Figure 431 | Junction, Chg 0.44m

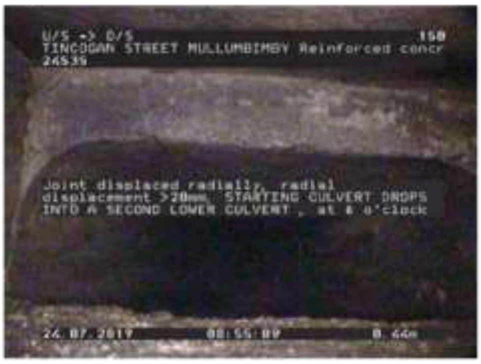

Figure 432 | Vertical step, Chg 0.44m

Figure 433 | Obstruction, Chg 0.44m

Figure 434 | Displacement, Chg 4.18m

Figure 435 | Obstruction, Chg 4.31m

Table 102 | Line U/S / D/S			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 4.31	-	Main	450W x 150H RCBC
0.44	431	Junction	Junction 450W x 250H open in good condition at 3 O'clock
0.44	432	Vertical step	Vertical step in the flow path resulting in an obstruction of the flow path ~30%
0.44	433	Obstruction	Rubble in the invert of the culvert obstructing flow ~15%
4.18	434	Displacement	Radial joint displacement 10-20mm at 6 O'clock
4.31	435	Obstruction	Rubble in the invert of the culvert obstructing flow ~25% and the assessment

2.103 Studal Lane | Line KIP-1317 / HWL-1316 | D-MBY-UBC-1042 | (49.90m)

The entire culvert is comprised of a DN375 RCP. The culvert is in a reasonable condition with primary defects including joint displacement and cracking. There are no junctions on this culvert which was installed in 1997 (22 years). Refer to the below figures and table 103 for a summary of findings.

Figure 436 | Cracking, Chg 23.31m

Figure 437 | Displacement, Chg 34.39m

Figure 438 | Cracking, Chg 38.21m

Figure 439 | Cracking, Chg 40.56m

Figure 440 | Displacement, Chg 49.27m

Table 103 | Line KIP-1317 / HWL-1316			
Chainage (m)	**Figure**	**Item**	**Observation**
0 – 49.90	-	Main	DN375 RCP
23.31	436	Cracking	Longitudinal cracking 2mm wide at 9 O'clock
34.39	437	Displacement	Longitudinal joint displacement 10-20mm
38.21	438	Cracking	Multiple cracking 2mm wide from 11-1 O'clock
40.56	439	Cracking	Circumferential cracking 2mm wide from 8-4 O'clock
49.27	440	Displacement	Longitudinal joint displacement 10-20mm

2.104 Studal Lane | Line FIP-1338 / D/S | D-MBY-UPI-1318 | (31.80m)

The entire culvert is comprised of a DN375 RCP. The culvert is in a reasonable condition with the primary defect being joint displacement. There are no junctions on this culvert which was installed in 1979 (40 years). refer to the below figures and table 104 for a summary of findings.

Figure 441 | Roughened, Chg 2.27m

Figure 442 | Breaking, Chg 9.64m

Figure 443 | Displacement, Chg 16.92m

Figure 444 | Rubber ring, Chg 26.76m

Table 104 | Line KIP-1317 / HWL-1316

Chainage (m)	Figure	Item	Observation
0 – 31.80	-	Main	DN375 RCP
2.27	441	Roughened	Culvert wall has become roughened from 12-12 O'clock
9.64	442	Breaking	Culvert wall breaking at joint 100mm long at 8 O'clock
16.92	443	Displacement	Longitudinal joint displacement 10-20mm
26.76	444	Rubber ring	Rubber ring has become displaced from the joint and is within the flow path obstruction <5%

2.105 Burringbar Street | Line KIP-1298 / D/S | D-MBY-UPI-0954 | (15.55m)

The entire culvert is comprised of a DN375 RCP. The culvert is in good condition with the primary defect being joint displacement. There are no junctions on this culvert which was installed in 1993 (26 years). refer to the below figures and table 105 for a summary of findings.

Figure 445 | Displacement, Chg 2.88m

Figure 446 | Displacement, Chg 7.91m

Figure 447 | Displacement, Chg 15.41m

Table 105 | Line KIP-1298 / D/S

Chainage (m)	Figure	Item	Observation
0 – 15.55	-	Main	DN375 RCP
2.88	445	Displacement	Longitudinal joint displacement 10-20mm
7.91	446	Displacement	Longitudinal joint displacement 10-20mm
15.41	447	Displacement	Radial joint displacement 10-20mm at 6 O'clock

2.106 Stuart Street | Line HWL-1483 / GIP-1482 | D-MBY-UPI-1254 | (49.90m)

The entire culvert is comprised of a DN600 RCP. The culvert is in poor condition with various defects including joint displacement, cracking, holes, and breaking. There are three junctions on this culvert which was installed in 1940 (79 years). refer to the below figures and table 106 for a summary of findings.

Figure 448 | Breaking, Chg 0.30m

Figure 449 | Breaking, Chg 0.59m

Figure 450 | Breaking, Chg 1.37m

Figure 451 | Hole, Chg 1.88m

Figure 452 | Displacement, Chg 5.23m

Figure 453 | Reinforcement, Chg 7.25m

Figure 454 | Hole, Chg 15.84m

Figure 455 | Junction, Chg 23.87m

Figure 456 | Junction, Chg 33.42m

Figure 457 | Junction, Chg 43.78m

Figure 458 | End structure, Chg 49.90m

Table 106 | Line KIP-1298 / D/S

Chainage (m)	Figure	Item	Observation
0 – 49.90	-	Main	DN600 RCP
0.30	448	Breaking	Culvert wall breaking at joint 100mm long at 12 O'clock
0.59	449	Breaking	Culvert wall breaking throughout from 12-12 O'clock
1.37	450	Breaking	Culvert wall breaking at joint with pieces missing 200mm long from 11-1 O'clock

1.88	451	Hole	Hole in culvert wall 100mm long through to soil
5.23	452	Displacement	Radial joint displacement 10-20mm at 5 O'clock
7.25	453	Reinforcement	Reinforcing steel exposed ad corroding from 1-2 O'clock
15.84	454	Hole	Hole in culvert wall 200mm long through to soil from 11-1 O'clock
23.87	455	Junction	Junction open good condition 100mm dia at 12 O'clock
33.42	456	Junction	Junction open 100mm dia at 12 O'clock large void around connection through to soil
43.78	457	Junction	Junction open 100mm dia at 12 O'clock void around connection through to soil and junction protruding into flow path, obstruction 5-20%
49.90	458	End structure	End structure with grated lid

2.107 Stuart Street | Line GIP-1482 / JPT-1481 | D-MBY-UPI-1253 | (47.04m)

The entire culvert is comprised of a DN600 RCP. The culvert is in poor condition with various defects including joint displacement, cracking, holes, and root intrusion. There are two junctions on this culvert which was installed in 1940 (79 years). Refer to the below figures and table 107 for a summary of findings.

Figure 459 | Junction, Chg 4.57m

Figure 460 | Cracking, Chg 4.62m

Figure 461 | Root intrusion, Chg 11.54m

Figure 462 | Root intrusion, Chg 14.03m

Figure 463 | Root intrusion, Chg 14.61m

Figure 464 | Junction, Chg 14.65m

Figure 465 | Root intrusion, Chg 27.70m

Figure 466 | Hole, Chg 34.00m

Figure 467 | Root intrusion, Chg 37.70m

Figure 468 | Root intrusion, Chg 41.41m

Figure 469 | Displacement, Chg 45.16m

Table 107 | Line GIP-1482 / JPT-1481

Chainage (m)	Figure	Item	Observation
0 – 47.04	-	Main	DN600 RCP
4.57	459	Junction	Junction open good condition 150mm dia at 12 O'clock
4.62	460	Cracking	Multiple cracking 3mm wide from 11-1 O'clock
11.54	461	Roots	Root intrusion in joint obstruction <5% from 3-5 O'clock

14.03	462	Roots	Root intrusion in joint obstruction <5% from 3-5 O'clock
14.61	463	Roots	Root intrusion in joint obstruction <5% at 8 O'clock
14.65	464	Junction	Junction open good condition 150mm dia at 12 O'clock protruding into flow path obstruction 5-20%. Large void around junction penetration
27.70	465	Roots	Root intrusion in joint obstruction 5-20% from 4-5 O'clock
34.00	466	Hole	Hole in culvert wall due to breaking 200mm long from 10-3 O'clock
37.70	467	Roots	Root intrusion in joint obstruction 5-20% from 5-7 O'clock
41.41	468	Roots	Root intrusion in joint obstruction 5-20% from 4-5 O'clock
45.16	469	Displacement	Longitudinal joint displacement 10-20mm

2.108 Fern Street | Line JPT-1481 / D/S Outfall into Creek | D-MBY-UPI-1253 | (15.57m)

The entire culvert is comprised of a DN600 RCP. The assessment was terminated at 15.57 due to an obstruction from a collapsed pipe. The culvert had to be assessed three times due to failed attempts from rubble obstructions. The culvert is in poor condition with various defects including joint displacement, cracking, breaking, and root intrusion. There is a single junction on this culvert which was installed in 1940 (79 years). refer to the below figures and table 108 for a summary of findings.

Figure 470 | Spalling, Chg 0.02m

Figure 471 | Cracking, Chg 2.46m

Figure 472 | Junction, Chg 3.66m

Figure 473 | Displacement, Chg 3.88m

Figure 474 | Reinforcement, Chg 9.07m

Figure 475 | Hole, Chg 11.19m

Figure 476 | Displacement, Chg 11.44m

Figure 477 | Displacement, Chg 12.34m

Figure 478 | Root intrusion, Chg 13.90m

Figure 479 | Deformation, Chg 15.28m

Table 108 | Line JPT-1481 / D/S Outfall into Creek

Chainage (m)	Figure	Item	Observation
0 – 57.92	-	Main	DN600 RCP
0.02	470	Spalling	Spalling of culvert wall from 8-4 O'clock
2.46	471	Cracking	Multiple cracking 3mm wide from 12-12 O'clock
3.66	472	Junction	Junction open good condition 100mm dia at 1 O'clock
3.88	473	Displacement	Longitudinal joint displacement >30mm with minor root intrusion
9.07	474	Reinforcement	Reinforcing steel exposed and corroding from 8-10 O'clock
11.19	475	Hole	Hole through culvert wall from 5-7 O'clock
11.44	476	Displacement	Radial joint displacement >20mm at 12 O'clock
12.34	477	Displacement	Longitudinal joint displacement >30mm with minor root intrusion
13.90	478	Roots	Root intrusion in joint obstruction 5-20% from 5-7 O'clock
15.28	479	Deformation	Pipe collapse due to severe cracking/breaking, assessment terminated

3. SUMMARY OF FINDINGS

Table 109 | Summary Table

ID	PIPE INFORMATION							INSPECTION	JUNCTION				MAIN			
#	Asset ID (D-MBY-XXX-XXXX)	Street Name	Mat	Dia. (mm)	Year Const.	Pipe Age (yrs)	Length (m)	CCTV Complete (Y/N-m)	Total # of Junctions	Minor Defects (Cracking, Displacement)	Moderate Defects (Cracking, Displacement)	Major Defects (Cracking, Displacement)	Root Intrusion Score (1-5)	Minor Defects (Cracking, Displacement) (#)	Moderate Defects (Cracking, Displacement) (#)	Major Defects (Cracking, Displacement) (#)
1	UPC-1089	Tincogan Street	RCP	375	1940	79	16.76	Y	0				1	1	2	
2	UPC-1091	Tincogan Street	RCP	225	1940	79	3.12	Y	0				4	3	1	
3	UPC-1092	Brunswick Terrace	RCP	450	1940	79	18.15	Y	0				1	2		
4	UBC-1093	Brunswick Terrace	RCBC	600W x 400H	1940	79	3.64	Y	0				1		2	
5	UPI-1061	Burringbar Street	RCP	375	1960	59	25.92	Y	0				1	1		
6	UPI-1309	Station Street	RCP	450	1979	40	24.69	Y	2	2			1	8		
7	UPI-0983	Orchid Street	RCP	450	1975	44	27.27	Y	1					3	1	
8	UPI-0982	Orchid Street	RCP	450	1975	44	19.69	Y	0				1			
9	UPI-0982	Orchid Street	RCP	450	1975	44	15.09	Y	0				1	2		
10	UPI-0981	Orchid Street	RCP	375	1996	23	6.86	N-Root obstruction 6.96m D/S from FIP-1222	0				5	1	1	
11	UPI-6416	Station Street	PVC	225	2017	2	14.54	Y	0				1			
12	UPI-6417	Station Street	PVC	225	2017	2	14.46	Y	0				1			
13	UPI-0960	Burringbar Street	RCP	375	1993	26	8.41	Y	0				1	2	1	
14	UPI-0955	Burringbar Street	RCP	375	1993	26	15.74	Y	0				1		3	
15	UPI-0951	Burringbar Street	RCP	525	1993	26	19.76	Y	0				1	1	2	
16	UPI-0950	Burringbar Street	RCP	525	1993	26	64.11	Y	0				1	2	1	
17	UPI-0952	Burringbar Street	RCP	375	1993	26	39.14	Y	0				1		2	
18	UPI-0956	Burringbar Street	RCP	375	1993	26	16.1	Y	0				1	3		
19	UPI-0953	Burringbar Street	RCP	375	1993	26	9.27	Y	0				1	2	1	
20	UPI-0980	Fern Street	RCP	450	1996	23	52.5	N-Collapsed pipe at 29.42m from GIP-1221	0				1		1	1
21	UPC-0988	Cedar Street	RCP	225	1940	79	6.3	Y	0				3	3	1	
22	UPC-0984	Myokum Street	RCP	300	1940	79	25.52	Y	0				1		1	5
23	UPC-0987	Byron Street	RCP	300	1940	79	23.06	Y	0				1	5	5	
24	UPI-0986	Byron Street	RCP	300	1940	79	33.56	N-Root obstruction 24.93m D/S from HWL-1231	0				5		4	5
25	UPI-0976	Orchid Street	RCP	600	1975	44	24.55	N-conflicting pipe at 4.36m from JPT-1319	0				1		2	2
26	UPI-0979	Fern Street	RCP	450	1975	44	>40.00	N-CCTV camera lost traction	0				1	3	8	1

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27	UPI-1255	Fern Street	RCP	450	1940	79	28.54	Y	1				1	3	7	
28	UPI-1322	Burringbar Street	RCP	450	1993	26	6.85	Y	0				1		2	
29	UPI-1067	Burringbar Street	RCP	300	1984	35	27.03	N-Root obstruction 1.43m D/S from JPT-1285	0				5		3	
30	UPI-1075	Burringbar Street	RCP	750	1993	26	88.95	Y	0				2	4	2	
31	UPI-0962	River Terrace	RCP	375	1980	39	9.82	Y	0				1		6	
32	UPI-0961	River Terrace	RCP	375	1980	39	16.84	Y	0				2	2	2	
33	UPI-0965	River Terrace	RCP	300	1940	79	2.47	Y	0				1		6	
34	UPI-1068	River Terrace	RCP	300	1984	35	5.1	Y	1				1	2	2	
35	UPI-1069	Dalley Street	RCP	300	1984	35	2.08	Y	0				1			
36	UPI-1070	Dalley Street	RCP	300	1984	35	10.14	Y	1				5		6	1
37	UPI-1064	River Terrace	RCP	350	1984	35	3.7	Y	0				3		2	
38	UPI-1076	Dalley Street	RCP	450	1993	26	12.49	Y	0				2	3		
39	UBC-1051	Tincogan Street	RCBC	470W x 300H	1940	79	13.22	Y	2	2			1	6		
40	UPI-3667	Tincogan Street	RCP	375	2011	8	19.09	Y	0				1	1	1	
41	UPI-3668	Tincogan Street	RCP	375	2011	8	6.55	Y	0				1		1	
42	UPI-3666	Tincogan Street	RCP	375	2011	8	6.56	Y	0				1	1		
43	UPI-3670	Station Street	RCP	375	2011	8	12.29	Y	0				1	2		
44	UBC-1050	McGoughans Lane	RCBC	580W x 300H	1940	79	11.78	N-Reduced diameter at 11.78m	0				1		8	
45	UPI-3669	Station Street	RCP	375	2011	8	4.87	Y	0				1	1		
46	UPI-3680	Station Street	RCP	600	2011	8	49.35	Y	0				1	1		
47	UPI-3671	Station Street	RCP	375	2011	8	14.89	Y	0				1			
48	UPI-3674	Station Street	RCP	300	2011	8	8.09	Y	0				1			
49	UPI-3675	Argyle Street	RCP	450	2011	8	5.64	Y	0				1	1		
50	UPI-3676	Station Street	RCP	450	2011	8	3.89	Y	0				1	1		
51	UPI-3681	Station Street	RCP	675	2011	8	48.13	Y	0				1	1		
52	UPI-3678	Station Street	RCP	525	2011	8	6.68	Y	0				1			
53	UPI-3677	Station Street	RCP	450	2011	8	47.67	Y	0				1			
54	UPI-3679	Station Street	RCP	450	2011	8	9.91	Y	0				1	2		
55	UBC-1040	Stuart Street	RCBC	600W x 300H	1940	79	20.05	Y	1	1			1	4	4	
56	UPI-1041	Stuart Street	RCP	300	1940	79	3.06	Y	0				1	2	2	
57	UBC-1052	Stuart Street	RCBC	450W x 300H	1940	79	11.32	Y	0				1	2	6	
58	UBC-1039	Tincogan Street	RCBC	450W 300H	1940	79	24.07	N-Obstruction beneath flow 18.65m from HWL-1324	0				1	3	1	
59	UPI-1066	Dalley Street	RCP	450	1984	35	13.42	Y	0				3	1	3	
60	UPI-1065	Burringbar Street	RCP	600	1984	35	>10	N-Item obstructing assessment 7.90m from KIP-1282	0				2	3	7	
61	UPI-0957	Stuart Street	RCP	450	1993	26	112.36	Y	0				1	5	5	
62	UPI-0967	Whian Street	PVC	225	1940	79	3.29	Y	0				1	1		
63	UPI-1317	McGoughans Lane	RCP	375	1979	40	5.5	Y	0				1			
64	UPI-1063	McGoughans Lane	RCP	450	1984	35	7.9	Y	0				1	2		
65	UPI-1062	River Terrace	RCP	600	1984	35	15.89	Y	0				3	3	1	
66	UPI-1065	River Terrace	RCP	600	1984	35	21.25	Y	3		2			5	7	

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67	UPC-1001	Poplar Avenue	RCP	450	1960	59	9.48	Y	0				1	1	3	
68	UPI-1000	Poplar Avenue	RCP	600	1960	59	13.24	Y	1				1		6	
69	UPI-0999	Poplar Avenue	RCP	600	1960	59	15.79	Y	0				1		5	
70	UPI-0999	Poplar Avenue	RCP	600	1984	2019	>20	N-Root intrusion 19.70m from New Pit	0				5	2	1	7
71	UPI-0959	Burringbar Street	RCP	375	1993	2019	7.42	Y	0				1	1		
72	UPI-1077	Burringbar Street	RCP	750	1993	2019	62.8	Y	0				1	2	2	
73	UPI-0948	Burringbar Street	RCP	750	1993	26	30.85	Y	0				1	1	1	
74	UPI-0993	Left Bank Road	RCP	375	1980	39	0.56	Y	0				1	1		
75	UPI-0992	Left Bank Road	RCP	450	1980	39	15.8	N-Junction obstructing assessment 8.69m from KIP-1237	0				1	3	1	
76	UPI-0994	Left Bank Road	RCP	300	1980	39	6.66	Y	0				1	5		
77	UPI-6393	Jubilee Street	PP	375	2018	1	37.02	Y	0				1	1		
78	UPI-6392	Jubilee Street	PP	375	2018	1	1	Y	0				1	1		
79	UPI-0995	Left Bank Road	RCP	450	1980	39	17.97	Y	1	1			3	5	1	
80	UPI-1090	Tincogan Street	RCP	225	1940	79	4.85	Y	0				1			2
81	UPC-1094	Burringbar Street	RCP	300	1940	79	4	Y	0				1		4	2
82	UBC-0966	Stuart Street	RCBC	600W x 350H	1940	79	20.34	Y	0				3	3	2	1
83	UPI-1311	Stuart Street	RCP	300	1979	40	9.21	Y	0				1	2	3	1
84	UPI-0977	Fern Street	RCP	375	1975	44	7.99	Y	0				1	2	4	1
85	UPI-0974	Fern Street	RCP	375	1975	44	14.66	Y	1	1			1	1	9	
86	UPI-0949	Burringbar Street	RCP	750	1993	26	21.47	Y	0				1	2		
87	UPI-1071	Burringbar Street	RCP	750	1993	26	20.14	Y	0				1	2	1	
88	UPI-0975	Orchid Place	RCP	300	1975	44	2	Y	0				1	1		1
89	UPI-0968	Whian Street	RCP	300	1940	79	4.14	Y	0				4	2	2	1
90	UPI-0963	Whian Street	RCP	300	1940	79	3.58	Y	0				1	1	2	
91	UPI-0964	Whian Street	RCP	375	1940	79	3.65	Y	0				1	1	2	
92	N/A	Dalley Street	RCP	450H x 300W	1940	79	31.2	Y	0				1	3	1	
93	UPI-3682	Argyle Street	RCP	1000H x 300W	1993	26	12.87	Y	0				1		4	
94	UPI-0970	Studal Lane	RCP	300	1940	79	22.7	Y	4		2		1	3	7	
95	UPI-1321	Studal Lane	RCP	300	1979	40	4.95	Y	4				1		6	1
96	UPI-0969	Studal Lane	RCP	300	1940	79	30.2	Y	2				4	2	6	
97	UBC-6474	McGoughans Lane	RCBC	600W x 300H	2018	1	4.82	Y	0				1			
98	UPI-425	McGoughans Lane	RCP	375	~2010	9	7.26	Y	0				1			
99	UPI-0973	Orchid Place	RCP	525	1975	44	1.87	Y	0				1			
100	UPI-0973	Orchid Place	RCP	525	1975	2019	39.73	Y	2		1		4	8	1	
101	UBC-1043	Studal Lane	RCBC	450W x 225H	1940	79	4.09	Y	2				1	1	1	1
102	UBC-1042	Studal Lane	RCBC	450W x 150H	1940	79	4.31	Y	1				1	1	3	
103	UPI-0971	Studal Lane	RCP	375	1997	22	49.9	Y	0				1	5		
104	UPI-1318	Studal Lane	RCP	375	1979	40	31.8	Y	0				1	3	1	
105	UPI-0954	Burringbar Street	RCP	375	1993	26	15.55	Y	0				1	3		
106	UPI-1254	Stuart Street	RCP	600	1940	79	49.9	Y	3		2		1	1	8	
107	UPI-1253	Stuart Street	RCP	600	1940	79	47.04	Y	2		1		4	5	5	
108	UPI-1253	Fern Street	RCP	600	1940	79	15.57	Y	1				4	2	6	1

4. DECISION TREE AND RISK MATRIX

A Decision Tree and Risk Matrix (Replacement Matrix) has been provided by Byron Shire Council to determine the actions required for the sections of stormwater culvert assessed in this report. Decision Tree and Risk Matrix is provided below in Table 110 and shows the relationship between the Consequence and the Likelihood of Failure.

Each decision level is also broken down further into Categories (Cat), which defines the level of priority within both 'Monitor' and 'Leave' risk decision levels. Note the 'Replace' decision has not been allocated a Category rating, simply on the basis that the asset is no longer prudent to maintain in its current condition, in which case, prompt attention is required. The Category rating of the risk decision will assist in designating timeframes for follow-up assessment on the 'Monitor' and 'Leave' risk decision levels and therefore enable scheduling of future Capital Works programs.

Table 110 | Decision Tree and Risk Matrix (Replacement Matrix)

Likelihood of Failure \ Consequence	Very Low	Low	Medium	High	Very High
Very High	Replace	Replace	Replace	Replace	Replace
High	Monitor (Cat 2)	Monitor (Cat 1)	Replace	Replace	Replace
Medium	Leave (Cat 3)	Monitor (Cat 2)	Monitor (Cat 1)	Monitor (Cat 1)	Replace
Low	Leave (Cat 4)	Leave (Cat 3)	Monitor (Cat 2)	Monitor (Cat 1)	Monitor (Cat 1)
Very Low	Leave (Cat 4)	Leave (Cat 4)	Monitor (Cat 2)	Monitor (Cat 2)	Monitor (Cat 1)

Cat' = Category - referring to ranking within the risk decision matrix, 1 being higher priority over 2, 2 being higher priority over 3 etc.

The above categories for the 'Monitor' and 'Leave' outcomes have been determined through a combination of the most applicable levels from the Likelihood of Failure and Consequence matrix's detailed in Tables 111 and 112. Table 113 provides the outcomes of the assessment for each culvert considered in the Mullumbimby township. Table 114 provides an outlook of the proposed scheduling for follow up assessments on each section of stormwater culvert. Typically, each category level incurs an additional 4 year follow up timeframe.

Table 111 | Determining the Likelihood of Failure

Level	Likelihood	Criteria
1	Very High	• >3 blockages per annum, or • Affected by future road reconstruction, or • Pipe wall pitting well into design wall thickness, or • Lining not effective corrosion of substrate has commenced, or • Age >=75% of adopted useful life in aggressive environment
2	High	• >3 bloackages over past two years, or • Asset with an increasing failure rate e.g. >20% per annum increase, or • Numerous wall pits exceed corrosion allowance, or • Effective lining reduced to <25% of original thickness major splits or cracks, or • Age between >=60% and 75% of adopted useful life in aggressive environment
3	Medium	• Performance is acceptable and • Loss of wall thickness to corrosion allowance and • >50% effective lining thickness with some cracking or splitting, or • Age between >40% of adopted useful life in aggressive environment
4	Low	• Performance is acceptable and • Minor surface damage and • Minor loss of lining
5	Very Low	• Performance is acceptable and • As new wall and • As new lining

Table 112 | Determining Consequence

Level	Descriptor	Severity				
		Environmental	PR/ Reputation	Legal/ Regulatory	Quantity	Customer Type
1	Very Low	Minor effects on biological or physical environment	Public complaint retained in-house or dealt with via normal procedures	• Minor legal issues	< 10 Retail customers affected	• Low Density Residential • Rural
2	Low	Moderate, short term effects but not affecting ecosystem functions	Minor adverse local public or media attention or complaints	• Minor non compliance with regulation	< 50 Retail customers affected	• High Density Residential
3	Medium	Serious Medium term environment effects	Attention from media and/or heightened concern by local community	• Breach of regulation with investigation and report to authority and/or moderate fine possible	< 200 Retail customers affected	• Small Industry • Small Commercial
4	High	Very serious long-term environmental impairment of ecosystem functions	Significant adverse national media attention	• Major breach of regulation. • Major litigation	> 500 Retail customers affected >8 hours unplanned outage	• Institutional • CBD Premises • Large Industry
5	Very High	Most serious irreversible environment impairment of ecosystem functions	Serious public or media outcry	• Loss of licence • Significant prosecution and fines • Very serious litigation including class action	> 2000 Retail customers affected >24 hours unplanned outage	• Critical Facilities le Hospital

Table 113 | Decision Table – Mullumbimby Catchment

#	Line	Street	Length (m)	Likelihood of Failure	Primary Justification *Assumed 100yr useful life	Consequence of Failure	Primary Justification	Decision Outcome	Comments and Recommendations
1	24892	Tincogan Street	16.76	High	- Age ~80% of the life expectancy - 1 x minor and 2 x moderate defects	Low	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
2	24893	Tincogan Street	3.12	High	- Age ~80% of the life expectancy - Major root intrusion - 3 x minor and 1 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN225 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Clear root intrusion 2.37m from HWL-1273 then monitor as recommended
3	24894	Brunswick Terrace	18.15	Medium	- Age ~80% of the life expectancy - 2 x minor defects	Medium	Culvert is located beneath a road pavement Culvert is DN450 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
4	24540	Brunswick Terrace	3.64	High	- Age ~80% of the life expectancy - 2 x moderate defects	Low	Culvert is located within the grassed verge Culvert is 600W x 400H RCBC Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
5	24639	Burringbar Street	25.92	Medium	- Age ~60% of the life expectancy - 1 x minor defect	Medium	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
6	24858	Station Street	24.69	Medium	- Age 40% of the life expectancy - 8 x minor defects	Low	Culvert is located within the grassed verge Culvert is DN450 RCP Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
7	24583	Orchid Street	27.27	High	- Age >40% of the life expectancy - 3 x minor and 1 moderate defects	Low	Culvert is located within the grassed verge Culvert is DN450 RCP Minor community impact to replace vis open trench	Monitor (Cat 1)	Monitor as recommended
8	24582	Orchid Street	19.69	Low	- Age >40% of the life expectancy - No defects identified	Low	Culvert is located within the grassed verge Culvert is DN450 RCP Minor community impact to replace via open trench	Leave (Cat 3)	Monitor as recommended
9	82306	Orchid Street	15.09	Medium	- Age >40% of the life expectancy - 2 x minor defects	Low	Culvert is located within the grassed verge Culvert is DN450 RCP Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
10	24581	Orchid Street	19.33	Medium	- Age >20% of the life expectancy - Critical root intrusion, obstructing assessment - 1 x minor and 1 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Clear root intrusion 8.31m from GIP-1221 then monitor as recommended
11	82308	Station Street	14.54	Very Low	- Age <5% of the life expectancy - No defects identified	Medium	Culvert is located beneath a road pavement Culvert is DN225 PVC Moderate community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
12	82307	Station Street	14.46	Very Low	- Age <5% of the life expectancy - No defects identified	Medium	Culvert is located beneath a road pavement Culvert is DN225 PVC Moderate community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
13	24561	Burringbar Street	8.41	Medium	- Age >20% of the life expectancy - Critical root intrusion, obstructing assessment - 2 x minor and 1 x moderate defects	Medium	Culvert is located beneath a single lane of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended

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14	24556	Burringbar Street	15.74	Medium	- Age >20% of the life expectancy - No defects identified	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
15	24552	Burringbar Street	19.76	Medium	- Age >20% of the life expectancy - 1 x minor and 2 x moderate defects	Medium	Culvert is located beneath a single lane of a main road pavement Culvert is DN525 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
16	24551	Burringbar Street	64.11	Medium	- Age >20% of the life expectancy - 2 x minor and 1 x moderate defects	High	Culvert is located beneath a single lane of a main road pavement Culvert is DN525 RCP Major community impact to replace via open trench Culvert is >50m in length	Monitor (Cat 1)	Monitor as recommended
17	24553	Burringbar Street	39.14	Medium	- Age >20% of the life expectancy - No defects identified	Medium	Culvert is located beneath a single lane of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
18	24557	Burringbar Street	16.1	Medium	- Age >20% of the life expectancy - 3 x minor defects	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
19	24554	Burringbar Street	9.27	Medium	- Age >20% of the life expectancy - 2 x minor and 1 x moderate defects	Medium	Culvert is located beneath a single lane of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
20	24580	Fern Street	52.5	Very High	- Age >20% of the life expectancy - Collapsed pipe obstructing flow and assessment - 1 x moderate and 1 x major defects	Low	Culvert is predominantly located within the grassed verge Culvert is DN450 RCP Moderate community impact to replace via open trench	Replace	Replace as a priority
21	24877	Cedar Street	6.3	High	- Age ~80% of the life expectancy - Moderate root intrusion - 3 x minor and 1 x moderate defects	Low	Culvert is located within the grassed verge Culvert is DN225 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
22	24875	Myokum Street	25.52	Very High	- Age ~80% of the life expectancy - 1 x moderate and 5 x major defects	Low	Culvert is located beneath a road pavement Culvert is DN300 RCP Moderate community impact to replace via open trench	Replace	Replace as a priority
23	24876	Byron Street	23.06	High	- Age ~80% of the life expectancy - 5 x minor and 5 x moderate defects	Low	Culvert is located beneath a road pavement Culvert is DN300 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
24	24584	Byron Street	33.56	Very High	- Age ~80% of the life expectancy - Critical root intrusion obstructing assessment - 4 x moderate and 5 x major defects	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN300 RCP Major community impact to replace via open trench	Replace	Replace as a priority
25	24576	Orchid Street	24.55	High	- Age ~80% of the life expectancy - Penetrating pipe obstructing assessment - 2 x moderate and 2 x major defects	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN600 RCP Major community impact to replace via open trench	Replace	Replace as a priority. Penetrating pipe obstructing flow 3.75m from JPT-1319

26	24579	Fern Street	>40.00	High	- Age >40% of the life expectancy - 3 x minor 8 x moderate and 1 x major defects	Low	Culvert is predominantly located within the grassed verge Culvert is DN450 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Re-assess and monitor as recommended
27	24812	Fern Street	28.54	High	- Age >40% of the life expectancy - 3 x minor and 7 x moderate defects	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN450 RCP Major community impact to replace via open trench	Replace	Replace as a priority. Defective repair with street sign obstructing flow 24.25m from D/S MH
28	24869	Burringbar Street	6.85	Medium	- Age ~25% of the life expectancy - 2 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is DN450 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
29	24645	Burringbar Street	27.03	Medium	- Age 35% of the life expectancy - Critical root intrusion obstructing assessment - 3 x moderate defects	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN300 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Clear root intrusion, re-assess and monitor as recommended
30	24653	Burringbar Street	88.95	Medium	- Age ~25% of the life expectancy - Minor root intrusion - 4 x minor and 2 x moderate defects	High	Culvert is located beneath a main road pavement Culvert is DN750 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
31	24563	River Terrace	9.82	High	- Age ~40% of the life expectancy - 6 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
32	24562	River Terrace	16.84	Medium	- Age ~40% of the life expectancy - Minor root intrusion - 2 x minor and 2 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
33	24566	River Terrace	2.47	High	- Age ~80% of the life expectancy - Minor root intrusion - 6 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
34	24646	River Terrace	5.1	High	- Age ~35% of the life expectancy - 2 x minor and 2 x moderate defects	Low	Culvert is located within a busy footpath Culvert is DN300 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
35	24647	Dalley Street	2.08	Low	- Age ~35% of the life expectancy - No defects identified	Medium	Culvert is located within a busy footpath Culvert is DN300 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
36	24648	Dalley Street	10.14	High	- Age ~35% of the life expectancy - Critical root intrusion - 6 x moderate and 1 x major defects	Low	Culvert is located within a busy footpath Culvert is DN300 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Clear roots throughout
37	24642	River Terrace	3.7	High	- Age ~35% of the life expectancy - Moderate root intrusion - 2 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN350 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
38	24654	Dalley Street	12.49	Medium	- Age ~25% of the life expectancy - Minor root intrusion - 3 x minor defects	High	Culvert is located beneath a main road pavement Culvert is DN450 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended

39	24538	Tincogan Street	13.22	Medium	- Age ~80% of the life expectancy - 2 x minor defects on junction lines - 6 x minor defects	Medium	Culvert is located beneath a road pavement Culvert is 470W x 300H RCBC Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
40	52637	Tincogan Street	19.09	Low	- Age <10% of the life expectancy - 1 x minor and 1 x moderate defects	High	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
41	52641	Tincogan Street	6.55	Medium	- Age <10% of the life expectancy - 1 x moderate defect	Medium	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
42	52642	Tincogan Street	6.56	Low	- Age <10% of the life expectancy - 1 x minor defect	High	Culvert is located beneath a road pavement Culvert is DN375 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
43	52636	Station Street	12.29	Low	- Age <10% of the life expectancy - 2 x minor defects	High	Culvert is located beneath a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
44	24537	McGoughans Lane	11.78	High	- Age ~80% of the life expectancy - A reduction in the diameter obstructed the assessment - 8 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is 300W x 600H RCBC Moderate community impact to replace via open trench	Replace	Replace as a priority
45	52634	Station Street	4.87	Low	- Age <10% of the life expectancy - 1 x minor defect	High	Culvert is located beneath a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
46	52628	Station Street	49.35	Low	- Age <10% of the life expectancy - 1 x minor defect	High	Culvert is located beneath a main road pavement Culvert is DN600 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
47	52635	Station Street	14.89	Very Low	- Age <10% of the life expectancy - No defects identified	High	Culvert is located beneath a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
48	52631	Station Street	8.09	Very Low	- Age <10% of the life expectancy - No defects identified	High	Culvert is located beneath a road pavement Culvert is DN300 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
49	52630	Argyle Street	5.64	Very Low	- Age <10% of the life expectancy - 1 x minor defect	Medium	Culvert is partially located beneath a road pavement Culvert is DN450 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
50	52632	Station Street	3.89	Very Low	- Age <10% of the life expectancy - 1 x minor defect	High	Culvert is located beneath a road pavement Culvert is DN450 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
51	52626	Station Street	48.13	Very Low	- Age <10% of the life expectancy - 1 x minor defect	High	Culvert is located beneath a main road pavement Culvert is DN675 RCP Major community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
52	52639	Station Street	6.68	Very Low	- Age <10% of the life expectancy - No defects identified	High	Culvert is located beneath a main road pavement Culvert is DN525 RCP Moderate community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended

53	52629	Station Street	47.67	Low	- Age <10% of the life expectancy - No defects identified	High	Culvert is located beneath a main road pavement Culvert is DN450 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
54	52633	Station Street	9.91	Low	- Age <10% of the life expectancy - 2 x minor defects	High	Culvert is located beneath a main road pavement Culvert is DN450 RCP Major community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
55	24534	Stuart Street	20.05	High	- Age ~80% of the life expectancy - 1 x minor defect on a junction line - 4 x minor and 4 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is 600W x 300H RCBC Moderate community impact to replace via open trench	Replace	Replace as a priority
56	24628	Stuart Street	3.06	High	- Age ~80% of the life expectancy - 2 x minor and 2 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
57	24539	Stuart Street	11.32	High	- Age ~80% of the life expectancy - 2 x minor and 6 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is 450W x 300H RCBC Moderate community impact to replace via open trench	Replace	Replace as a priority
58	24533	Tincogan Street	24.07	Medium	- Age ~80% of the life expectancy - Obstruction beneath flow stopped assessment - 3 x minor and 1 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is 450W x 300H RCBC Moderate community impact to replace via open trench	Monitor (Cat 1)	Clear obstruction, re-assess and monitor as recommended
59	24644	Dalley Street	13.42	High	- Age ~35% of the life expectancy - Moderate root intrusion - 1 x minor and 3 x moderate defects	Low	Culvert is located within the footpath Culvert is DN450 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
60	24643	Burringbar Street	>10	Very High	- Age ~35% of the life expectancy - Item obstructing the assessment - Minor root intrusion - 3 x minor and 7 x moderate defects	Very Low	Culvert is located within the footpath Culvert is DN450 RCP Minor community impact to replace via open trench	Replace	Replace as a priority, same line as #66
61	24558	Stuart Street	112.36	High	- Age ~25% of the life expectancy - 5 x minor and 5 x moderate defects	High	Culvert is located beneath a main road pavement Culvert is DN450 RCP Major community impact to replace via open trench Culvert is >50m in length	Replace	Replace as a priority
62	24567	Whian Street	3.29	Very Low	- Age ~80% of the life expectancy - 1 x minor defect	Very Low	Culvert is located within the grassed verge Culvert is DN225 RCP Minor community impact to replace via open trench Culvert is <10m in length	Leave (Cat 4)	Monitor as recommended
63	24864	McGoughans Lane	5.5	Very Low	- Age ~40% of the life expectancy - No defects identified	Very Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench Culvert is <10m in length	Leave (Cat 4)	Monitor as recommended
64	24641	McGoughans Lane	7.9	Medium	- Age ~35% of the life expectancy - 2 x minor defects	Low	Culvert is primarily located within the grassed verge Culvert is DN450 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
65	24640	River Terrace	15.89	Medium	- Age ~35% of the life expectancy - Moderate root intrusion - 3 x minor and 1 x moderate defects	Medium	Culvert is located beneath a road pavement Culvert is DN600 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
66	24643	River Terrace	21.25	High	- Age ~35% of the life expectancy - 2 x moderate defects on junction lines - 5 x minor and 7 x moderate defects	Very Low	Culvert is located within the footpath Culvert is DN600 RCP Minor community impact to replace via open trench	Replace	Despite the risk matrix not recommending this for replacement, it should be replaced as it is the same line as #60, just assessed from other end due to an obstruction.

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67	24878	Poplar Avenue	9.48	High	- Age ~60% of the life expectancy - 1 x minor and 3 x moderate defects	Low	Culvert is located beneath an access road pavement Culvert is DN450 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
68	24596	Poplar Avenue	13.24	High	- Age ~60% of the life expectancy - 6 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN600 RCP Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
69	24595	Poplar Avenue	15.79	High	- Age ~60% of the life expectancy - 5 x moderate defects	Low	Culvert crosses beneath an access road pavement Culvert is DN600 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
70	24595	Poplar Avenue	>20	Very High	- Age ~35% of the life expectancy - Root intrusion obstructing assessment - 2 x minor, 1 x moderate, and 7 x major defects	Very Low	Culvert crosses beneath an access road pavement Culvert is DN600 RCP Minor community impact to replace via open trench	Replace	Replace as a priority. Update GIS to reflect the new maintenance hole that separates #69 and #70 that is 15.79m D/S from MH JPT-1420
71	24560	Burringbar Street	7.42	Medium	- Age ~25% of the life expectancy - 1 x minor defect	Medium	Culvert is located beneath a single lane of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
72	24655	Burringbar Street	62.8	Medium	- Age ~25% of the life expectancy - 2 x minor and 2 x moderate defects	High	Culvert is located beneath a main road pavement Culvert is DN750 RCP Major community impact to replace via open trench Culvert is >50m in length	Monitor (Cat 1)	Monitor as recommended
73	24549	Burringbar Street	30.85	Medium	- Age ~25% of the life expectancy - 1 x minor and 1 x moderate defects	High	Culvert is located beneath a main road pavement Culvert is DN750 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
74	24589	Left Bank Road	0.56	Medium	- Age ~40% of the life expectancy - 1 x minor defect	Very Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench	Leave (Cat 3)	Monitor as recommended
75	24588	Left Bank Road	15.8	Medium	- Age ~40% of the life expectancy - Protruding junction obstructing assessment - 3 x minor and 1 x moderate defects	Very Low	Culvert is located within the grassed verge Culvert is DN450 RCP Minor community impact to replace via open trench	Leave (Cat 3)	Re-assess and monitor as recommended
76	24590	Left Bank Road	6.66	High	- Age ~40% of the life expectancy - 5 x minor defects	Very Low	Culvert is located within the grassed verge Culvert is DN300 RCP Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
77	80059	Jubilee Street	37.02	Very Low	- Age ~1% of the life expectancy - No defects identified	Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench	Leave (Cat 4)	Monitor as recommended
78	80060	Jubilee Street	1	Very Low	- Age ~1% of the life expectancy - 1 x minor defect	Very Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench Culvert is <10m in length	Leave (Cat 4)	Monitor as recommended
79	24591	Left Bank Road	17.97	High	- Age ~40% of the life expectancy - 1 x minor defect on junction line - Moderate root intrusion - 5 x minor and 1 x moderate defects	Low	Culvert crosses beneath a road pavement Culvert is DN450 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
80	24664	Tincogan Street	4.85	Very High	- Age ~80% of the life expectancy - 2 x major defects	Very Low	Culvert crosses beneath a road pavement Culvert is DN225 RCP Minor community impact to replace via open trench Culvert is <10m in length	Replace	Replace as a priority

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81	24895	Burringbar Street	4	Very High	- Age ~80% of the life expectancy - 4 x moderate and 2 x major defects	Very Low	Culvert crosses beneath a road pavement Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Replace	Replace as a priority
82	24531	Stuart Street	20.34	High	- Age ~80% of the life expectancy - Moderate root intrusion - 3 x minor, 2 x moderate, and 1 x major defects	Low	Culvert crosses beneath a road pavement Culvert is 600W x 350H RCBC Minor community impact to replace via open trench	Monitor (Cat 1)	Isolated dig up to fix collapsed section 2.24m from D/S MH then monitor as recommended
83	24860	Stuart Street	9.21	High	- Age ~40% of the life expectancy - 2 x minor, 3 x moderate, and 1 x major defects	Very Low	Culvert is located within the grassed verge and crosses a driveway Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 2)	Monitor as recommended
84	24577	Fern Street	7.99	High	- Age ~45% of the life expectancy - 2 x minor, 4 x moderate, and 1 x major defects	Low	Culvert crosses beneath an access road pavement Culvert is DN375 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
85	24574	Fern Street	14.66	High	- Age ~45% of the life expectancy - 1 x minor defect on junction line - 1 x minor and 9 x moderate defects	Low	Culvert crosses beneath an access road pavement Culvert is DN375 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
86	24550	Burringbar Street	21.47	Medium	- Age ~25% of the life expectancy - 2 x minor defects	High	Culvert is located beneath a main road pavement Culvert is DN750 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
87	24649	Burringbar Street	20.14	Medium	- Age ~25% of the life expectancy - 2 x minor and 2 x moderate defects	Medium	Culvert is predominantly located within the grassed verge Culvert is DN750 RCP Moderate community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
88	24575	Orchid Place	2	Very High	- Age ~45% of the life expectancy - 1 x minor and 1 x major defects	Very Low	Culvert is located within the grassed verge Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Replace	Replace as a priority
89	24568	Whian Street	4.14	High	- Age ~80% of the life expectancy - Major root intrusion - 2 x minor, 2 x moderate, and 1 x major defects	Low	Culvert crosses beneath an access road pavement Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
90	24564	Whian Street	3.58	High	- Age ~80% of the life expectancy - 1 x minor and 2 x moderate defects	Low	Culvert crosses beneath an access road pavement Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
91	24565	Whian Street	3.65	High	- Age ~80% of the life expectancy - 1 x minor and 2 x moderate defects	Low	Culvert crosses beneath an access road pavement Culvert is DN300 RCP Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
92	N/A	Dalley Street	31.2	Medium	- Age ~80% of the life expectancy - 3 x minor and 1 x moderate defects	Low	Culvert is located within the footpath Culvert is 450W x 300H RCBC Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended. Asset not shown in GIS
93	52638	Argyle Street	12.87	Medium	- Age ~25% of the life expectancy - 4 x moderate defects	High	Culvert is located beneath a main road pavement Culvert is 1000W x 300H RCBC Major community impact to replace via open trench	Monitor (Cat 1)	Clear rubble obstruction between 11-13m from D/S MH then monitor as recommended
94	24570	Studal Lane	22.7	High	- Age ~80% of the life expectancy - 2 x moderate defects on junction lines - 3 x minor and 7 x moderate defects	Low	Culvert is beneath an access road pavement Culvert is DN300 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended

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95	24868	Studal Lane	4.95	High	- Age ~40% of the life expectancy - 6 x moderate and 1 x major defects	Low	Culvert crosses beneath an access road pavement Culvert is DN300 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Clear obstruction at D/S MH then monitor as recommended
96	24569	Studal Lane	30.2	High	- Age ~80% of the life expectancy - Major root intrusion - 2 x minor and 6 x moderate defects	Low	Culvert is beneath an access road pavement Culvert is DN300 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
97	84421	McGoughans Lane	4.82	Very Low	- Age ~1% of the life expectancy - No defects identified	Medium	Culvert crosses beneath an access road pavement Culvert is 600W x 300H RCBC Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
98	65497	McGoughans Lane	7.26	Very Low	- Age ~10% of the life expectancy - No defects identified	Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench Culvert is <10m in length	Leave (Cat 4)	Monitor as recommended
99	24573	Orchid Place	1.87	Low	- Age ~45% of the life expectancy - No defects identified	Low	Culvert is located within the grassed verge Culvert is DN525 RCP Minor community impact to replace via open trench Culvert is <10m in length	Leave (Cat 3)	Monitor as recommended
100	24573B	Orchid Place	39.73	High	- Age ~25% of the life expectancy - 1 x moderate defect on a junction line - Major root intrusion - 8 x minor and 1 x moderate defects	Low	Culvert is located within the grassed verge Culvert is DN525 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
101	24536	Studal Lane	4.09	High	- Age ~80% of the life expectancy - 1 x minor, 1 x moderate, and 1 x major defects	Low	Culvert is beneath an access road pavement Culvert is 450W x 225H RCBC Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
102	24535	Studal Lane	4.31	High	- Age ~80% of the life expectancy - 1 x minor and 3 x moderate defects	Low	Culvert crosses beneath an access road pavement Culvert is 450W x 150H RCBC Minor community impact to replace via open trench Culvert is <10m in length	Monitor (Cat 1)	Monitor as recommended
103	24571	Studal Lane	49.9	Medium	- Age ~20% of the life expectancy - 5 x minor defects	Low	Culvert is located within the grassed verge Culvert is DN375 RCP Minor community impact to replace via open trench	Monitor (Cat 2)	Monitor as recommended
104	24865	Studal Lane	31.8	Medium	- Age ~40% of the life expectancy - 3 x minor and 1 x moderate defects	Medium	Culvert is beneath an access road pavement Culvert is DN375 RCP Minor community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
105	24555	Burringbar Street	15.55	Medium	- Age ~25% of the life expectancy - 3 x minor defects	High	Culvert is located beneath two lanes of a main road pavement Culvert is DN375 RCP Major community impact to replace via open trench	Monitor (Cat 1)	Monitor as recommended
106	24811	Stuart Street	49.9	High	- Age ~80% of the life expectancy - 2 x moderate defects on junction lines - 1 x minor and 8 x moderate defects	High	Culvert is located within private property Culvert is DN600 RCP Major community impact to replace via open trench	Replace	Replace as a priority
107	24810	Stuart Street	47.04	High	- Age ~80% of the life expectancy - 1 x moderate defect on a junction line - Major root intrusion - 5 x minor and 5 x moderate defects	High	Culvert is located within private property Culvert is DN600 RCP Major community impact to replace via open trench	Replace	Replace as a priority
108	24809	Fern Street	57.92	High	- Age ~80% of the life expectancy - Major root intrusion - 2 x minor, 6 x moderate, and 1 x major defects	Very Low	Culvert is located within the grassed verge - easement Culvert is DN600 RCP Minor community impact to replace via open trench	Monitor (Cat 2)	Isolated dig up to repair collapsed section 15.28m from JPT-1481 then monitor as recommended

Table 114 | Capital Works Program - Follow up Assessment

#	Pipe Section	Decision Outcome	Capital Works Delivery Period					Pipe Age at Next Assessment (yrs.)
			2019	2023	2027	2031	2035	
1	24892	Monitor (Cat 1)		Assess				83
2	24893	Monitor (Cat 2)	Clear Roots		Assess			87
3	24894	Monitor (Cat 1)		Assess				83
4	24540	Monitor (Cat 1)		Assess				83
5	24639	Monitor (Cat 1)		Assess				63
6	24858	Monitor (Cat 2)			Assess			48
7	24583	Monitor (Cat 1)		Assess				48
8	24582	Leave (Cat 3)				Assess		56
9	82306	Monitor (Cat 2)			Assess			52
10	24581	Monitor (Cat 1)	Clear Roots	Assess				27
11	82308	Monitor (Cat 2)			Assess			10
12	82307	Monitor (Cat 2)			Assess			10
13	24561	Monitor (Cat 1)		Assess				30
14	24556	Monitor (Cat 1)		Assess				30
15	24552	Monitor (Cat 1)		Assess				30
16	24551	Monitor (Cat 1)		Assess				30
17	24553	Monitor (Cat 1)		Assess				30
18	24557	Monitor (Cat 1)		Assess				30
19	24554	Monitor (Cat 1)		Assess				30
20	24580	Replace	Immediate					23
21	24877	Monitor (Cat 1)		Assess				83

22	24875	Replace	Immediate						79
23	24876	Monitor (Cat 1)		Assess					83
24	24584	Replace	Immediate						79
25	24576	Replace	Immediate - relocate conflicting pipe						44
26	24579	Monitor (Cat 1)	Re-assess	Assess					48
27	24812	Replace	Immediate						79
28	24869	Monitor (Cat 1)		Assess					30
29	24645	Monitor (Cat 1)	Clear roots and re-assess	Assess					39
30	24653	Monitor (Cat 1)		Assess					30
31	24563	Monitor (Cat 2)			Assess				47
32	24562	Monitor (Cat 1)		Assess					43
33	24566	Monitor (Cat 2)			Assess				87
34	24646	Monitor (Cat 1)		Assess					39
35	24647	Monitor (Cat 2)			Assess				43
36	24648	Monitor (Cat 1)		Assess					39
37	24642	Monitor (Cat 2)			Assess				43
38	24654	Monitor (Cat 1)		Assess					30
39	24538	Monitor (Cat 1)		Assess					83
40	52637	Monitor (Cat 1)		Assess					12
41	52641	Monitor (Cat 1)		Assess					12
42	52642	Monitor (Cat 1)		Assess					12
43	52636	Monitor (Cat 1)		Assess					12
44	24537	Replace	Immediate						79
45	52634	Monitor (Cat 1)		Assess					12

46	52628	Monitor (Cat 1)		Assess				12
47	52635	Monitor (Cat 2)			Assess			16
48	52631	Monitor (Cat 2)			Assess			16
49	52630	Monitor (Cat 2)			Assess			16
50	52632	Monitor (Cat 2)			Assess			16
51	52626	Monitor (Cat 2)			Assess			16
52	52639	Monitor (Cat 2)			Assess			16
53	52629	Monitor (Cat 1)		Assess				12
54	52633	Monitor (Cat 1)		Assess				12
55	24534	Replace	Immediate					79
56	24628	Monitor (Cat 2)			Assess			87
57	24539	Replace	Immediate					79
58	24533	Monitor (Cat 1)	Clear obstruction and re-assess	Assess				83
59	24644	Monitor (Cat 1)		Assess				39
60	24643	Replace	Immediate					35
61	24558	Replace	Immediate					26
62	24567	Leave (Cat 4)					Assess	95
63	24864	Leave (Cat 4)					Assess	56
64	24641	Monitor (Cat 2)			Assess			43
65	24640	Monitor (Cat 1)		Assess				39
66	24643	Replace	Immediate					35
67	24878	Monitor (Cat 1)		Assess				63
68	24596	Monitor (Cat 2)			Assess			67
69	24595	Monitor (Cat 1)		Assess				63

70	24595	Replace	Immediate					35
71	24560	Monitor (Cat 1)		Assess				30
72	24655	Monitor (Cat 1)		Assess				30
73	24549	Monitor (Cat 1)		Assess				30
74	24589	Leave (Cat 3)				Assess		51
75	24588	Leave (Cat 3)	Re-assess			Assess		51
76	24590	Monitor (Cat 2)			Assess			47
77	80059	Leave (Cat 4)					Assess	17
78	80060	Leave (Cat 4)					Assess	17
79	24591	Monitor (Cat 1)		Assess				43
80	24664	Replace	Immediate					79
81	24895	Replace	Immediate					79
82	24531	Monitor (Cat 1)	Isolated repair	Assess				83
83	24860	Monitor (Cat 2)			Assess			48
84	24577	Monitor (Cat 1)		Assess				48
85	24574	Monitor (Cat 1)		Assess				48
86	24550	Monitor (Cat 1)		Assess				30
87	24649	Monitor (Cat 1)		Assess				30
88	24575	Replace	Immediate					44
89	24568	Monitor (Cat 1)		Assess				83
90	24564	Monitor (Cat 1)		Assess				83
91	24565	Monitor (Cat 1)		Assess				83
92	N/A	Monitor (Cat 2)	Update GIS		Assess			87
93	52638	Monitor (Cat 1)	Clear rubble	Assess				30
94	24570	Monitor (Cat 1)		Assess				83

95	24868	Monitor (Cat 1)	Clear obstruction	Assess				44
96	24569	Monitor (Cat 1)		Assess				83
97	84421	Monitor (Cat 2)			Assess			9
98	65497	Leave (Cat 4)					Assess	25
99	24573	Leave (Cat 3)				Assess		56
100	24573B	Monitor (Cat 1)		Assess				48
101	24536	Monitor (Cat 1)		Assess				83
102	24535	Monitor (Cat 1)		Assess				83
103	24571	Monitor (Cat 2)			Assess			30
104	24865	Monitor (Cat 1)		Assess				44
105	24555	Monitor (Cat 1)		Assess				30
106	24811	Replace	Immediate					79
107	24810	Replace	Immediate					79
108	24809	Monitor (Cat 2)	Isolated repair		Assess			87

5. CONCLUSIONS AND RECOMMENDATIONS

Willow & Sparrow Pty Ltd have assessed the CCTV footage and completed the decision tree and risk/replacement matrix for the relevant stormwater culverts within Mullumbimby, NSW. The assessment of 108 culverts was undertaken with 15 lines unable to be assessed due to having buried lids, restricted access, or that could not be found. It is recommended that the culverts that were not assessed during the first pass of the catchment be undertaken in FY19/20.

With regards to the 108 mains that were assessed, 16 are recommended for immediate replacement in addition to another 10 mains that are recommended for immediate minor rectification works such as clearing blockages, completing incomplete assessments, and isolated repairs. The 92 mains that are not recommended for immediate replacement are recommended for re-assessment as per Table 114.

The culverts identified for replacement and the associated conceptual construction cost estimates for each are listed below in Table 115. A detailed breakdown of the construction cost estimate for each culvert can be found in **Attachment 1**.

The scope for the mains that are recommended for future assessment subject to immediate minor rectification works being undertaken are listed below in Table 116 with the associated conceptual construction/civil cost estimates. The associated rates for each item can be found in **Attachment 2**. These rates have been applied to each main as applicable to fulfil the scope.

In addition to works derived from assessments that were completed/partly completed, Table 117 identifies the stormwater culverts that have not been assessed or are reported not to exist. It is recommended that these assets be investigated and confirmed to exist or not prior to updating the asset register accordingly.

It is recommended that the scope identified in both Tables 115 and 116 (replacement and minor rectification/civil works) be cross-reference with the WSUD recommendations to ensure that there are no conflicting works. Once confirmed, the recommended scope should be prepared for tender and completed in FY19/20 at a total estimated cost of **$506,053.40** (±20%) (excl GST). Additionally, investigations should be undertaken to determine whether the assets identified in Table 117 do exist and if so, assess these assets to establish whether rectification works are required.

Table 115 | Commercial Comparison of Rectification Options

#	Line	Dia.	Length (m)	# of Junctions	Primary Location	Conceptual Cost Estimate ($)		Proposed Methodology and Key Notes
						Open Trench Excavation	Structural Lining	
20	24580	450	52.50	0	Grass verge	$44,200.00	N/A	Open trench construction, Traffic control, Standard work hours
22	24875	300	25.52	0	Road pavement	$26,350.40	$9,780.00	Structural lining, Traffic control, Standard work hours
24	24584	300	33.56	0	Main road pavement	$36,541.20	N/A	Open trench construction, Traffic control, Night works
25	24576	600	24.55	0	Main road pavement	$43,106.00	N/A	Open trench construction, Traffic control, Night works
27	24812	450	28.54	1	Main road pavement	$42,310.80	N/A	Open trench construction, Traffic control, Night works
44	24537	600W x 300H	11.78	0	Road pavement	$21,049.60	N/A	Open trench construction, Traffic control, Standard work hours
55	24534	600W x 300H	20.05	1	Road pavement	$35,666.00	N/A	Open trench construction, Traffic control, Standard work hours
57	24539	450W x 300H	11.32	0	Road pavement	$18,744.40	N/A	Open trench construction, Traffic control, Standard work hours
60/66	24643	600	35.00	3	Footpath	$55,900.00	N/A	Open trench construction, Standard work hours
61	24558	450	112.36	0	Main road pavement	$134,907.20	$52,029.40	Structural lining, Traffic control, Night works
70	24595	600	20.00	0	Access road pavement	$30,100.00	N/A	Open trench construction, Traffic control, Standard work hours
80	24664	225	4.85	0	Road pavement	$8,992.00	N/A	Open trench construction, Traffic control, Standard work hours
81	24895	300	4.00	0	Road pavement	$8,580.00	N/A	Open trench construction, Traffic control, Standard work hours
88	24575	300	2.00	0	Grass verge	$5,320.00	N/A	Open trench construction, Standard work hours
106	24811	600	49.90	3	Private property	$110,800.00	$36,640.00	Structural Lining, Standard work hours
107	24810	600	47.04	2	Private property	$78,300.00	$33,424.00	Structural Lining, Standard work hours
TOTAL			482.97	10				$482,383.40

*Depth of culverts is currently unknown, a depth of 1.5m has been assumed for all conceptual cost estimates apart from #70 (Line 24595) where there is no cover above the culvert

Table 116 | Scope of Minor Rectification Works

#	Line	Dia.	Length (m)	Primary Location	Issue	Required Works	Location	Conceptual Cost Estimate ($)
2	24893	225	3.12	Grass verge	Assessment incomplete due to obstruction - rubble	Clear and re-assess culvert	3.12m from MH HWL-1273	$800.00
10	24581	375	19.33	Road pavement	Assessment incomplete due to obstruction - root intrusion	Clear, re-assess, and patch repair culvert	8.31m from MH GIP-1221	$3,640.00
26	24579	450	40.00	Grass verge	Track camera lost traction	Re-assess	34.69m from MH JPT-1220	$1,000.00
29	24645	300	27.03	Main road pavement	Assessment incomplete due to obstruction - root intrusion	Clear, re-assess, and patch repair culvert	1.43m from MH JPT-1285	$3,780.00
58	24533	450W x 300H	24.07	Road pavement	Assessment incomplete due to obstruction - object beneath flow	Clear and re-assess culvert	18.65m from MH HWL-1324	$1,220.00
75	24588	450	15.80	Grass verge	Assessment incomplete due to obstruction - protruding junction	Locate and uncover MH JPT-1238 and re-assess culvert	8.67m from IP-1237	$1,700.00
82	24531	600W x 350H	20.34	Road pavement	Roof collapsed	Isolated excavation, repair, and re-assessment	2.24m from D/S MH	$4,870.00
93	52638	1000W x 300H	12.87	Main road pavement	Flow obstruction - rubble	Clear culvert	11-13m from D/S gully pit	$1,420.00
95	24868	300	4.95	Access road pavement	Flow obstruction - material	Clear obstruction	MH IPT-1314	$380.00
108	24809	600	57.92	Grass verge	Culvert deformation	Isolated excavation, repair, and re-assessment	15.28m from MH JPT-1481	$4,860.00
			183.08m				**TOTAL**	**$23,670.00**

Table 117 | Assets that were not assessed

No.	Line	Dia.	Material	Length (m)	Primary Location	Issue	Required Works
1	24559	375	RCP	12.44	Road pavement	Not assessed	Undertake assessment
2	24572	375	RCP	15.32	Access road pavement	Line doesn't exist	Await survey information to determine whether line exists
3	24578	450	RCP	29.36	Grass verge	Unable to access due to pit configuration	Undertake assessment
4	24532	1800W x 1200H	RCBC	25.52	Road pavement	Line doesn't exist	Await survey information to determine whether line exists
5	24650	450	RCP	4.20	Grass verge	Unable to access due to buried DS pit - total time taken to locate and mark buried pit 2 hours	Undertake assessment
6	24651	375	RCP	9.77	Grass verge	This line doesn't exist. Just an open drain leading into downstream side entry pit. Unable to get a camera in to look around. Side entry is too narrow. There no entry from next line downstream either as it is buried too.	Await survey information to determine whether line exists
7	24652	500	RCP	87.62	Grass verge	Line doesn't exist. It is only a gulley next to footpath.	Await survey information to determine whether line exists
8	24653	750	RCP	91.60	Major road pavement	Not assessed	Undertake assessment
9	24856	Unknown	RCP	17.68	Beneath driveways	Line doesn't exist	Await survey information to determine whether line exists
10	24548	1800W x 1200H	RCBC	27.28	Road pavement	Line doesn't exist	Await survey information to determine whether line exists
11	24909	Unknown	RCP	3.42	Road pavement	Line doesn't exist	Await survey information to determine whether line exists
12	24910	Unknown	RCP	3.59	Road pavement	Line doesn't exist	Await survey information to determine whether line exists
13	52031	2500W x 2000H	RCBC	20.52	Major road pavement	Unable to asses	Manned assessment
14	57672	200	RCP	2.00	Road pavement	Line not on map	Undertake assessment
15	65496	375	RCP	7.40	Access road pavement	Line not on map	Undertake assessment

ATTACHMENT 1 – CONCEPTUAL CONSTRUCTION COST ESTIMATES FOR COMPLETE RECTIFICATION OF CULVERTS

Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24580

M HP	G P			P MF P	P p r
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	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P MF P	P p r
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	d r			d r	r d
N P PM M P N M RM					
M HP	G P			P MF P	P p r
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	d r r r d				d
	d r				
N P PM M P N M RM					
M HP	G P			P MF P	P p r
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N P PM M P N M RM					
M HP	G P			P MF P	P p r
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N P PM M P N M RM					
M HP	G P			P MF P	P p r
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N P PM M P N M RM					

Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24875

Summary of Schedule of Rates

Schedule of uantities and Prices

Structural Lining Construction Cost Estimate - 24875

Summary of Schedule of Rates

Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24584

M HP	G P			P ME P	P P r
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	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P r
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	d r			d r	r d
N P PM M P N M RM					
M HP	G P			P ME P	P P r
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	d r r r d				d
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N P PM M P N M RM					
M HP	G P			P ME P	P P r
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M HP	G P			P ME P	P P r
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N P PM M P N M RM					
M HP	G P			P ME P	P P r
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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24576

M HP	G P			P ME P	P P f
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	d d r d M			d	r r
	r r r				
N P PM M P P N M					
M HP	G P			P ME P	P P f
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	d r			d r	r d
N P PM M P N M RM					
M HP	G P			P ME P	P P f
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M HP	G P			P ME P	P P f
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N P PM M P N M RM					
M HP	G P			P ME P	P P f
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M HP	G P			P ME P	P P f
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Summary of Schedule of Rates

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Open Excavation Construction Cost Estimate - 24812

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N P PM M P P N M					
M HP	G P			P MEP	P P r
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	d r			d r	r d
N P PM M P N M RM					EE
M HP	G P			P MEP	P P r
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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24537

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N P PM M P P N M					
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N P PM M P N M RM					
M HP	G P			P MP	P P r
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	d r r r d				d
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N P PM M P N M RM					
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Summary of Schedule of Rates

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Schedule of uantities and Prices Open Excavation Construction Cost Estimate - 24534					
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M HP	G P			P ME P	P P f
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N P PM M	P N M RM				
M HP	G P			P ME P	P P f
	r d				
	d r r r d				d
	d r		d		
N P PM M	P N M RM				D
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Summary of Schedule of Rates		
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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24539

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	r r r				
N P PM M	P P N M				
M HP	G P			P MP E	P P t
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M HP	G P			P MP E	P P t
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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24643

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Open Excavation Construction Cost Estimate - 24558

Summary of Schedule of Rates

Schedule of uantities and Prices

Structural Lining Construction Cost Estimate - 24558

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Open Excavation Construction Cost Estimate - 24595

M HP	G P			P MP	P P t
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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24664

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	r r r				
N P PM M	P P N M				
M HP	G P			P ME P	P P t
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	d r			d r	r d
N P PM M	P N M RM				EB
M HP	G P			P ME P	P P t
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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24895

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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24575

M HP	G P			P ME P	P P t
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	d d r d M			d	r r
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N P PM M P P N M					
M HP	G P			P ME P	P P t
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Summary of Schedule of Rates

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Schedule of uantities and Prices

Open Excavation Construction Cost Estimate - 24811

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Structural Lining Construction Cost Estimate - 24811

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Open Excavation Construction Cost Estimate - 24810

Summary of Schedule of Rates

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Structural Lining Construction Cost Estimate - 24810

Summary of Schedule of Rates

ATTACHMENT 2 – CONCEPTUAL CONSTRUCTION COST RATES FOR MINOR RECTIFICATION WORKS

Rates for Minor Rectification Works Items		
[illegible]	[illegible]	[illegible]
[illegible]		[illegible]
[illegible]		
[illegible]		
[illegible]		
[illegible]		
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END OF REPORT

Willow+
Sparrow

Mullumbimby (4001)

Stormwater Maintenance Hole

Condition Assessment

Prepared for: Byron Shire Council

DOCUMENT CONTROL

Revision number	Description	Prepared	Reviewed	Issued	Issue date
0	Final Report	JV	MC	MC	8/10/19

Document title: Mullumbimby – Stormwater Maintenance Hole Condition Assessment

Document number: BSC_MBY-SWMHCA

Author: Julian Vivoli, *BEng*

Client name: Byron Shire Council

Client's representative: Dean Baluch

Approved for use by:

Name: Michael Chamberlain **Signature:** **Date:** 8th October 2019

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Contents

1. INTRODUCTION

Willow & Sparrow Pty Ltd has been engaged by Byron Shire Council (BSC) to prepare a Condition Assessment report for the stormwater catchment in the township of Mullumbimby, NSW.

Project background

Byron Shire Council is aware that flooding occurs throughout the town during relatively minor rainfall (3-month ARI). This is an indication that this portion of the network may be subject to insufficient/poor conveyance and storage. Council wishes to undertake a prudent process to confirm the actual condition of the stormwater maintenance holes (MH) to determine which MHs require rehabilitation or replacement, and to then procure the rehabilitation or replacement of the selected MHs.

Due to the uncertainty as to which MHs are to be replaced or rectified, it is anticipated that the project be delivered in two stages, with a hold point at the completion of stage 1. This hold point will enable Council to review this Condition Assessment report and determine which MHs will be carried forward into the replace/rectification phase of the project in FY19/20.

The two stages of work are:

- Stage 1 – Condition Assessment of each MH, and
- Stage 2 – Procurement and delivery of the MH rectification works

Scope

This Condition Assessment report provides a record of the findings of the condition assessments that were based on visual inspections. The report also provides recommendations for rectification works and a re-assessment schedule to maintain the integrity and function of the network.

Site description

This Condition Assessment report has been prepared for the stormwater catchment as shown in Figure 1. The Mullumbimby catchment comprises a stormwater network that services hundreds of residential properties in addition to the Mullumbimby CBD. The red MHs encompassed by the blue hatch in Figure 1 are the MHs that have been addressed in this Condition Assessment report.

Figure 1 | Stormwater catchment– Mullumbimby, NSW, Source: Byron Shire Council GeoCortex 2019

2. MAINTENANCE HOLE CONDITION ASSESSMENT RECORDS – MULLUMBIMBY CATCHMENT

2.1 JPT-1295 – Burringbar Street

Attributes	
Location	Road Pavement
Dimensions (mm)	Unknown
Depth (m)	Unknown
Year of Construction	1993
Condition	
Accessible	Junction pit is buried beneath the roadway (bike lane)

2.2 JPT-1420 – Azalea Street

Attributes	
Location	Grassed verge
Dimensions (mm)	920 x 920
Depth (m)	900
Year of Construction	1960
Condition	
Structure	Field inlet / junction pit is in good condition

2.3 HWL-1289 – Burringbar Street

Attributes	
Location	Grassed verge
Dimensions (mm)	Unknown
Depth (m)	Unknown
Year of Construction	1993
Condition	
Structure	Entrance to headwall is completely obstructed

2.4 HWL-1307 – River Terrace

Attributes	
Location	Beneath rock retaining wall
Dimensions (mm)	375
Depth (m)	1.5m
Year of Construction	1980
Condition	
Structure	Entrance to headwall is significantly obstructed

2.5 HWL-1329 – Stuart Street

Attributes	
Location	Road pavement
Dimensions (mm)	600W x 300H
Depth (m)	0.3
Year of Construction	1940
Condition	
Structure	Entrance to headwall is significantly obstructed

2.6 HWL-1422 – Azalea Street

No image of the pit internals provided as part of the assessment

Attributes	
Location	Asphalt footpath
Dimensions (mm)	650 x 1000
Depth (m)	0.7
Year of Construction	1960
Condition	
Structure	Junction pit is in good condition

2.7 JPT-1285 – Burringbar Street


Attributes	
Location	Paved footpath
Dimensions (mm)	560 x 560
Depth (m)	0.6
Year of Construction	1984
Condition	
Structure	Junction pit is in good condition

2.8 JPT-1288 – Burringbar Street


Attributes	
Location	Road pavement
Dimensions (mm)	1000
Depth (m)	4.2
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.9 JPT-1292 – Burringbar Street


Attributes	
Location	Road pavement
Dimensions (mm)	1200
Depth (m)	3.1
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.10 JPT-1294 – Burringbar Street


Attributes	
Location	Road pavement
Dimensions (mm)	1200
Depth (m)	2.8
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.11 JPT-1297 – Burringbar Street

Attributes	
Location	Road pavement
Dimensions (mm)	1200
Depth (m)	2.6
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.12 JPT-1299 – Burringbar Street

No image of the pit internals provided as part of the assessment

Attributes	
Location	Road pavement
Dimensions (mm)	1200
Depth (m)	2.0
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.13 JPT-1302 – Burringbar Street

	No image of the pit internals provided as part of the assessment
Attributes	
Location	Road Pavement
Dimensions (mm)	1.9
Depth (m)	1200
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.14 JPT-1303 – Burringbar Street

	
Attributes	
Location	Road pavement
Dimensions (mm)	1200
Depth (m)	1.5
Year of Construction	1993
Condition	
Structure	Junction pit is in good condition

2.15 JPT-1310 – Studal Lane

No image of the pit internals provided as part of the assessment

Attributes	
Location	Grassed verge
Dimensions (mm)	Unknown
Depth (m)	Unknown
Year of Construction	1940
Condition	
Structure	Could not be accessed without mechanical means due to the significant weight of the lid

2.16 JPT-1319 – Orchid Place

Attributes	
Location	Grassed verge
Dimensions (mm)	600 x 600
Depth (m)	1.7
Year of Construction	1975
Condition	
Structure	Junction pit is in good condition

2.17 JPT-1420 – Azalea Street

Attributes	
Location	Grassed verge
Dimensions (mm)	Unknown
Depth (m)	Unknown
Year of Construction	1960
Condition	
Structure	Junction pit is buried beneath the grassed verge

2.18 JPT-4212 – Station Street

Attributes	
Location	Road pavement
Dimensions (mm)	1400
Depth (m)	1.6
Year of Construction	2011
Condition	
Structure	Junction pit is in good condition

2.19 JPT-4216 – Station Street

Attributes	
Location	Concrete footpath
Dimensions (mm)	1000
Depth (m)	1.3
Year of Construction	2011
Condition	
Structure	Junction pit is in good condition

2.20 JPT-4217 – Station Street

Attributes	
Location	Grassed verge
Dimensions (mm)	1200 x 630
Depth (m)	0.7
Year of Construction	2011
Condition	
Structure	Junction pit is in good condition

2.21 JPT-4220 – Station Street


Attributes	
Location	Road pavement
Dimensions (mm)	1500
Depth (m)	1.5
Year of Construction	2011
Condition	
Structure	Junction pit is in good condition

2.22 JPT-4221 – Station Street


Attributes	
Location	Road pavement
Dimensions (mm)	1200
Depth (m)	1.6
Year of Construction	2011
Condition	
Structure	Junction pit is in good condition

2.23 KIP-1238 – Azalea Street


Attributes	
Location	Roadside kerb
Dimensions (mm)	Unknown
Depth (m)	Unknown
Year of Construction	Unknown
Condition	
Structure	Kerb inlet is completely buried

2.24 KIP-1542 – Burringbar Street

Attributes	
Location	Grassed verge
Dimensions (mm)	Unknown
Depth (m)	Unknown
Year of Construction	1993
Condition	
Structure	Entrance to chamber is significantly obstructed

2.25 JPT-1220 – Station Street

No image of the pit internals provided as part of the assessment

Attributes	
Location	Road pavement
Dimensions (mm)	450
Depth (m)	1.3
Year of Construction	1975
Condition	
Structure	Junction pit is in good condition

2.26 KIP-1320 – Orchid Place

No image of the pit internals provided as part of the assessment

Attributes	
Location	Footpath
Dimensions (mm)	600
Depth (m)	1.7
Year of Construction	1975
Condition	
Structure	Kerb inlet pit is in good condition

2.27 Maintenance holes that could not be located

MH ID - Street	GC/3 – Station Street	BE/1 – Stuart Street	E/11 – Jubilee Avenue
			

3. DETERMINATION OF RISK AND RECOMMENDATIONS

As MH's are isolated structures with a similar and predominantly low potential consequence of failure, it is recommended that their ongoing management doesn't consider the consequence of their failure in their risk determination. The overall condition score should solely be considered as the risk of failure.

With the above being considered, overall condition scores have been assigned to each of the assessed MHs (1 being as new, and 5 requiring immediate rectification). The recommended assessment schedule has been developed off the assigned overall condition scores. Typically, each integer aligns with an additional 4 year period in which the MH is to be assessed e.g. a MH with a risk score of 3 will be assessed in 8 years where as a MH with a risk score of 2 will be assessed in 12 years.

Table 1 below provides a summary of the information presented in the report, recommends an overall condition score (risk of failure), and proposes rectification works and the timing for re-assessment.

4. SUMMARY OF FINDINGS

Table 1 | Summary / Decision Table

#	Asset ID	Street	Is it a Maintenance Structure?	Diameter	Depth	Shape	Year	Primary Location	Condition Score	Required Rectification Works
1	D-MBY-JPT-1295	73 Burringbar St	y	-	-	-	1993	Road pavement	N/A	Locate and uncover, MH is buried beneath roadway (bike lane)
2	D-MBY-JPT-1420	Azalea Street	y	920 x 920	900	Rectangular	1960	Grassed verge	2	
3	D-MBY-HWL-1289	Burringbar Street	y	-	-	-	1993	Grassed verge	N/A	Clear obstruction of pit inlet and assess condition of culvert
4	D-MBY-HWL-1307	River Terrace	n	-	-	-	1980	Beneath rock wall	N/A	Clear obstruction of culvert and assess condition of culvert
5	D-MBY-HWL-1329	Stuart Street	n	-	-	-	1940	Beneath roadway	N/A	Clear obstruction of culvert and assess condition of culvert
6	D-MBY-HWL-1422	Azalea Street	y	650 x 1000	700	Rectangular	1960	Asphalt footpath	N/A	Re-assess MH
7	D-MBY-JPT-1285	Burringbar St	y	560 x 560	600	Rectangular	1984	Paved footpath	2	
8	D-MBY-JPT-1288	Burringbar St	y	1000	4200	Circular	1993	Road pavement	2	
9	D-MBY-JPT-1292	Burringbar St	y	1200	3100	Circular	1993	Road pavement	2	
10	D-MBY-JPT-1294	Burringbar St	y	1200	2800	Circular	1993	Road pavement	2	
11	D-MBY-JPT-1297	Burringbar St	y	1200	2600	Circular	1993	Road pavement	2	
12	D-MBY-JPT-1299	Burringbar St	y	1200	2000	Circular	1993	Road pavement	2	
13	D-MBY-JPT-1302	Burringbar St	y	1200	1900	Circular	1993	Road pavement	2	
14	D-MBY-JPT-1303	Burringbar St	y	1200	1500	Circular	1993	Road pavement	2	
15	D-MBY-JPT-1310	Studal Lane	y	-	-	-	1940	Grassed verge	N/A	Mechanical means required to lift lid and condition assess the MH
16	D-MBY-JPT-1319	Orchid Place	y	600 x 600	1700	Rectangular	1975	Grassed verge	2	
17	D-MBY-JPT-1420	Azalea Street	y	-	-	-	1960	Grassed verge	N/A	Locate, uncover, and assess the condition of the MH
18	D-MBY-JPT-4212	Station Street	y	1400	1600	Circular	2011	Road pavement	2	
19	D-MBY-JPT-4216	Station Street	y	1000	1340	Circular	2011	Concrete footpath	2	
20	D-MBY-JPT-4217	Station Street	y	1200 x 630	680	Rectangular	2011	Grassed verge	2	
21	D-MBY-JPT-4220	Station Street	y	1500	1500	Circular	2011	Road pavement	2	
22	D-MBY-JPT-4221	Station Street	y	1200	1600	Circular	2011	Road pavement	2	
23	D-MBY-KIP-1238	Azalea Street	y	-	-	-	-	Grassed verge	N/A	Locate, uncover, and assess the condition of the MH
24	D-MBY-KIP-1542	Burringbar Street	y	-	-	-	1993	Grassed verge	N/A	Uncover and assess the condition of the MH
25	D-MBY-JPT-1220	Station Street	y	450	1300	Circular	1975	Road pavement	2	
26	D-MBY-KIP-1320	Orchid Place	y	600	1700	Circular	1975	Footpath	2	

5. CONCLUSIONS AND RECOMMENDATIONS

As part of this project, 24 stormwater maintenance holes (MHs) were assessed within the township of Mullumbimby, NSW.

Willow & Sparrow Pty Ltd have assessed the available condition assessment information and assigned overall condition scores (risk of failure) to each MH with justification provided in Section 2 for each asset. Furthermore, rectification works have been recommended where deemed necessary to maintain the assets integrity and function or where works are required to perform a condition assessment of the asset.

Of the 24 MHs that formed the assessment scope, 7 could not be assessed due to being buried or significantly obstructed, the remaining 17 MHs were assessed and found to be in good condition without the need for any rectification works. The 7 MHs that could not be assessed are proposed for uncovering and assessment. Additionally, 2 culverts that were assessed as part of this scope are recommended for clearing of obstruction and assessment.

It is recommended that the scope identified in Table 1 be prepared for tender and completed in FY19/20 at an anticipated cost no greater than **$5,000.00** (±20%) (excl GST).

END OF REPORT

Report No. 4.2	**Effects of water mining in Byron and surrounding shires on groundwater resources**
Directorate:	Infrastructure Services
Report Author:	Dean Baulch, Principal Engineer, Systems Planning
File No:	I2019/2131

Summary:

The NSW Chief Scientist & Engineer undertake an independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW. The effects appear to be negligible.

Rous Water through its Future Water Supply Strategy is conducting investigation for groundwater sources.

RECOMMENDATION:

That the Committee note the report.

Attachments:

1 Independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW - Final Report - NSW Chief Scientist & Engineer - 31 October 2019, E2019/91097 , page 555⇩

REPORT

At the Council Meeting of 22 November 2018, it adopted the following Committee Recommendation as Resolution 18-742:

> 2. *That Council request information from surrounding shires, Rous County Council, Southern Cross University and DOI on:*
>   a) *Current water extraction quantities and locations*
>   b) *Research on short term and long term impacts of these activities on aquifers and ground water resources. (Richardson/Hackett)*

In November 2018 the (then) Minister for Regional Water, the Hon Niall Blair MLC, requested that the NSW Chief Scientist & Engineer undertake an independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW. This was finalised on 31 October 2019, see attachment 1.

A critical element in the management of water under the Water Sharing Plans (WSPs) is the prioritisation of water to the environment and between water users and purposes. WSPs establish priorities of allocation with environmental first, Basic Landholder Rights second, town water supply and stock and domestic licences third and all other licensed extraction for industrial and commercial purposes fourth.

The Review identified seven operators in the Northern Rivers region with allocations of 240.5 ML/y who are actively extracting for water bottling purposes, representing 0.55% of water licences and basic landholder rights (together defined in the Water Sharing Plans as 'total water requirements') and 0.008% of estimated total annual aquifer recharge in the four groundwater sources. The report does not include the location of individual extraction licences.

Rous Water through its Future Water Supply Strategy is conducting investigation for groundwater sources.

NSW GOVERNMENT | Chief Scientist & Engineer

Independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW

Final Report

NSW Chief Scientist & Engineer

31 October 2019

www.chiefscientist.nsw.gov.au/reports/independent-review-of-impacts-of-the-bottled-water-industry-on-groundwater-resources-in-the-northern-rivers-region-of-nsw

NSW GOVERNMENT | Chief Scientist & Engineer

The Hon. Melinda Pavey MP
Minister for Water, Property and Housing
52 Martin Place
SYDNEY NSW 2000

31 October 2019

Dear Minister

Final report: Independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW

In November 2018, the Hon Niall Blair MLC, the (then) Minister for Regional Water, requested that I undertake an independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW. I submitted an initial report from the Review on 1 February 2019. I am pleased to submit this Final Report.

The Initial Report outlined the preliminary analysis of available information and reports on the bottled water industry, local groundwater systems, the regulatory framework, as well as the range of stakeholder views gathered through consultations and two site visits to the region in December 2018 and January 2019.

The Final Report draws on further work undertaken to understand better the potential growth of the bottled water industry in the region, the sustainability of water extraction limits in the relevant Water Sharing Plan and the assessment of associated impacts.

I would like to thank all stakeholders who provided contributions to the Review including local residents, farmers, community groups, the bottled water industry, researchers and academics, local government councillors and staff, state government agencies and local water utilities. Their input has greatly informed the analysis of all relevant issues.

Yours sincerely

H. Durrant-Whyte.

Professor Hugh Durrant-Whyte
Chief Scientist & Engineer

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EXECUTIVE SUMMARY

In November 2018 the (then) Minister for Regional Water, the Hon Niall Blair MLC, requested that the NSW Chief Scientist & Engineer undertake an independent review of the impacts of the bottled water industry on groundwater resources in the Northern Rivers region of NSW.

The Initial Report submitted in February 2019 followed two site visits to the Tweed and Ballina areas to meet with stakeholders, reported on issues raised in consultations and described relevant groundwater and surface water systems including available data, management frameworks and industry allocations.

This Final Report provides an update to the industry allocations and current and proposed bottled water licences and considers potential growth of the industry, the sustainability of the extraction limits for the groundwater systems in scope and the impacts that extraction of groundwater for bottling may have on groundwater resources, surface water and other local environmental consequences. In doing so, the Review examined available hydrogeological assessments for the industry, how they are developed and assessed, and how localised impacts are accounted for and managed. Technical approaches to address issues relating to truck movements, road integrity and plastics are included.

The Northern Rivers region has alluvial, fractured rock, coastal sands and porous rock aquifers. Four groundwater sources are relevant to the Review, being the New England Fold Belt Coast, the Alstonville Basalt Plateau, the North Coast Volcanics and the Clarence Morton Basin. All are fractured or porous rock aquifer systems and are part of the North Coast Fractured and Porous Rock Water Sharing Plan.

Overall, fractured rock systems in particular are highly variable and complex, making them difficult to characterise on a regional scale. In September, an expert workshop was held on water sharing plans, extraction impacts and current knowledge to inform the technical review findings.

The Review has occurred during a period of widespread concern and public debate about extended drought and long-term water futures.

The issues that prompted this Review also go beyond technical and scientific matters. They encompass fundamental views of community and how resources are valued and allocated. For some respondents, a major concern is potential lack of water resources for agricultural purposes. For others, any extractive activity for water bottling purposes is not supported for a broader range of reasons articulated in the initial Review report. Although beyond the scope of this report, legislative and policy frameworks include requirements for community engagement and consideration of social, economic and environmental factors in planning decisions as well as assessment of risk and scientific knowledge.

Questions of risk and uncertainty and how these are managed are central to many of the issues raised. Importantly, it became apparent over the course of the Review that there were different understandings of these concepts. For this reason, this report includes an explanation about how these concepts were approached by the Review and informed consideration of sustainability factors and impacts under the Terms of Reference.

For the purposes of this report, an impact refers to the physical change that occurs from an action, such as depressurisation of groundwater due to its extraction. Consequences are a result of the impact, for example, temporary or permanent loss of water access or loss of environment for groundwater dependent ecosystems and associated flora and fauna.

High-level findings and recommendations are presented in this Executive Summary. A complete reading of the full report provides further detail for the basis of conclusions reached.

FINDINGS

The bottled water industry

- Available industry data indicates that across Australia, over three-quarters of bottled water is sourced from underground wells, and the remainder from standard reticulated water supplies. Approximately 8% of Australian bottled water production is exported.
- The Review identified seven operators in the Northern Rivers region with allocations of 240.5 ML/y who are actively extracting for water bottling purposes, representing 0.55% of water licences and basic landholder rights (together defined in the WSP as 'total water requirements') and 0.008% of estimated total annual aquifer recharge in the four groundwater sources.
- Four further proposals, if approved, would amount to an additional 168 ML/y, being an additional 0.38% of estimated total water requirements and 0.006% of total annual aquifer recharge.
- Changing consumer preferences, trade imbalances, the availability of tap water and private ('no name') brands and population growth are expected to impact future bottled water production and consumption volumes.
- Scenario analyses conducted by the Review suggest the Australian bottled water industry is most likely to grow at a rate of less than 2% per annum to 2024 and that growth in the Northern Rivers region is likely to be consistent with this trend. Under most scenarios to 2024 considered, the 168 ML/y of additional proposed bottled water operations would be sufficient to meet fully projected growth in demand.
- The Review also considered 'highly unlikely' and 'extremely unlikely' scenarios to 2034, being growth continuing at the current rate of 10% per annum and establishment of a major premium bottled water exporter in the Northern Rivers, respectively.
    - If the 'highly unlikely' scenario occurred, the bottled water industry would represent less than 2.3% of 'total water requirements' and 0.034% of estimated total annual aquifer recharge.
    - If the 'extremely unlikely' scenario occurred, the bottled water industry would represent less than 4.6% of 'total water requirements' and 0.069% of estimated total annual aquifer recharge.
- As the scenario analyses considered an unchanged regulatory and policy environment, these forecasts may be affected by regulatory intervention which directly or indirectly impacts the bottled water industry in this region.
- For the purposes of water extraction licensing, the bottled water industry is treated the same as other prospective commercial users. However, development consent under the *Environmental Planning and Assessment Act 1979* is required for water bottling activities. Approvals identified by the Review for bottled water extraction in the Northern Rivers region date from 1993.

Allocations

- The WSP determines the allowable extraction limit, set from the recharge value of each aquifer, with an amount of the recharge reserved for the environment and the reminder determining the Upper Extraction Limit or the LTAAEL
- Under the North Coast Fractured and Porous Rock Water Sharing Plan (WSP), environmental water and basic landholder rights are given priority over licensed

water extraction. Among licensees, priority is given to water utilities and licensed stock and domestic over commercial licensed purposes.

- At the commencement of the WSP for the four groundwater sources, 100% of storage is reserved for the conservation of the groundwater system.
- Water available for extraction is a portion of the estimated recharge value for each groundwater source. This is determined by the WSP. An amount of the recharge is reserved for the environment. The amount reserved for the environment equates to 97% of the estimated recharge value for New England Fold Belt Coast, 96% for North Coast Volcanics, 82% for Alstonville Basalt Plateau and 48% for Clarence Moreton Basin.
- The remaining amounts can be allocated for licensed purposes. Of these amounts, 38.0% of the New England Fold Belt Coast is allocated, 51.3% of the North Coast Volcanics and 1.7% in the Clarence Moreton Basin. Alstonville is fully allocated.
- These are average values over the groundwater source areas; which means that the environment is not protected to these levels in locally impacted areas.

Water Sharing Plan assumptions and uncertainty

- In groundwater studies and management, there will always be a level of uncertainty associated with predictions (e.g. recharge rates) and a precise value may not be achieved due to the complex and heterogeneous nature of groundwater movement. This is particularly evident in fractured rock systems that are difficult to characterise fully.
- The WSP plan was developed based on the best available data at hand and followed a standard procedure. The assumptions made in the WSP are practical, reasonable and in agreement with standard practice. In general, the WSP incorporates a reasonable level of conservatism for extraction limits based on the risks identified.
- The portion of the estimated recharge value available for extraction is a function of rainfall recharge over low environmental value areas together with an assessment of environmental and socio-economic risk.
- Calculating recharge is complex due in part to the variability and complexity of the hydrogeology and limited knowledge of the systems. Based on the analysis, the Review considers the recharge rates used in the WSP are reasonable and conservative. This statement is made with a relatively low level of confidence due to lack of data for the groundwater sources of interest.
- In practical terms the groundwater sources are treated as geologically homogenous which adds uncertainty and would benefit from further work. The Review recognises that the complexity of the geology makes it difficult to incorporate heterogeneity into the WSP recharge calculations. Particular attention should be given to the effects of geological variability within groundwater sources, and soils and vegetation overlying aquifer outcrops. The Review acknowledges the conservatism incorporated into the current WSP through the allowable allocation figures.
- The application of the sustainability index appears to be a cost and time effective risk tool that is applied as an additional means to protect resources where limited information is available.
- The WSP incorporates a reasonable level of conservatism for the extraction limits when the groundwater sources are not fully allocated and where they are fully allocated at Alstonville, monitoring is applied.

- Additional monitoring in strategic locations in the Tweed would help inform gaps in knowledge on a regional scale and provide a path towards better conceptual understanding of aquifer flows.
- The overall system is managed with some level of adaptive management, including an annual determination of the volume of water per licence share and WSP are subject to an interim review at five years with a full review at ten years.
- Impacts of climate change should be considered in future WSP methodologies. Development of Regional Water Strategies, which are incorporating climate change in calculations, may provide a valuable source of information.

Sustainability of Water Sharing Plan extraction limits

- Due to limited extraction levels (where known allocations in the Tweed region are much lower than the extraction limits contemplated in the WSP), limited data and uncertainties described regarding the WSP parameters, it is not possible to conclude whether the extraction limits are currently sustainable. However, the Review found no evidence at this point in time that current WSP extraction limits are not sustainable.
- Water levels in Department piezometers should be regularly assessed to ensure periods of any sustained water level decline are identified early.
- Analysis of the last thirteen years' data at Alstonville found lagged rainfall an important variable for understanding water levels. This was observed in shallow-sited piezometers and in deeper piezometers sited in systems that are well connected to surface waters and upper aquifers. Observations from deep piezometers showed a greater stability and a steady upward trend over time of groundwater levels and/or pressures. In contrast, readings from shallower piezometers showed greater variability and appear to be recharged regularly with rainfall.

Assessment and management of potential impacts from water extraction

- Based on the review of available information, there is no measured evidence that current bottled water extractions have impacts on other properties' bores, surface water or GDEs in the Northern Rivers region. This is at least partly due to the relatively low current levels of extractions, hydrogeological conditions and lack of monitoring detecting these impacts.
- While all groundwater extractions have impacts, the magnitude of those impacts and potential consequences will vary. Assessment of risks and measurement of local impacts is complex due to the spatial and temporal variability of the hydrogeology of fractured and porous rock systems. There are established approaches to measuring and modelling to better understand local impacts. All have challenges in terms of accuracy, practicability and cost.
- Bore water extraction can potentially impact water within the same aquifer, within a connected aquifer, or within a connected surface water body, leading to possible changes in water quantity and quality. The pump test is a common field technique, used in hydrogeological assessments, to derive local scale aquifer properties and to indicate proposed impacts of the extraction. In fractured rock systems, the fracture network that intersects the point of extraction will determine the response to pumping, which is complex and requires hydrogeological investigations and interpretation of results in order to design the pump test. Impacts may be proximate to or at distance from the point of extraction, and occur vertically as well as horizontally.
- Noting the low level of current groundwater monitoring in three of the four relevant groundwater sources, there would be merit in reviewing the need for additional

monitoring that will provide the baseline data, conceptual hydrogeological models and recharge estimates commensurate with potential future risk levels.

- At a regional scale, the cost of traditional monitoring bore infrastructure is likely to be an ongoing challenge. This is particularly the case in fractured rock systems subject to high hydrogeological variability. Emerging sensing technologies able to gather data over large areas and at depth may provide a step-change to the field, subject to cost and commercial availability. Whether at the local or regional scale the choice of monitoring will be informed by the level of risk and the cost-effectiveness of the monitoring.
- Local scale monitoring during extraction operations can assist with better understanding of local hydrology and extractive impacts and consequences. This may include piezometric monitoring of the pathway between the point of extraction and locations where there is perceived risk. The cost of this monitoring is likely to be a challenge and its requirement should be justified by the risks as identified by an expert following analysis of pump test data.
- Local scale monitoring during extraction operations could potentially support adaptive management, for example, through additional reporting and cease-to-pump rules related to observed groundwater pressures.
- An assessment of hydrological reports submitted to support development applications by bottled water proponents undertaken by the Review indicates both industry and decision makers would substantially benefit from greater clarity, specificity and standardisation of requirements for hydrological reports. Current technology is available to enable standardised templates and reports to be managed electronically.
- Robust local assessment of potential connectivity between aquifer and overlying shallow groundwater and surface water should form part of pump tests and feature in hydrogeological reports. This is important, as observed in Alstonville, where deeper aquifers are not necessarily confined and may have connections to surface systems or shallower aquifers. It is important to increase understanding of how confined the aquifer is, as assessment criteria of allowable drawdown differs between confined and unconfined systems. In addition, field verification is an important part of the process.
- The Review received anecdotal information suggesting bottled water extractors were generally extracting water at an approximately evenly spaced production rate year-round compared with other commercial users who extract on a more periodic basis. The Review was not able to verify these observations. Further, all groundwater users are subject to future changing environmental conditions, which may influence their future patterns of use. The implementation of the NSW Non-Urban Water Metering Policy will provide information about use patterns in the bottled water industry and enable analyses of interactions and impacts.
- The Review received consistent reports from the community and sometimes neighbours of bottled water extractors about observed changes including environmental effects of drying watercourses and loss of water from previously productive bores. The Review has not identified scientific studies or other evidence establishing a causal link between these observed effects and extraction specifically undertaken by the bottled water industry. Going forward, data from extraction bores, together with monitoring bores (piezometers), local studies and other sources of information should help improve knowledge of impacts from a range of sources.

Data

- Lack of extraction data is an impediment to establishing appropriate extraction limits for individual bores, measuring impacts, and at a regional scale, development of WSP and making determinations of available water. A state-wide metering policy for qualifying groundwater works with bore diameters of 200mm and above will take effect in the Northern Rivers region from 2023. Four of the bottled water extractors in the region are currently required by the regulator to have meters installed.
- The accessibility of any data is central and manual collection can be an impediment in this regard. Advances in technology to provide robust and tamper-proof telemetering options that are commercially cost competitive would have a significant impact.
- Making water extraction and monitoring data available in standardised formats through open databases would benefit decision-makers, researchers and the general public to understand better activities and impacts, including cumulative impacts at local and regional scale. Approvals by relevant state and local government authorities could include requirements that all hydrogeological data are published. There are state managed environmental databases (e.g. SEED) that could be utilised.

Decision-making

- As with any environmental, engineering, resource activity, the proponents and decision makers and regulators operate in a realm of imperfect information. This leads to levels of uncertainty around data and information; however, uncertainty need not prevent decisions being made.
- There are a number of approaches and tools employed to reduce uncertainty with regard to the assumptions, hydrological domain, impacts, and consequences of water extraction. These include taking conservative estimates, using multiple lines of analysis, being judicious in decisions around the type and location of monitoring, employing adaptive management approaches.
- There is a lack of clarity around water planning, management and decision-making roles and processes at state and local government level and between relevant authorities.
- State government agencies and local government should work to clarify roles and responsibilities to streamline assessment and approval processes, to avoid duplication of effort, and to address any gaps in the assessment and approvals process.
- If local government is to undertake hydrogeological assessment as part of the development application process, then it needs access to relevant expertise to interpret modelling and technical reports to inform its decision-making, including requirements for development applications.
- Access to government and industry water data through a common open platform housing standardised, well-curated and long-term data sets that can be expanded would assist assessment and decision-making of applications.
- Regional Water Strategies will be developed over the coming months for the 12 catchment regions across the state and will assist to manage the regions' water resources. The Greater Hunter Regional Water Strategy is already in place. These will improve water security within each region and influence decisions about infrastructure, water reuse, water sharing including during droughts, protect the regions' environmental assets as well as addressing community and industry needs.

Truck movements and road impacts

- There are technologies available that can provide accurate, consistent and real-time data on truck movements, which could be included as a condition of the development consent.
- Responsibility for governing truck safety, movements and size spans Federal, State and Local Government authorities. Each of the responsible bodies has measures to regulate and monitor heavy vehicles through existing legalisation, approval of applications and technologies.
- Technologies and strategies are available to measure traffic volumes and impacts. Local government can levy heavy vehicle road users to contribute to the cost of road maintenance and repair.

Plastics

- The presence and management of plastics is international in scope and management of the impacts and solutions will be influenced significantly by factors and developments beyond those extracting water for bottling purposes in the Northern Rivers region.
- The NSW Government is developing a 20-year waste strategy and plastics plan in the context of broader Federal Government and inter-jurisdictional commitments to address waste and transition from linear to circular economies.
- There is a NSW Government container deposit scheme, which has resulted in a one-third reduction across the state of eligible containers, including bottles entering the litter stream.
- Research and development efforts to replace, repurpose and recycle plastics is a fast-moving and evolving space that is predicted to show significant growth within the next five to ten years.

RECOMMENDATIONS

1. Further work is undertaken to incorporate climate change into the development of recharge estimates for the Water Sharing Plan.
2. Consideration should be given to incorporate geological heterogeneity and soil and vegetation types into recharge estimates where practicable. This may be dependent in part on technological advances, including remote sensing, to characterise systems.
3. Improved monitoring of piezometric water levels is needed in locations with a perceived risk and/or lack of knowledge of groundwater responses and flow directions. This could provide baseline data, conceptual hydrogeological models and recharge estimates commensurate with potential future risk levels. Additional investments in monitoring should balance the value of expected improvements in data availability and data quality against the resources required.
4. Robust local hydrogeological assessments of aquifer connectivity with overlying shallow groundwater and surface water should be investigated via well-designed pump tests. This information should feature in hydrogeological reports.
5. Work should continue towards developing practical and comprehensive guidance on the contents of hydrogeology reports to be submitted by proponents, including specificity and standardisation of information provided and reporting requirements. Ideally, these would be able to be lodged electronically and made publically available.

6. State government agencies and local government should work to clarify roles and responsibilities to streamline assessment and approval processes, to avoid duplication of effort, and to address any gaps in the assessment and approvals process. The first step for this would be by February 2020, relevant officers from Water NSW, DPIE Water, NRAR and Tweed Council convene a workshop for Northern Rivers region bottled water to discuss and develop an approach between them.
7. Water extraction and monitoring data should be made available in standardised formats through open and accessible portals. State managed databases and portals (e.g. SEED) should be utilised where relevant.

Contents

Tables

Figures

1 INTRODUCTION

In November 2018, the (then) Minister for Primary Industries, Minister for Regional Water and Minister for Trade and Industry requested the NSW Chief Scientist and Engineer to conduct an independent review and provide expert advice on the impacts on groundwater quantity arising from extraction by the bottled water industry in the Northern Rivers region of NSW.

In February 2019 an Initial Report was submitted that focused on the local bottled water industry identified in the first phase of work, the geology and hydrogeology of the region and local groundwater systems, the regulatory framework in which activities are undertaken and issues raised in submissions and during consultations and site visits.

This second and final report addresses the sustainability of extraction limits and the impacts and consequences of groundwater extraction. This includes a review of how extraction limits are assessed at the macro level through the Water Sharing Plan (WSP) and locally through water access licences (WAL) and development applications; an assessment of knowledge and data gaps; and sources of uncertainty and how these are managed. An update of the entitlements of the local bottled water industry is provided having regard to total access rights, as is comment on factors influencing demand trends and growth scenarios considered by the Review. Technological approaches to managing issues of truck movements associated with the industry and plastics are provided.

1.1 BACKGROUND

The North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan (the WSP) sets out extraction limits and rules for all four groundwater sources in scope within the Northern Rivers region:

- Alstonville Basalt Plateau Groundwater Source – fractured rock aquifer
- Clarence Moreton Basin Groundwater Source – porous rock aquifer
- New England Fold Belt Coast Groundwater Source – fractured rock aquifer
- North Coast Volcanics Groundwater Source – fractured rock aquifer (Figure 1)

The Alstonville source stands in contrast to the three sources further north in the Tweed valley. The Alstonville source is the only fully allocated groundwater system of the four groundwater sources; it has higher use, and it has a network of state operated monitoring bores or piezometers. This Report analyses the monitoring data from these bores from 2006 to present.

Overall use of the other three groundwater systems, in the Tweed, is very low compared with the size of the aquifers, but monitoring data on these systems is also sparse.

For all four aquifers, the parameters used to determine the extraction limits are considered by the Review and focus is also put on local impacts and protection of features.

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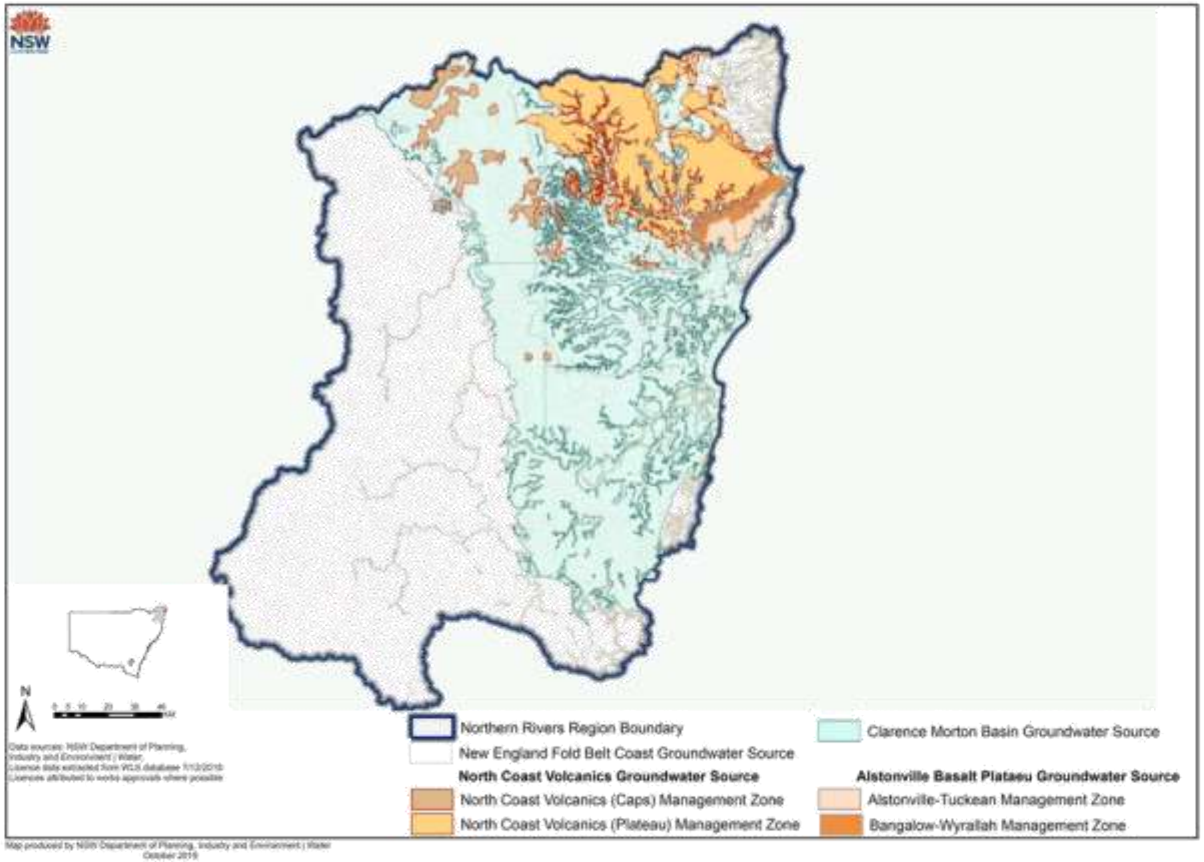

Figure 1: Map of Northern Rivers region showing boundaries of the four groundwater systems

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1.1.1 Proposal from Tweed Shire Council to prohibit water bottling facilities

In November 2018, the Tweed Shire Council resolved to prepare a planning proposal to remove clause 7.15 from the 2014 Tweed Local Environment Plan (LEP) with the intended outcome that a water bottling facility will no longer be permitted in RU2 Rural Landscape Zone (TSC, 2019b).[1]

In May 2019, a Gateway Determination allowed the amendment to the LEP to proceed subject to a set of conditions (DPE, 2019).

Tweed Shire Council put a revised proposal on public exhibition in July 2019, accepting submissions until September 2019. At the time of drafting this report, the Tweed Shire Council had not finalised the amendment to the LEP and was in the process of meeting the set of conditions set out in the Determination.

1.2 REVIEW PROCESS

1.2.1 Updated Terms of Reference

On 28 February 2019, the Review Terms of Reference were expanded to include advice on:

- scientific and technical approaches to examining socio-economic factors and impacts and possible solutions using locally relevant examples
- localised environmental consequences related to extraction for bottled water.

The full TOR are at Appendix 1.

1.2.2 Experts

The Office of the NSW Chief Scientist & Engineer (OCSE) engaged technical experts in a range of fields to assist the Review, including hydrology, groundwater, surface water, groundwater and surface water interactions, modelling, monitoring, statistics and uncertainty analysis. Experts engaged included:

- Associate Professor Will Glamore, Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney (Phase 1 and 2)[2]
- Alice Harrison, Project Engineer, Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney (Phase 1 and 2)
- Dr Mahmood Sadat-Noori, Research Associate, Water Research Laboratory, School of Civil and Environmental Engineering, UNSW Sydney (Phase 2)
- Professor Neil McIntyre, Principal Research Fellow, Centre for Water in the Minerals Industry, Sustainable Minerals Institute, University of Queensland (Phase 1 and 2)
- Dr Liliana Pagliero, Postdoctoral Research Fellow, Centre for Water in the Minerals Industry, Sustainable Minerals Institute, University of Queensland (Phase 1 and 2)
- Dist. Professor Louise M. Ryan, Professor of Statistics, School of Mathematical and Physical Sciences, University of Technology Sydney (Phase 1 and 2)

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[1] Section 7.15 of *Tweed Local Environmental Plan 2014* states, Water bottling facilities in Zone RU2 Rural Landscape (1) Despite any other provision of this Plan, development may be carried out with development consent for the purposes of a water bottling facility on land in Zone RU2 Rural Landscape if the consent authority is satisfied that development will not have an adverse impact on natural water systems or the potential agricultural use of the land. (2) Despite any other provision of this Plan, development may be carried out with development consent for the construction of a pipe or similar structure on any land for the purposes of conveying groundwater to a water bottling facility. (3) In this clause— water bottling facility means a building or place at which groundwater from land in Zone RU2 Rural Landscape is extracted, handled, treated, processed, stored or packed for commercial purposes.

[2] Phase 1 is work prior to Initial Report; phase 2 is work from Initial Report to Final Report.

Over the course of the Review, information and advice on data, policy, guidelines, monitoring, modelling and regulation, was sought from agencies with roles and responsibilities relevant to the TOR. This included DPIE Water; Water NSW; the Natural Resource Access Regulator; NSW Environmental Protection Agency; Energy, Climate Change & Sustainability (DPIE); Rous County Council, Tweed Shire Council and others.

1.2.3 Site visits and consultations

The Review made two site visits to the Northern Rivers region, in December 2018 and January 2019. These initial site visits concentrated on the areas near and around Dungay, Urliup, Murwillumbah, Uki, Mt Warning, Ballina and Alstonville. Stakeholder meetings were conducted with representatives from local government, the local community and industry. Requests for relevant reports, additional information and data, and details of other interested stakeholders were made to all stakeholders as part of these site visits and meetings. In the second phase of work, the Review Team held various consultations with community members and industry representatives.

Further details are at Appendix 2.

1.2.4 Submissions

Fourteen submissions were received over the course of the Review. Submissions are available on the website of the NSW Chief Scientist & Engineer.

1.2.5 Workshop

To inform the Review, OCSE hosted a one-day multi-disciplinary expert workshop in Sydney on 6 September 2019. The workshop brought together experts in hydrogeology, groundwater hydrology and modelling, groundwater ecology, surface water, climate modelling, geology, planning, uncertainty and statistics. Discussion encompassed:

- Science to inform extraction limits in Water Sharing Plan
- What the data from the Alstonville Basalt Plateau Groundwater Source tells us
- Assessing local impacts – hydrogeological studies
- Assessing impacts – research needs and approaches

Diverse views were presented at the workshop. However, all agreed that characterising fractured rock systems, in particular, are complex due to their heterogeneous structure and there are significant knowledge gaps in the region. High-level observations from the sessions are referred to in relevant parts of the report. A list of participants that attended the workshop is at Appendix 2.

1.3 STRUCTURE OF THIS REPORT

- Chapter 2 analyses growth trends and potential growth scenarios for the industry in the Northern Rivers region, as well as the allocations for the industry compared with overall allocations in the WSP.
- Chapter 3 addresses the TOR seeking advice on the sustainability of the extraction limits in the Water Sharing Plan.
- Chapter 4 addresses impacts and environmental consequences from the bottled water industry extraction, including impact mechanisms, the challenges to understanding impacts and consequences, how impacts are assessed and managed, and further information to assess impacts.
- Chapter 5 considers technical approaches to the socio-economic issues raised in the review, including the use of plastic bottles and truck movements.
- Chapter 6 provides findings and recommendations.

2 THE BOTTLED WATER INDUSTRY

The Review TOR include data on the bottled water industry entitlements and extractions having regard to total water access rights and WSPs; and advice on potential impacts on groundwater resources arising from current industry activities and proposed or potential expansion.

An analysis was undertaken of economic factors influencing supply and demand, which were used to develop growth scenarios to predict future growth of the industry in the region.

Consideration was also given to whether the industry has different extraction patterns to other users that could result in different extraction impacts. This chapter includes findings on industry pumping characteristics as well as monitoring and data collection undertaken by industry.

Issues specifically related to sustainability and impacts and environmental consequences are addressed in subsequent chapters.

2.1 BOTTLED WATER INDUSTRY

2.1.1 The bottled water industry supply chain

The bottled water industry extracts, manufactures and bottles spring water, mineral water, purified water and bulk water for sale (Table 1).[3] Spring and mineral water represent 75% of the bottled water market. The water is extracted from groundwater sources, processed, bottled and primarily sold through grocery and convenience stores, restaurants, bars and vending machines (IBISWorld, 2019).

Table 1: Product segments in the bottled water industry

Product segment	Description	Market share
Spring water	Sourced from underground wells and contains a unique mix of minerals based on the characteristics of the well.	50%
Mineral water	Sourced from underground wells and contains a higher concentration of dissolved salts. No minerals are added.	25%
Purified water	Generally sourced from standard town water supply. Purified to remove impurities and contaminants.	12.5%
Bulk and packaged water	Large bottled water products (>3 litres), generally sold to businesses.	12.5%

Source: (IBISWorld, 2019)
Note 1: Market share measured by reference to segment revenue versus overall market revenue.
Note 2: Bulk and packaged water suppliers source water from both standard water supply and groundwater.

The supply chain in the water bottling industry is generally divided between extractors (operators specialising in water extraction) and water bottlers (operators who process, bottle and distribute to retailers) (Figure 2). This is because most water bottlers (particularly major bottlers) outsource the extraction of water to small local operators who hold the relevant water access licences and approvals. However, some extractors also have small bottling plants.

[3] The bottled water industry typically does not include suppliers of water for soft drinks and other beverages, (for example alcoholic beverages), as this water is generally supplied from standard water supplies (for example town water).

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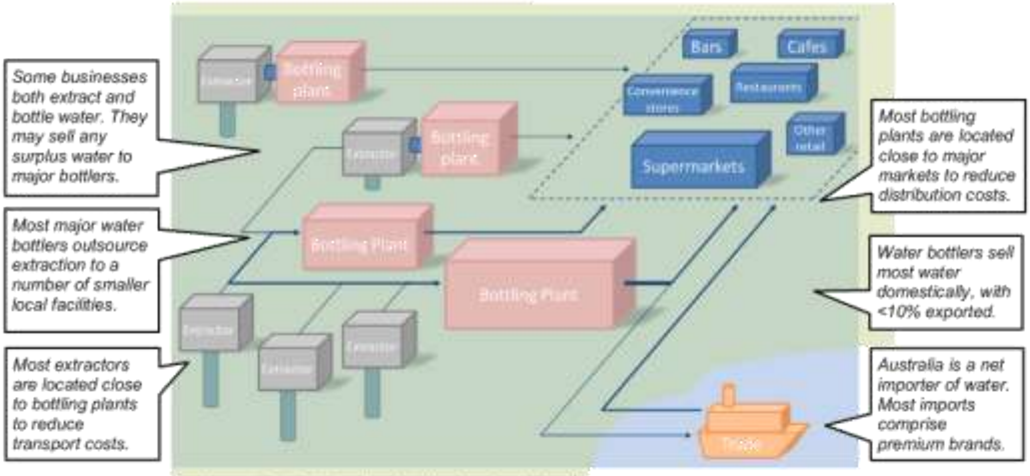

Figure 2: High level supply chain in the bottled water industry

There are approximately 50 water bottlers in Australia, of which approximately 35% are based in NSW (IBISWorld, 2019). As bottled water products are heavy and of low value relative to their weight and size, the distribution of bottled water manufacturing facilities largely reflects population distribution to minimise transportation costs, with most facilities located near major population centres. As a result, larger manufacturers will often collocate water bottling facilities with other bottling facilities (for example soft drinks) to reduce manufacture and distribution costs through economies of scale and scope (IBISWorld, 2019).

Most bottled water manufactured in Australia is sold domestically, with only 8% of revenue generated from exports (IBISWorld, 2019). Australia is a net importer of bottled water.[4] Due to the high costs of transport most of these imports comprise premium bottled water brands which charge higher retail prices. These include brands such as Evian, Voss, Fiji Water, Perrier, San Pellegrino and Vittel (IBISWorld, 2019).

Market share amongst water bottlers is highly concentrated. Coca-Cola Amatil Ltd (CCA), Asahi Holdings (Australia) Pty Ltd and Nu-Pure Pty Ltd represent approximately three-quarters of market share (IBISWorld, 2019). CCA's major spring and mineral bottled water brands manufactured in Australia include Mount Franklin, Pump, Neverfail Springwater, Peats Ridge, and Glaceau Smartwater. Asahi Holdings' major spring and mineral bottled water brands manufactured in Australia include Cool Ridge and Frantelle. However, the industry is also characterised by many small businesses, with 50% of businesses earning less than $200,000 revenue per annum (IBISWorld, 2019).[5]

Market share amongst extractors is more fragmented. Some extractors operate a network of extraction facilities across the country. There are also small extractors who operate only a single site and compete with other extractors to supply water to water bottling plants. Competition between extractors is driven by the quality and price of water that each extractor can supply. Water quality is affected by the characteristics of the groundwater source. Price is influenced by the costs of extraction, processing, transport, economies of scale and margins. Extractors are often geographically proximate to water bottling facilities to reduce transport costs.

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[4] In 2018-19, Australia imported approximately $340m of bottled water for domestic consumption and exported approximately $56.1m of bottled water for international markets. Imports have been increasing faster than exports and Australia's net trade deficit of bottled water is expected to exceed $300m by 2022 (up from $283.9m in 2018-19) (IBISWorld, 2019)

[5] Only 7% of businesses earn more than $5m per annum.

The industry reports that the manufacturing of bottled water contributes $186M to the NSW economy per annum, and supports 1,047 full time jobs.[6]

2.1.2 Performance of the bottled water industry in Australia

Between 2014 and 2018, consumption of bottled water in Australia grew at an average rate of 10% per annum by water volume, reaching approximately 1,100 ML in 2018 (Figure 3). This growth in consumption has been driven by several factors, including by consumer preferences trending towards snacks and takeaway meals (IBISWorld, 2019); water being perceived as a healthier beverage alternative to soft drinks (Asahi Group Holdings, 2019); and major grocery stores launching low cost private label bottled water products.[7]

Figure 3: Bottled water consumption in Australia
Source: 2014 to 2018 (Asahi Group Holdings, 2019)

While consumption of bottled water has grown in recent years, overall revenue of the Australian bottled water industry has not been growing. Industry revenue is expected have fallen by 0.4% per annum between 2014 and 2019 to $706.8m (IBISWorld, 2019). This reflects the fact that low cost private label bottled water brands have grown volumes at the expense of the higher priced brands.[8] Overall industry revenue is expected to be flat or grow modestly (at less than 1.5% per annum) over the period 2019-24 (IBISWorld, 2019; Statista, 2019).

2.1.3 Outlook for the bottled water industry in Australia

The Australian bottled water industry is influenced by a number of trends. The extent to which these trends will influence future production is expected to vary. Table 2 sets out the likely trends based on currently available forecasts. Based on these trends, the following section explores a range of future scenarios.

[6] Economic and employment contribution of manufacturing comprises direct manufacturing contribution of $73M and 281 FTEs, and manufacturing supply chain contribution of $113M and 766 FTEs (from activities including extraction, other manufacturing, transport, infrastructure, utilities and professional services) (ABC, 2019).

[7] While bottled water consumption has been growing, this growth has been largely concentrated in sales of private label bottled water products. Major bottled water brands have struggled to grow volumes due to this aggressive price competition from private labels (Asahi Group Holdings, 2019; IBISWorld, 2019)

[8] For example, despite growth in overall Australian bottled water consumption from 2014 to 2018, CCA has reported falling still beverage sales since 2014 and sales volume declines of bottled water of 1.7% from FY17 to FY18. See Coca Cola Amatil Full Year Results 2018 (Coca-Cola Amatil, 2019a), 2017 (Coca-Cola Amatil, 2018a); 2016 (Coca-Cola Amatil, 2017); 2015 (Coca-Cola Amatil, 2016)); and 2014 (Coca-Cola Amatil, 2019b). At the same time, sales of private label bottled water have grown from 21.2% of all bottled water sales in Australia in 2014 to 50% in 2018. However, the growth in market share of private label bottled water has also slowed significantly from 12.2% growth between 2014 and 2015, to 3.2% growth between 2017 and 2018. (Asahi Group Holdings, 2019).

Table 2: Trends influencing bottled water production

Trends impacting bottled water production in Australia	Past impact on production	Forecast future impact on production	
(a) Increasing consumer preferences for takeaway meals	▲	▲▲	Consumer preferences for takeaway meals are expected to increase as disposable incomes increase (RBA, 2019) and economies of scale reduce takeaway cost.
(b) Increasing consumer preferences for healthier beverages	▲	~	Sugar free, artificially sweetened beverage alternatives are now widely available and accepted.
(c) Increased availability of private label bottled water	▲	~	Private label availability is already high and is unlikely to increase further, evidenced by growth in private label market share having been strong (12.2% between in 2014 and 2015) but having slowed significantly (3.2% between 2017 and 2018) (Asahi Group Holdings, 2019).
(d) Population growth	▲	▲	Population growth is forecast to remain constant at 1.4-1.8% p.a. to 2027. From 2027 to 2042 population growth is expected to reduce to 0.9-1.5% p.a (ABS, 2018).
(e) Increasing international demand for Australian bottled water exports	▲	▲	Exports are forecast to continue to increase modestly, particularly if the Australian dollar remains depreciated (IBISWorld, 2019).
(f) Increasing Australian demand for imported bottled water	▼	▼▼	The trade imbalance in bottled water is forecast to grow as imports increase much faster than exports (IBISWorld, 2019).
(g) Increasing consumer awareness of the environmental impacts of plastic	▼	▼▼	Consumer awareness is expected to increase rapidly due to media campaigns and incentives (e.g. container deposit schemes) (IBISWorld, 2019).
(h) Wide availability of tap water in Australia	▼	~	Drought may impact the availability of water and reduce disposable incomes in certain communities (RBA, 2019).
(i) High quality of Australian tap water	▼	▼	Quality of Australian tap water is expected to remain high (IBISWorld, 2019).

Note: ▲ = increased production; ▼ = decreased production; ~ = no impact on production

2.1.3.1 Bottled water consumption and production scenarios

The trends set out in Table 2 were used to assess potential future growth in the Australian bottled water industry. Two scenarios were considered – the most likely ('probable') scenario and an 'unlikely' scenario using available data over the next five years to 2024. Two more scenarios are considered later in this Chapter – a 'highly unlikely' scenario and an 'extremely unlikely' scenario using available data over the next 15 years to 2034.

Scenario 1 (probable) – 2% growth per annum

Industry forecasts predict that the most likely scenario is that the Australian bottled water industry experiences modest revenue growth of approximately $11 million per annum (1.5%) over five years from 2019 to 2024 (IBISWorld, 2019). Under this scenario, growth in consumption of bottled water in Australia will slow to 2% per annum (IBISWorld, 2019). Based on the trends in Table 2, under this scenario production growth is likely to slow to less than 2% per annum; in particular because:

- Although consumption of bottled water in Australia grew at an average rate of 10% per annum by water volume between 2014 and 2018, this growth has been trending down, from 13% per annum in 2015 to 6% in 2018, and industry forecasts predict average consumption growth of approximately 2% per annum to 2024 (Asahi Group Holdings, 2019; IBISWorld, 2019).

- Low cost private label bottled water products have grown market share strongly (from 21.2% of all bottled water sales in Australia in 2014 to 50% in 2015), and driven bottled water consumption growth by aggressive price competition. However, the availability of private label products is now high, and the growth in market share of private label bottled water has slowed significantly from 12.2% growth in 2015, to 3.2% growth in 2018 (Asahi Group Holdings, 2019; IBISWorld, 2019). As a result, private labels are unlikely to drive significant consumption growth as they have done in the past.
- The trade deficit in bottled water is expected to grow as imports increase faster than exports. Growth in imported bottled water is forecast to exceed approximately $15 million per annum over five years from 2019 to 2024, while growth in exported water is expected to be more modest at approximately $3 million per annum over five years from 2019 to 2024 (IBISWorld, 2019). Therefore, growth in Australian consumption is likely to be served increasingly by imported bottled water.

At a production growth rate of 2% per annum, the market would reach approximately 1,200 ML per annum by 2024 (a 10% increase).

Scenario 2 (unlikely) – 10% growth per annum

An alternative but unlikely scenario is that growth in consumption and production of bottled water continues at 10% per annum. This scenario is unlikely because of the trends described in Table 2 and discussed above, in particular because of the slowing growth in bottled water consumption; the slowing growth in market share of private label brands; the increasing trade deficit in bottled water; the increased availability of sugar free beverages; and increased consumer concerns over plastic waste (IBISWorld, 2019).

At this growth rate, the market would reach approximately 1,900 ML per annum by 2024 (a 70% increase). Under this scenario, Australia's per capita consumption of bottled water would not reach that of the United States until 2034. The United States has one of the highest levels of bottled water consumption per capita amongst developed economies – four times greater than Australia (Figure 4).

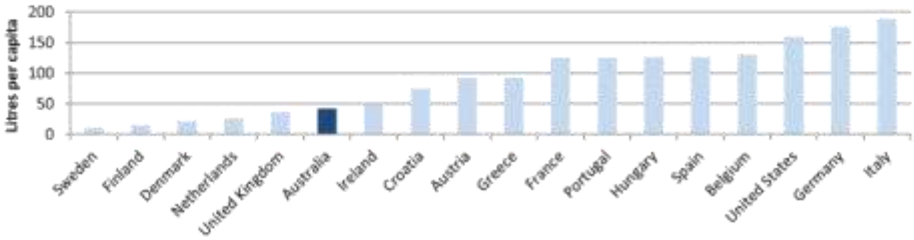

Figure 4: Consumption of bottled water in 2017 in developed economies
Source: (Beverage Marketing Corporation, 2018; Asahi Group Holdings, 2019; EFBW, 2019)

This scenario is also unlikely to occur in Australia because many of the factors that influence high consumption in certain developed economies (e.g. Italy, United States, Germany and France) are not present in Australia. These factors include that:

- High quality tap water is widely available in homes, restaurants, bars and workplaces in Australia. Many other countries do not have high quality tap water or do not offer free tap water in bars and restaurants, and other public spaces (IBISWorld, 2019).
- Many of these other countries have major premium international bottled water brands, such as Evian in France and San Pellegrino in Italy. These brands contribute to increased consumption in those countries through consumer loyalty.

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It is also important to note that consumption in many of these markets appears to have reached saturation and growth has peaked. For example, Italy and Germany have experienced bottled water volume growth of only 0.1% and 0.7% respectively from 2012 to 2017 (Beverage Marketing Corporation, 2018). This suggests that there is an effective limit on consumption volumes, even in high consumption markets. This is theoretically sound since consumers can only drink a certain amount of water per day.

Under this scenario, where growth continues at 10% per annum until Australian annual consumption reaches a limit of 160 L per capita (equivalent to the United States), the bottled water market would reach approximately 4,500 to 5,000 ML per annum (depending on population growth). Assuming that the percentage of Australian bottled water demand met by imports remains constant, this would represent an approximately five fold increase in Australia's bottled water production by 2034.

2.1.4 The bottled water industry in the Northern Rivers region of NSW

The Review has identified seven operators, with allocations totalling 240.5 ML/y, that are actively extracting for water bottling purposes from four groundwater sources in the Northern Rivers region (Table 3).[9] In addition to these, the Review also identified:

- two operators that have had their development applications approved but are not yet extracting,
- one application to expand existing operations progressing through the development application process,
- one application that has had the development application refused.

These four proposals, if approved and actioned, would amount to additional extraction volumes of 168 ML/y across the four groundwater sources (Table 3). The Review also identified one application which had been progressing through the development application process but was subsequently withdrawn.

Table 3: Water licences associated with existing and proposed water bottling

Groundwater source	Water licences associated with the bottled water industry (ML/y)	Water licences associated with proposed expansions in bottled water industry (ML/y)
Alstonville Basalt Plateau (fractured)	7.5	-
Clarence Moreton Basin (porous)	50	100
New England Fold Belt Coast (fractured)	163	68
North Coast Volcanics (porous)	20	-

Water licences associated with the current and proposed future expansions in the bottled water industry represent a very small portion of the overall water requirements[10] from groundwater sources in the Northern Rivers region (Figure 5). These licences represent an even smaller portion of total groundwater recharge in the Northern Rivers region, as most groundwater recharge is reserved for the environment or is not licenced (Figure 6).

[9] The Review identified active and proposed water bottling operations in the Northern Rivers region through a search of secondary sources, including local council development applications and related documents, internet searches and information from state agencies, the community and councils. This is because the public water access licence registers (for example, the NSW Water Register and the NSW Water Access Licence Register) do not record the purpose of each licence.
[10] 'Requirements' is a term used in the WSP, which is the sum of the estimated basic landholder rights, town water supply and all other licenced entitlements (ML/yr).

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Figure 5: Water requirements in the Northern Rivers region by groundwater source

[a] Potential future water requirements includes proposals for water extraction for water bottling where the proponent (1) has already obtained water allocations or works approval; and (2) is seeking, or has indicated that they will seek a development application, or will commence operation. This analysis assumes that no additional non-bottled water industry water requirements are created – however if this occurred, then the fraction of water requirements associated with the water bottling industry would be even smaller.

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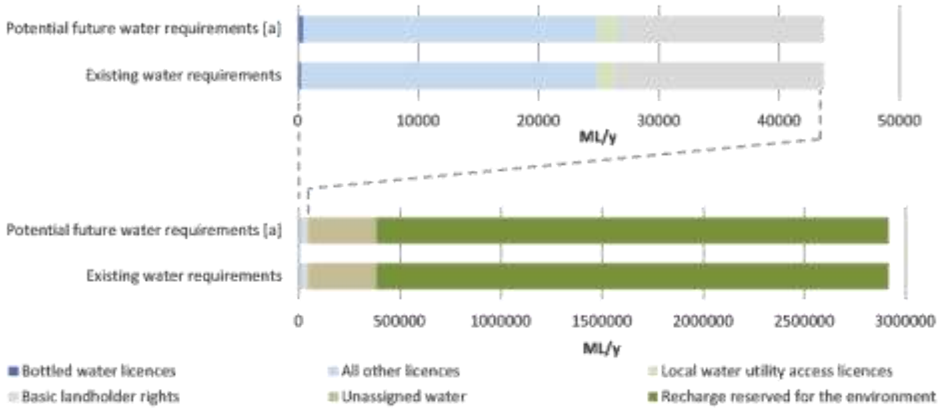

Figure 6: Water requirements, unassigned water, and groundwater recharge reserved for the environment in the Northern Rivers region
[a] See note [a] at Figure 55 above.
Note: Northern Rivers region comprises Alstonville Basalt Plateau, Clarence Moreton Basin, New England Fold Belt Coast, and North Coast Volcanics groundwater sources

2.1.5 Outlook for the bottled water industry in the Northern Rivers region

Based on the scenarios described above for potential future growth in the Australian bottled water industry,[11] forecasts have been made for growth in the bottled water industry in the Northern Rivers region to 2024 and 2034. These forecasts assume that growth rates are likely to be evenly distributed across Australia close to major population centres, and are unlikely to be concentrated in a single region. Bottled water products are bulky and low value relative to their weight and size, and therefore incur relatively high transport costs. Extractors and water bottlers are close to major population centres to reduce these costs through economies of scale in both production and transport (IBISWorld, 2019). For this reason, most large water bottlers have processing facilities across Australia near major capital cities. It is likely any future expansion in the bottled water industry would also be undertaken at multiple sites close to major markets to minimise distribution costs.

As a result, the rate of growth of the bottled water industry (including production and extraction) in the Northern Rivers region is unlikely to significantly exceed the rate of growth bottled water consumption in nearby markets. Furthermore, if the bottled water industry in the Northern Rivers region obtains significant additional water allocations beyond future local demand for bottled water, it is likely that these allocations would not be fully utilised, or would offset existing uncompetitive extraction – under the probable (*Scenario 1*) and unlikely (*Scenario 2*) scenarios discussed below.

2.1.5.1 Forecast groundwater extraction by the bottled water industry to 2024

Scenario 1 (probable) – 2% growth per annum to 2024

As discussed, the most likely scenario for growth in bottled water production in Australia is that it is likely to slow to less than 2% per annum, representing a 10% increase to 2024 (*Scenario 1*). Based on this forecast, and assuming that the 240.5ML/y of water allocated to the current bottled water industry in the Northern Rivers region are fully utilised, then 2% growth in demand for water extraction is likely to be approximately 265 ML/y by 2024 (Figure 7).

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[11] Note: scenarios considered were Scenario 1 (probable) – 2% production growth per annum, and Scenario 2 (unlikely) – 10% production growth per annum.

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Under this scenario, the 168 ML/y of water licences associated with proposed expansions in the bottled water industry are well in excess of the approximately 25 ML per annum necessary to meet anticipated demand in 2024. Therefore, these water licences would likely be underutilised and/or offset approximately 145 ML/y of water licences associated with the existing bottled water industry in the region (Figure 7).

Scenario 2 (unlikely) – 10% growth per annum to 2024

An unlikely scenario would be that growth in the bottled water industry in the Northern Rivers region will be 10% per annum, representing a 60% increase to 2024 (*Scenario 2*). Under this high growth scenario, the 168 ML/y of water licences associated with proposed expansions in the bottled water industry will still be sufficient to fully meet growth in demand of approximately 150 ML/y in the region by 2024 and no additional expansions would be expected (unless they offset existing extractions) (Figure 7).

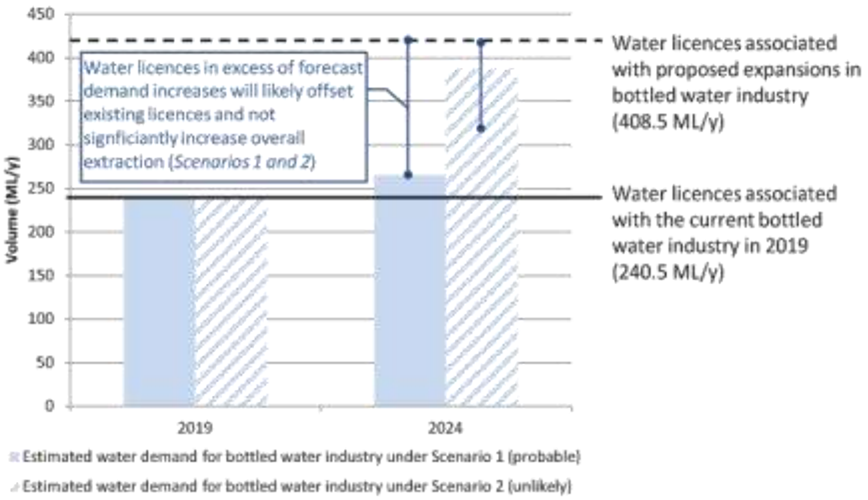

Figure 7: Bottled water industry growth scenarios 1 (probable) and 2 (unlikely)

2.1.5.2 Highly unlikely and extremely unlikely groundwater extraction scenarios to 2034

While the expected growth in the bottled water industry in the Northern Rivers region is expected to be modest to 2024 (see *Scenario 1*), it is useful to consider the impact of highly unlikely scenarios where the industry experiences high growth over a long timescale. These scenarios assist in understanding the theoretical limits on the industry in this region. Two extreme growth scenarios are considered:

- *Scenario 3* is highly unlikely and considers the impact of 10% growth per annum in the bottled water industry in the Northern Rivers region until 2034, under this scenario the growth rate of *Scenario 2* continues an additional 10 years.
- *Scenario 4* is extremely unlikely and considers the impact of a major bottled water exporter being established in the Northern Rivers region.

The impacts of *Scenario 3* and *Scenario 4* are analysed below.

Scenario 3 (highly unlikely) – 10% growth per annum to 2034

Scenario 3 assumes that the bottled water industry in the Northern Rivers region grows at 10% per annum, reaching approximately 1,000 ML/y in 2034, but does not exceed this level (Figure 8). Under this scenario, Australian bottled water consumption peaks at four times

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current volumes in 2034 – similar to current per capita consumption volumes in the United States (Figure 4).[12] This scenario also adopts the same assumptions as those in *Scenarios 1* and 2: that growth rates are likely to be evenly distributed across Australia close to major population centres, and are unlikely to be concentrated in a single region.

Scenario 4 (extremely unlikely) – a major bottled water exporter is established in the region

Although the size of the bottled water industry in a region is generally influenced by bottled water consumption in nearby markets, there are a number of international premium bottled water brands that extract water from groundwater sources in a single area, and bottle and distribute it to international markets.[13] This scenario assumes that a major premium bottled water brand is established and that it:

- obtains the necessary licences and approvals to extract water from groundwater sources in the North Rivers Region,
- extracts solely from sources in this region to satisfy its entire customer demand,
- establishes world leading brand recognition and availability in multiple major global markets (e.g. Europe, the Americas, Asia, the Middle East),
- overcomes well-established international competitors to build up significant market share, and
- becomes one of the world's largest producers of bottled water.

If a brand were able to overcome all of these hurdles, this process would take many years. Most premium bottled water brands exporting to international markets have long histories (San Pellegrino, 2019; VOSS, 2019). This is because it takes a significant amount of time to build up an international brand identity that can charge a premium necessary to cover the cost of large scale distribution to international markets.

Evian is one of the largest bottled water brands in the world and sells premium bottled water in more than 140 countries (Danone, 2019). The company has extracted and sold water from groundwater sources near a single bottling plant in Evian-les-Bains in France since 1826 (Evian, 2017). Evian produced 1,441 ML of bottled water in 1999 (Danone, 2000). Assuming this scenario occurred, and a brand of the scale of Evian (i.e. of approximate production of 1400 ML/y) was able to be established, it would still represent a small fraction of groundwater extraction, unassigned water and total estimated groundwater recharge in the region (Figure 8).

[12] Bottled water consumption per capita in the United States is currently four times greater than Australia. This scenario models a four-fold increase in Australian consumption volumes – equivalent to a 3.2-fold increase in Australia's per capita consumption plus forecast population growth in Australia to 2034.
[13] For example, Evian in France, San Pellegrino in Italy, and Voss in Norway.

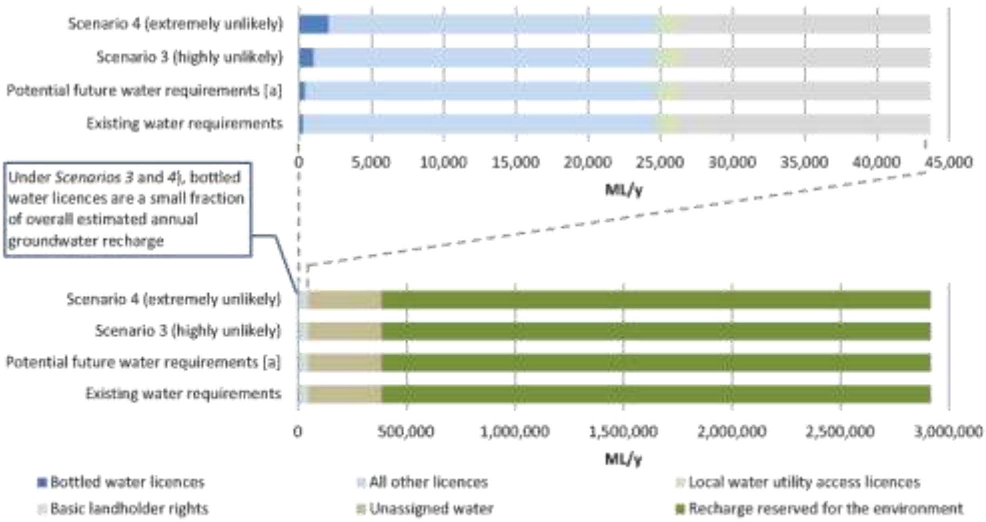

Figure 8: Bottled water industry growth scenarios 3 and 4
Note 1: Northern Rivers region comprises Alstonville Basalt Plateau, Clarence Moreton Basin, New England Fold Belt Coast, and North Coast Volcanics groundwater sources.
Note 2: For *Scenario 4*, this analysis assumes that the impact of a newly established bottled water plant producing 1,400 ML/y would result in an increase in extraction volumes by an additional 1,610 ML/y.[14]
[a] See note [a] at Figure **5**5 above.

2.1.6 Policy and regulatory interventions

The bottled water industry is subject to local council[15] and NSW Government[16] policy, planning and regulatory requirements. These are discussed in detail at Appendix 4 of the Initial Report. It is not possible to forecast possible future changes in laws or regulations which impact groundwater extraction. While regulatory intervention may directly or indirectly restrict groundwater extraction for water bottling in particular areas, these restrictions would be unlikely to impact underlying consumer demand for bottled water or overall bottled water consumption.

[14] As a conservative assumption, this analysis assumes a Water Use Ratio of 1.46L/L (WUR, the litres of water including product water used to make one litre of bottled water) and assumes 30% of the additional water required to produce 1,400 ML/y of bottled water is extracted groundwater, and that the remaining additional water comes from other sources. The WUR for the bottled water industry is 1.32L/L in North America and 1.46L/L internationally (Antea Group, 2015). Note that the Australian bottled water industry anecdotally reports lower WURs. The WUR includes all water used by the facility, including product water, and water used for facility processes (e.g., treatment, cleaning, maintenance).
[15] Local councils can indirectly control the volume of water extraction in their local government areas (LGAs) through restrictions in the development consent, for example, by imposing limits on truck movements. Local councils can also (within limits) control the types of businesses in certain zones through the terms of the relevant LEP, which govern the conditions and types of development that can occur in their LGAs.
[16] The NSW Government, through the *Water Management Act 2000* and WSPs, controls the volume and manner of water extraction from particular groundwater sources. These instruments also regulate the water licencing, allocation and trading process with the objective of ensuring the economically efficient allocation of water to the commercial uses of highest economic value. These instruments also establish priorities between environmental, domestic and stock, and industrial and commercial extraction in particular groundwater sources. However, within the category of industrial and commercial extraction there is no distinction made between the purposes of the groundwater extraction. As a result, the laws and regulations do not incentivise or disincentivise water extraction for water bottling over extraction for other commercial purposes (for example, farming, other manufacturing).

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2.2 WATER ENTITLEMENTS FOR BOTTLED WATER FACILITIES IN THE NORTHERN RIVERS

The Initial Report outlined challenges in determining the scope of the bottled water industry, in part due to commercial water access licences specifying allowable extraction rates and not the intended use of the extraction. Other means, including sourcing and reviewing development applications and consents, are required to confirm if groundwater extraction is being used for bottled water.

Table 5 provides an updated overview of the total available water for all purposes by groundwater source. It includes landholder rights and entitlements, as well as an estimate of the water entitlements held by the bottled water industry in the Northern Rivers area. It is emphasised that Table 5 provides a summary of the licence *entitlements*, not a record of *actual* water taken. It also does not reference any additional restrictions imposed on water take imposed through the development consent or any self-imposed limits on water take, so it is likely to overestimate actual water extraction. The Review is aware of several examples where the licence entitlement is higher than the allowable extraction through the development consent; this table reflects the entitlement volume only.

This section examines the volume of existing and proposed total licence allocations for the bottled water industry against the total water requirements, including all licences and basic landholder rights, for each of the four groundwater sources. The percentages of existing and proposed licences used for the bottled water industry for each sources is at Table 4. Under the WSP, environmental water and Basic Landholder Rights are given priority over licensed water extraction. Among licensees, priority is given to water utilities and licensed stock and domestic over commercial licensed purposes.

Table 4: Existing and proposed bottled water licence entitlements as a proportion of total water requirements (including licenced extraction and BLR) by groundwater source

Groundwater source	Existing	Existing and proposed
Alstonville Basalt Plateau	0.1%	0.1%
Clarence Moreton Basin	1.0%	3.0%
New England Fold Belt Coast	0.7%	1.0%
North Coast Volcanics	0.3%	0.3%

Figure 9 illustrates the total estimated annual aquifer recharge for each relevant groundwater source in the WSP, the amounts of the recharge that are reserved for the environment in the WSP and the long-term annual average extraction limit (LTAAEL), including the breakdown by licence, Basic Landholder Rights and unassigned water. This figure does not consider the Upper Extraction Limit (UEL), which in the case of the New England Fold Belt Coast and the North Coast Volcanics, as shown in Table 5, are higher than the LTAAEL.

In the case of the New England Fold Belt Coast and the North Coast Volcanics, the vast majority of the recharge is reserved for the environment (97% and 96% respectively), with only a small proportion that can be allocated to licences. This is because the LTAAEL for these water sources is set as the current entitlement plus estimated future water entitlements for the term of the plan rather than as a percentage of recharge. In these water sources the percentage of recharge protected from extraction (75%) is defined in the UEL. For Clarence Moreton Basin, the amount reserved for the environment is 48% of the recharge, but for this groundwater source, only 1.7% of the amount which can be allocated for licences is allocated. For Alstonville, 82% of the recharge is reserved for the environment, but the remainder that is available for licences is fully allocated. The total volume of storage of the four aquifers is fully reserved for the conservation of the groundwater system.

Of the recharge that is not reserved for the environment (i.e. the LTAAEL in the case of these four aquifers), some is allocated to Basic Landholder Rights and licences, while the remainder remains unassigned water. At present, approximately 38.0% of LTAAEL in the New England Fold Belt Coast is allocated, 51.3% of the North Coast Volcanics and 1.7% in the Clarence Moreton Basin is allocated. Alstonville is fully allocated. A fraction of these allocations are for licences for the bottled water industry (Table 4 and Table 5).

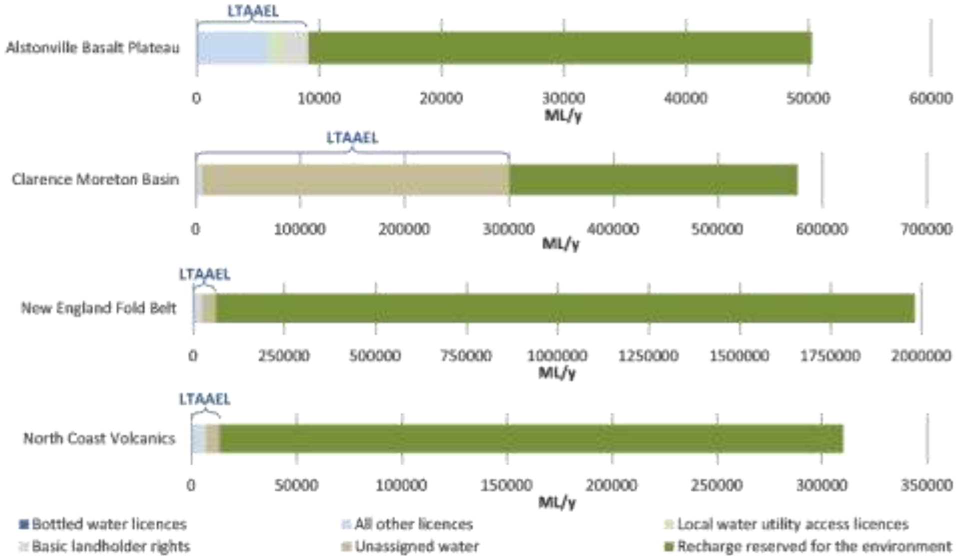

Figure 9: Breakdown of total estimated annual aquifer recharges in the Northern Rivers region by water requirements, unassigned water, groundwater recharges reserved for the environment and LTAAELs

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Table 5: Available water, extraction limits and requirements by purpose and groundwater source (updated October 2019)

Groundwater Source	A (ML) Estimated Total Aquifer Storage [1,a,k]	B (ML/yr) Estimated total annual aquifer recharge [3]	C (ML/yr) Recharge amount reserved for environment [3,a]	D (ML/yr) Upper Extraction Limit (UEL) [2,3]	E (ML/yr) LTAAEL [2,3,c]	F (ML/yr) Un-assigned Water [3,4]	G (ML/yr) Total requirements (BLR and licences)	H (ML/yr) Basic landholder rights (BLR) [2,3,d]	I (ML/yr) Local water utility access licences [4]	J (ML/yr) All other aquifer access licences [l]	K (ML/yr) Bottled Water Licences (Existing Industry) [e,f]	L (ML/yr) Bottled Water Licences (Proposed Industry) [f,g]	M Total no. water access licences (WALs) [4,k]
Alstonville Basalt Plateau	640,000	50,079	41,184	na	8,895	0[h]	9,086[h]	2,014	1,230	5,842[h,i]	7.5	0	192
Clarence Moreton Basin	na	576,000	276,000	na	300,000	294,847	5,153	2,341	31	2,781[l]	50	100	136
New England Fold Belt Coast	24,000,000	1,980,000	1,920,000	375,000	60,000	37,227	22,773	9,605	240	12,928[l]	163	68	558
North Coast Volcanics	4,380,000	310,000	297,000	55,000	13,000	6,327	6,673	3,402	0	3,271[l]	20	-	205
Relationship between columns		*B=C+E*	*(C=B-E)*	*D*	*E*	*F =E-G*	*G=H+I+J*				*Subset of J*	*Subset of J*	

Sources and notes:

1 Estimated based on total area, porosity, average saturated thickness of source (EMM, 2018)
2 WSP NCFPR (July 2016)
3 WSP NCFPR – Background document (Sept 2016)
4 NSW Water Register https://waterregister.waternsw.com.au/water-register-frame - data used is from 19/20 year for each groundwater source
5 Supplied by DPIE Water (DOI Water, 2019)
a. Sources 2 and 3 define Planned Environment Water as equal to the total recharge minus the LTAAEL plus the portion of storage not available for extraction. At the commencement of the WSP NCFPR, 100 percent of groundwater storage is reserved as planned environmental water.
b. Reserved as part of Planned Environment Water – allocations made only on recharge
c. LTAAEL is long-term average annual extraction limit.
d. BLRs comprise domestic and stock but do not include volumes for Native Title Rights due to difficulty predicting volumes used
e. Column K is based on the full volume of a licence entitlement where all or part of that licence may be extracted for bottled water. This number does not reflect any other restrictions on the licences, e.g. through development consent conditions or voluntary etc.
f. Due to difficulty in confirming bottled water industry participants, there may be some small extractions captured in 'all other aquifer licence entitlements' column J that are not yet captured in columns K and L.
g. Under Column L, WALs, water supply approvals or general terms of approval may have been issued; and there is some indication in the public domain of either works approval or development application in process to start/expand extraction.
h. There is no unassigned water in Alstonville Basalt Plateau Groundwater Source. The total requirements do not represent actual take. When considering AWDs, actual water take is assessed against LTAAEL to determine volume or percentage of unit share.
i. DoI Water noted that two licences were handed back to the Water Administration Ministerial for a total of 10 ML/yr. The figure reflects this (DOI Water, 2019)
j. The WSP NCFPR (2016) reflects unassigned water as LTAAEL minus total requirements (p. 35). This method is used with updated figures.
k. Includes Water Utility Licences
l. Total Share Component

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2.3 REGULATION AND CHARACTERISTICS OF EXTRACTION

There is a requirement for all food for sale in NSW, including bottled water, to be safe and suitable for human consumption.[17] Bottled water also is subject to the Australian New Zealand Food Standard Code.[18] The Code defines bottled water (the term 'packaged' water is used), its composition and labelling requirements. Bottled water is required to comply with certain limits on with microbiological and chemical contaminants, toxicants and processing aids. For example, the Code specifies a microbiological limit for packaged water, whereby *E. Coli* should not be detected in a sample of 100mL of water.[19]

Although, the Code requires that the bacteriological and physical quality of bottled water comply with these criteria, it does not specify frequency of analysis. However, if samples are found to be contaminated or exceed limits specified in the Code, then appropriate action would be taken by the manufacturer or the relevant regulatory agency. As the Code applies nationally but is enforced locally, the responsible agency will vary in each case but may be the local council, the NSW Food Authority or interstate agencies.

2.3.1 Australasian Bottled Water Institute Model Code

Some members of the bottled water industry within the Northern Rivers region are members of the Australian Beverages Council (ABC), which is an industry body representing the non-alcoholic beverage industry. The Australasian Bottled Water Institute (ABWI), a division of the ABC has developed a Model Code with guidelines relating to quality and safety, including Good Manufacturing Practices (GMP) (ABWI, 2018).

Members of the ABWI are required to comply with certain provisions of the Model Code when producing bottled water. The Code specifies key testing requirements relating to the extraction of water, the transport of water, and the processing of water to minimise the risk from biological, chemical or physical contaminants. In relation to water extraction, the Code also requires that a review be undertaken by a hydrogeologist that demonstrates the integrity of the source and the safety of the catchment operations. This review should also include (ABWI, 2018):

> *"(a) An evaluation of the chemical, physical, microbiological, and radiological characteristics of the source.*
>
> *(b) A report on the regional geology surrounding the site and the specific site geology … to define the recharge area of the aquifer, or in the case of regional aquifers, the zone of influence of the subject source.*
>
> *(c) A report detailing the development of the source …*
>
> *(d) A watershed survey of the recharge area or zone of influence of subject source that identifies and evaluates actual and potential sources of contamination, including any reported discharge that may affect the source.*
>
> *(e) Based on the findings in item (d), a plan for special monitoring of any significant contaminant source and for taking restrictive preventive or corrective measures as appropriate to protect the source water."*

In addition to this hydrogeology review, other tests are required including microbiology tests (for example, for Coliforms, and/or *E. Coli,* yeasts and moulds) and chemistry tests (physical, radiological, inorganics, organics and volatile organics). Testing frequency varies from weekly to every four years (ABWI, 2018).

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[17] *Food Act 2003*, s 3(a).
[18] *Australia New Zealand Food Standards Code*. Standard 2.6.2 Non-Alcoholic Beverages and Brewed Soft Drinks
[19] *Australia New Zealand Food Standards Code* – Schedule 27 – Microbiological limits in food, cl 4.

2.3.2 Characteristics of bottled water extractors

It appears that extractors in the bottled water industry in the Northern Rivers region are using bores which range from a depth of approximately 25 to 90 metres, but more typically range from 30-50 metres.[20] In contrast, stock and domestic bores tend to be shallower as they are generally sunk until water is reached (to minimise costs of drilling and construction). Anecdotally, the Review was advised the purpose is to draw from deeper aquifers to attempt to minimise or avoid interaction with surface water and other shallower bores. Interaction between groundwater sources and surface water can have negative impacts on water quality and quantity.

2.3.2.1 Managing water quality

As discussed, the bottled water industry is subject to the Food Standards Code which regulates the safety and quality of the water. Some operators are also subject to obligations under the ABWI Model Code which control the extraction, transport and processing of bottled water. However, groundwater extractors supplying water bottling plants also have direct commercial incentives in monitoring the quality of their product to ensure that it is of sufficient quality for sale. Unsafe or contaminated water poses issues of legal liability and brand reputation for the extractor and bottled water producer.

Groundwater from depth is generally microbiologically safe and chemically stable, however, contamination of the groundwater bores can still occur. Sources of contamination can include seepages associated with septic tank discharges (potentially introducing pathogens and nitrates), agricultural practices (potentially introducing pathogens, nitrates and pesticides) and industrial wastes (NHMRC & NRMMC, 2011). Contamination can also occur from natural sources including water flowing into the target aquifer from a connected aquifer that has different physical or chemical characteristics. If interference from other sources causes the water quality to change, the water may no longer be suitable for sale for bottling. For example, a connection between a groundwater source and an *E. Coli* contaminated surface stream could contaminate groundwater water for bottling purposes.

2.3.2.2 Managing water quantity

In addition to ensuring water is free from contamination, bottled water extractors have a commercial interest in ensuring a steady supply of water to meet contractual obligations and/or manage commercial risk. Sustainable extraction requires that groundwater levels recover during and after pumping.

The Review received anecdotal information that suggested that bottled water extractors were generally extracting water at an approximately evenly spaced production rate year-round compared with many other commercial users who extract on a more periodic basis. While theoretically sound given supply chain arrangements in the bottled water industry, the Review was not able to independently verify these observations. Further, all groundwater extractors are subject to changing environmental conditions which may influence future patterns of use.

As part of the pump testing requirements, extractors are required to conduct assessments on groundwater levels, pumping rates, drawdown and recovery, and water quality. Conditions of licence also require the collection of information about water extraction volumes and rates of extraction.[21] The implementation of the NSW Non-Urban Water Metering Policy (DOI, 2018b), with specific requirements around groundwater metering for groundwater extraction works over a specified size, will provide improved information about use patterns in the bottled water industry and enable analyses to be undertaken on interactions and impacts.

[20] Strictly, the depth at which the bore casing is slotted defines the depth of the extraction, however this tends to be close to the bore depth.
[21] Conditions of licences are discussed further in Section 4.5.1

2.4 CONCLUSIONS

The industry

- Available industry data indicates that across Australia, over three-quarters of bottled water is sourced from underground wells, and the remainder from standard reticulated water supplies. Approximately 8% of Australian bottled water production is exported.
- The Review identified seven operators in the Northern Rivers region with allocations of 240.5 ML/y who are actively extracting for water bottling purposes, representing 0.55% of water licences and basic landholder rights (together defined in the WSP as 'total water requirements') and 0.008% of estimated total annual aquifer recharge in the four groundwater sources.
- Four further proposals, if approved, would amount to an additional 168 ML/y, being an additional 0.38% of estimated total water requirements and 0.006% of total annual aquifer recharge.
- Changing consumer preferences, trade imbalances, the availability of tap water and private ('no name') brands and population growth are expected to impact future bottled water production and consumption volumes.
- Scenario analyses conducted by the Review suggest the Australian bottled water industry is most likely to grow at a rate of less than 2% per annum to 2024 and that growth in the Northern Rivers region is likely to be consistent with this trend. Under most scenarios to 2024 considered, the 168ML/y of additional proposed bottled water operations would be sufficient to meet fully projected growth in demand.
- The Review also considered 'highly unlikely' and 'extremely unlikely' scenarios to 2034, being growth continuing at the current rate of 10% per annum and establishment of a major premium bottled water exporter in the Northern Rivers, respectively.
  - If the 'highly unlikely' scenario occurred, the bottled water industry would represent less than 2.3% of 'total water requirements' and 0.034% of estimated total annual aquifer recharge.
  - If the 'extremely unlikely' scenario occurred, the bottled water industry would represent less than 4.6% of 'total water requirements' and 0.069% of estimated total annual aquifer recharge.
- As the scenario analyses considered an unchanged regulatory and policy environment, these forecasts may be affected by regulatory intervention which directly or indirectly impacts the bottled water industry in this region.
- For the purposes of water extraction licensing, the bottled water industry is treated the same as other prospective commercial users. However, development consent under the *Environmental Planning and Assessment Act 1979* is required for water bottling activities. Approvals for bottled water extraction in the Northern Rivers region identified by the Review date from 1993.

Water entitlements and allocations

- The WSP determines the allowable extraction limit, set from the recharge value of each aquifer, with an amount of the recharge reserved for the environment and the reminder determining the UEL or the LTAAEL.
- Under the North Coast Fractured and Porous Rock Water Sharing Plan (WSP), environmental water and basic landholder rights are given priority over licensed water extraction. Among licensees, priority is given to water utilities and licensed stock and domestic over commercial licensed purposes.

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- At the commencement of the WSP for the four groundwater sources, 100% of storage is reserved for the conservation of the groundwater system.
- Water available for extraction is a portion of the estimated recharge value for each groundwater source. This is determined by the WSP. An amount of the recharge is reserved for the environment. The amount reserved for the environment equates to 97% of the estimated recharge value for New England Fold Belt Coast, 96% for North Coast Volcanics, 82% for Alstonville Basalt Plateau and 48% for Clarence Moreton Basin.
- The remaining amounts can be allocated for licensed purposes. Of these amounts, 38.0% of the New England Fold Belt Coast is allocated, 51.3% of the North Coast Volcanics and 1.7% in the Clarence Moreton Basin. Alstonville is fully allocated.
- These are average values over the groundwater source areas, which means that the environment is not protected to these levels in locally impacted areas.

Characteristics of extraction

- The Review received anecdotal information suggesting that bottled water extractors were generally extracting water at an approximately evenly spaced production rate year-round compared with other commercial users who extract on a more periodic basis. The Review was not able to verify these observations.
- All groundwater users are subject to future changing environmental conditions, which may influence their future patterns of use.
- The implementation of the NSW Non-Urban Water Metering Policy will provide information about use patterns in the bottled water industry and enable analyses of interactions and impacts.

3 SUSTAINABILITY OF EXTRACTION LIMITS IN THE WATER SHARING PLAN

This Chapter reports on the analysis of how sustainability is assessed and managed under WSPs, and the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* (the WSP) in particular.

The *Water Management Act 2000* makes provision for WSPs to be developed which apply to groundwater and surface water systems in NSW and to implement the overall objective of the Act of "sustainable and integrated management of the State's Water" (DLWC 2001).

The WSP sets extraction limits and rules about groundwater extraction for the four groundwater sources in scope of this review based on multiple factors. These factors include groundwater recharge, a risk assessment, planned environmental water and current and future water requirements (including Basic Landholder Rights and licenced entitlements).

Groundwater sustainability relates to limiting the current (environmental and anthropogenic) use of the resource to ensure long-term water security in an aquifer. Short-term changes in an aquifer (e.g. water level declines) do not necessarily indicate unsustainable use due the variability of these natural systems which are inherently dynamic. As such, understanding the impact of groundwater extractions on long-term sustainability of an aquifer can be a complex issue even when substantial data is available.

The extraction limits in the WSP are designed to ensure the sustainable on-going use of the groundwater resource. The aim of this chapter is to understand whether the extraction limits adopted are considered 'sustainable' for the entire groundwater source. However, potential local scale social, environmental or economic effects are also important. These additional considerations are considered separately in Chapters 4 and 5.

This Review considers the impact of uncertainty arising from the variables used to determine extraction limits, particularly the recharge rates which ultimately drive the limits in the WSP, and compares the values to those available for comparable aquifers, as well as alternative methods of calculating recharge. A hypothetical scenario is also presented in this section, in which the impact of reducing the recharge rate by 80% is considered to illustrate the impact of the rate on sustainable groundwater extractions.

For most of the groundwater sources considered in this review, groundwater extraction per year is relatively small compared to the total size of the groundwater source and monitoring data is sparse. The exception to this is in the Alstonville Plateau which has a high (relative to its size) annual extraction, but is also equipped with a network of state operated monitoring piezometers or bores. This section analyses the available monitoring data from 2006 to present to assess the general levels of the aquifer and provide commentary on whether this data can be used to assess the sustainability of current groundwater extractions.

3.1 EXTRACTION LIMITS UNDER THE WSP

The Review's Initial Report included the legislative and policy framework under which water sharing plans are developed, operationalised and reviewed, including that for the Northern Rivers region, and the Initial Report also described the technical approach to assessing and determining extraction limits under the WSP. For convenience, relevant components are reproduced in Appendix 3 of this report. This Section describes the Review's analysis of the use of WSPs as regional water management tools, how sustainability is conceptualised and integrated into the WSP and how the impact of the WSP is monitored, reviewed and can be amended as part of an adaptive management approach.

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3.1.1 WSPs as regional water management tools

WSPs support the regional scale implementation of the objectives of the *Water Management Act 2000: "to provide for the sustainable and integrated management of the water sources of the State for the benefit of both present and future generations"*.[22] Generally, each WSP for groundwater will cover a number of different regional groundwater sources. Management zones within certain groundwater sources may be defined where specific access and trading rules are required to control extraction and prevent localised impacts in sensitive areas. An example of this is the Alstonville Basalt Plateau Groundwater Source which is comprised of the Alstonville-Tuckean Management Zone and the Bangalow-Wyrallah Management Zone.

WSPs are influenced by a number of other legislative instruments and policies guiding the management of water in NSW. These include:

- The *Water Management Act 2000:* which governs the management and extraction of water in NSW.[23]
- The *Access Licence Dealing Principles Order 2004:* which provides guidance and rules for water access licence dealings which are reflected in the WSPs.
- The National Water Initiative: an intergovernmental agreement to implement "*a nationally-compatible, market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes*". The NWI relates to water management elements including water access entitlements, environmental and other public benefit outcomes, adaptive management, risk management, managing over allocation, regional variability and allocation decisions.
- The Standard for Quality Natural Resource Management: developed by the Natural Resource Commission to inform natural resource management (including monitoring, evaluation and reporting arrangements) at all scales in NSW including state, regional, catchment and local level.
- Catchment Action Plans: which are non-regulatory plans prepared by Local Land Services jurisdiction that set a strategic direction for the sustainable use and care of natural resources in each region.
- DPIE Water is leading the development of Regional Water Strategies for each of 12 regions across NSW. The strategies will inform plans and management of a region's short and long-term water needs. They look at how much water a region will need to meet future demand and determine ways to manage risk to water availability and security. They will incorporate new data to improve understanding of climate risk, including consideration of climate change and the probability of extreme events.
- Other water planning policies and guidelines developed by NSW Government agencies which support the development and implementation of WSP plans and guide critical aspects of water management including WSP rule changes (DOI, 2018c), consultation (DPI Water, 2015), licensing (DOI, 2018a), assessment (WaterNSW, 2017), and metering (DOI, 2018b).

Most of these legislative instruments and policies apply on a state-wide basis, however some, such as the Catchment Action Plans are regionally focused. These legislative instruments and policies are critical in setting out the framework for water management in NSW and in specific regions, which is then codified in WSPs for each region. This enables a set of water management rules that aim to reflect the particular environmental, social and economic situations of different regions.

The critical elements of the water management approach for each region covered by the WSP are:

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[22] *Water Management Act 2000* s 3.

[23] The overall objective of the *Water Management Act 2000* is to "provide for the sustainable and integrated management of the water sources of the State for the benefit of both present and future generations". See *Water Management Act 2000* s 3.

- **Prioritisation** – the prioritisation of water to the environment and between water users (Table 6) and purposes.
- **Regional sustainability** – the establishment of water extraction limits to protect surface and groundwater sources at a macro level.
- **Local impacts** – the establishment of a set of rules to protect specific groundwater dependent ecosystems, significant sites and other water users and the implementation of take limits on particular bores to manage local impacts.

3.1.2 Prioritisation of water under WSPs

A critical element in the management of water under the WSPs is the prioritisation of water to the environment and between water users and purposes. WSPs establish priorities of allocation with environmental first, Basic Landholder Rights second, town water supply and stock and domestic licences third, and all other licensed extraction for industrial and commercial purposes fourth (Table 6).

Table 6: Prioritisation of water users under WSPs

Priority	Water use	Detail
1	Environmental water	Water reserved for the environment. WSPs reserve 'storage water'. They also reserve a portion of groundwater recharge for the environment before determining available licensed water extraction.
2	Basic Landholder Rights (BLRs) • Stock and domestic rights • Harvestable rights • Native Title rights	BLRs have a higher priority over licensed water extraction and cannot be limited through available water determinations. However, they can still be subject to temporary water restriction order.[24] WSPs must allow for BLRs before determining available licensed water extraction.
3	Local water utility licences Major water utility licences Stock and domestic licences[25]	Priority is given to groundwater extracted for local and major utilities for town water supply and to licensed stock and domestic bores over other licensed water users.[26] Licenced extraction under these licences can be limited through available water determinations and temporary water restriction orders.
4	Water Access Licences	Extraction under these licences can be limited through available water determinations and temporary water restriction orders. No distinction is made between the end use of the water (agriculture, industrial production, etc). The WAL is also separable from the property on which it is being used, so a WAL can be traded within management areas

3.1.3 Regional sustainability and the WSP

WSPs share water and manage the sustainability of extraction from particular groundwater sources through extraction limits. WSPs for most groundwater sources set extraction limits through calculations of the expected groundwater recharge for each groundwater source based on average rainfall, recharge rates, the sustainability index, the type of groundwater source (e.g. fractured versus porous rock aquifer), and the distribution of high conservation areas (e.g. National Parks) where water is excluded from the calculation.[27] The groundwater recharge is then used to calculate the UEL, the LTAAEL and Planned Environmental Water

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[24] *Water Management Act 2000* s 324.

25 Under section 52 of the *Water Management Act 2000*, an owner or occupier of a landholding is entitled to take water from an aquifer that is underlying their land for domestic consumption and stock watering, without the need for a water access licence. However, a domestic and stock access licence may be required for the taking of water for domestic or stock watering purposes where the land does not overly the aquifer from which water would be taken.

[26] *Water Management Act 2000* s 58.

[27] The sustainability index (SI) considers both the environmental risk (based on the prevalence of high priority groundwater dependent ecosystems, water quality, ecology, aquifer integrity and potential for mitigation) and social economic risk (based on the dependence of local communities on the groundwater sources, including alternative water sources and the contribution of groundwater to the local economy).

(PEW).[28] These calculations and the related assumptions as applied in the development of the WSP are described in detail in Appendix 3.

The UEL, LTAAEL, and PEW for each groundwater source are calculated with the intention of reducing the risk of unsustainable extraction from particular groundwater sources in the long term and to inform the distribution of water to achieve environmental, social and economic wellbeing in the region according to the prioritisation of water uses as described above:

- For *fractured rock groundwater sources* under the WSP, the UEL represents the upper limit of extraction that could occur from a groundwater source under the WSP each year taking into account the rainfall recharge over non-high environmental value areas and the sustainability index for that groundwater source.[29]
- For *fractured rock groundwater sources* under the WSP, the LTAAEL represents the long term maximum average volume of water that can be extracted from a groundwater source under the WSP each year taking into account the lower of the UEL, or the current and estimated future requirements for groundwater and a conservative buffer.[30]
- For *porous rock groundwater sources* under the WSP, the LTAAEL represents the long term maximum average volume of water that can be extracted from a groundwater source under the WSP each year taking into account the rainfall recharge over non-high environmental value areas and the sustainability index for that groundwater source.[31]
- The PEW represents the portion of water to be reserved for environmental purposes.[32]

Extraction limits are a critical part of the ongoing adaptive management of groundwater sources under the WSP. For example, during the term of the WSP, as the demand for extractions changes over time and the understanding of the relevant groundwater source improves, the LTAAEL may be increased to be closer to the UEL in those water sources where the LTAAEL is below the UEL.[33] Where growth in water take is assessed to have increased more than 5% above the LTAAEL on average over a three-year period, the water allocation may be reduced to less than 1ML per unit share to bring extraction levels back down to the LTAAEL.[34] This information will also critically inform reviews of WSPs at the end of their 10 year period and the development of replacement WSPs. Adaptive management is described in more detail below.

3.1.4 Local impacts and the WSP

WSPs include rules to address local impacts of water extraction. These rules set limits on the proximity of groundwater extractions to certain assets including groundwater dependent ecosystems (GDEs), other groundwater users, aboriginal heritage sites and major water supply bores (Appendix 7). This approach allows local impacts to be addressed on a case-by-case basis by:

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[28] Note that the UEL is not calculated for all groundwater sources.
[29] Note that the sustainability index for high environmental value areas under the WSP is 0%, and therefore 0% of recharge over high environmental value areas is considered available for extraction. The UEL is not calculated for porous rock groundwater sources as the WSP indicates a high level of confidence in the calculation of the LTAAEL for these groundwater sources. See WSP p.31.
[30] These calculations and the related assumptions as applied in the development of the WSP are described in detail in Section 3.2 of the Initial Report.
[31] Note that as high conservation areas are excluded from the extraction limit calculations, effectively 100% of recharge over high conservation areas is reserved for the environment.
[32] Planned environmental water (PEW), as defined in the WSP, comprises a portion of groundwater held in storage and a portion of groundwater generated from recharge. At the commencement of the WSP, 100% of groundwater storage is reserved as planned environmental water. However, this may be reduced to 99.998% for some porous rock groundwater sources in accordance with the *NSW policy for Managing Access to Buried Water Sources* (NSW Office of Water, 2011).
[33] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 60(1).
[34] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 29(2)-(3)

- a risk assessment which identifies medium and high risk proposed extractions, and
- if appropriate, an assessment that takes into account the particular hydrogeological characteristics of the groundwater source and the local area (including proximate sensitive areas).

The assessment of local impacts under the WSP is described in more detail in Chapter 4.

3.1.5 Adaptive management and the WSP

Adaptive management is a critical process in managing environmental sustainability of groundwater extraction. Adaptive management relies on the collection of information (for example, through monitoring and studies), the assessment of that information against indicators of performance, and if necessary, changes in rules and management actions in response to that information.

3.1.5.1 Monitoring and performance indicators

The WSP identifies monitoring as key to understanding whether the WSP is meeting its environmental, social and economic objectives. To guide the appropriate range of monitoring and to assess the outcomes of those monitoring activities, the WSP specifies a number of performance indicators for all groundwater sources. These are intended to measure the success of strategies in the WSP in reaching its objectives. The WSP performance indicators are the changes in:

- groundwater extraction relative to the LTAAEL
- water quality
- the ecological condition of these groundwater sources and their dependent ecosystems
- the extent to which domestic and stock rights and native title rights requirements have been met
- the economic benefits derived from water extraction and use
- the extent to which water has been made available in recognition of the Aboriginal, cultural and heritage values of these groundwater sources.[35]

However, the Background Document to the WSP notes that it is not practicable to monitor all of these indicators in all groundwater sources covered by the WSP (DPI Water, 2016f). In March 2011, the Department released the *Environmental flow response and socio-economic monitoring. North Coast - progress report 2009* while in 2006 a detailed hydrology report was published on the Alstonville monitoring data (Green, 2006). More information is available in relation to the Alstonville Groundwater source (Section 3.4.1).

3.1.5.2 Amendments and reviews of the WSP

WSPs allow for adaptive management responses at the level of individual licences[36] and through amendment of some provisions of the WSP during its term. The *Water Management Act 2000* permits the Minister to amend the WSP if it is in the public interest to do so, or is in accordance with the terms of the WSP, which allows for certain amendments, including to:

- Modify or add groundwater sources or management zones[37]
- Vary the amount of recharge reserved for the environment as planned environmental water[38]
- Increase the LTAAEL[39]

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[35] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 12.
[36] For example through available water determinations and temporary water restrictions discussed in further detail in Chapter 4 – Local Impacts.
[37] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 58.
[38] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 59.
[39] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 60.

- Allow for the granting of supplementary water (storage) access licences under a controlled allocation order in particular groundwater sources and the granting of Aboriginal Community Development licences[40]
- Establish access rules for managing major utility access licences and for access licences in particular groundwater sources[41]
- Add, remove or modify minimum distance rules[42]
- Impose rate and time restrictions on groundwater extraction [43]
- Amend the map of high priority groundwater dependant ecosystems. [44]

Most of these amendment provisions that allow for certain aspects of the WSP to be revised require evidence (for example hydrogeological studies), that evidence supporting an improved understanding of the system and justifying an adjustment to the WSP.

The WSP is also subject to a range of periodic and end of term reviews. For example, the WSP is subject to an initial review and audit by the NRC within five years of enactment, and a renewal or replacement review at the end of its 10-year life. These reviews focus on the water management principles specified in the *Water Management Act 2000*,[45] as well as the environmental, social and economic outcomes.[46] These review requirements are discussed in further detail in Appendix 4 of the Initial Report.

3.2 SOURCES OF UNCERTAINTIES AND THEIR MANAGEMENT IN THE WSP

The WSP estimates recharge (and ultimately the allowable extraction rates) for each groundwater source covered by the WSP using the equations outlined in Appendix 3. This section investigates the uncertainty associated with each parameter and what approaches are taken in the calculations to manage this uncertainty, with the aim to provide a comment, as far as possible, on the long-term sustainability of the extraction limits in the WSP as per the terms of reference.

There are a number of relevant environmental parameters that introduce levels of uncertainty to the extraction figures in the WSP including:

- Average annual rainfall
- Surface area and impact of confining geological layers
- Recharge rate
- Sustainability index.

This section analyses the uncertainties that have been identified through the review of the WSP. The term uncertainty is used to recognise a range of possible values that could be assigned to a given attribute, such as the recharge rate or the sustainability index. When there is a substantial body of research (or lines of evidence) on a given topic, the uncertainty is typically lower and a higher degree of confidence in the adopted values. Conversely, when there is limited available data and/or research, the uncertainty may be high, thereby including a large range of possible values.

[40] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 61.
[41] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 62.
[42] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 63(a).
[43] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 63(c).
[44] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 63(d).
[45] *Water Management Act 2000* ss 5 and 43(2).
[46] *Water Management Act 2000* ss 43A(1),(3).

The section below describes how each of the terms used in Equation 1 (Average Recharge) and 2 (UEL) were addressed and if improvements could be made.

Average Recharge (ML/yr) = Average Rainfall (mm/yr) x Area (km^2) x Recharge Rate (%)/100 (Equation 1)

UEL (ML/yr) = Recharge over non- high environmental areas (ML/yr) x SI(%) (Equation 2)

3.2.1 Average annual rainfall

Annual rainfall is variable over the relatively large area (76,000 km^2) covered by the WSP. Rainfall data used by the WSP was sourced from the Bureau of Meteorology (BOM) gridded rainfall data (approximately 5 km^2 grid) from 1901 – 2011. This rainfall model uses algorithms to estimate a weighted average rainfall in each grid based on the observations at the nearest BOM stations. This accounts for the spatial variability of rainfall throughout large catchments and is based on the best available data. More information on the rainfall data can be found on BOM (2015).

Rainfall data provided by BOM are considered reliable and the spatial distribution of BOM weather observation stations in NSW is considered sufficient to capture the spatial distribution of rainfall and represent the average rainfall over the WSP area. There are 94 BOM rain gauges currently operating in the Northern Rivers region and a further 229 historical gauges.

3.2.1.1 Climate change projection and its effects on rainfall

The earth's climate is expected to change globally in the future (IPCC, 2013). The DPIE's Energy, Environment and Science Branch, formerly Office of Environment and Heritage, has provided a detailed assessment of climate change effects on the North Coast region of NSW (OEH, 2014). The report uses information from the NSW and ACT Regional Climate Modelling project (NARCliM) to make climate change predictions. The NARCliM analysis uses 12 predictive models and report what the majority of models agree on.

The report projects that the North Coast region will see increase in temperatures in the near future (2020–2039) and far future (2060–2079), compared to recent years (1990–2009). The warming is projected to be on average about 0.7°C in the near future, increasing to about 2°C in the far future. An increase in temperatures with climate change could lead to greater or reduced evapotranspiration (evapotranspiration is a function of humidity, irradiance and wind). If evapotranspiration increases, this would contribute to drying over some land areas. With potentially more extreme rainfall (storms), but also longer dry spells in between, storm-affected areas are likely to experience increased risk of flooding, while also seeing increased risk of drought.

The majority of climate models agree that autumn and spring rainfall in the region will increase in both the near and far future, and that winter rainfall will decrease for both timeframes. For summer rainfall, the majority of models predict little change in the near future and an increase in the far future. High intensity rainfall results in fast moving surface water which may not have sufficient time to infiltrate the soil matrix to effectively recharge groundwater aquifers. While rainfall may be predicted to increase over some time horizons, if the increased rainfall is as a result of more frequent high intensity rainfall, recharge may not increase.

Climate modelling results should be interpreted with care as large uncertainties are associated with the direction of change in the region's predicted rainfall. In a CSIRO and Bureau of Meteorology report (Dowdy et al., 2015), projected changes in the region's annual rainfall over the next 20 years range from -15% to +10% relative to 1986–2005. That study also concluded for the region that intensity of heavy rainfall events will increase (with high confidence) and there will be longer periods of meteorological drought by late in the 21st century (with medium confidence). However, natural climate variability will likely remain the major driver of rainfall changes in the next decades. Regardless of the direction in rainfall change, rainfall patterns in the region will change in the future which will have a direct impact on recharge. This should be considered as part of future WSP planning.

3.2.2 Surface area and impact of confining geological layers

The method to determine the UEL in coastal fractured and porous rock groundwater sources assumes a spatially uniform recharge rate as a percentage of rainfall, which is contrary to the high variability in land use and cover, soils, geology and recharge processes that exists. While the uniform rate assumption is justified given lack of data, care must be taken when considering the groundwater source to ensure that the recharge rate is sufficiently conservative to protect the groundwater source, yet reasonably approximated for the region to provide a valid end point.

The WSP provides a surface area for high and non-high environmental value areas for each groundwater source but does not describe how the surface area was delineated. Typically, this information, as derived from a digitised aerial image and/or high-resolution satellite data, is widely used and acceptable.

Modelling reports and hydrogeological reports (e.g. (Bilge, 2003), (Eco Logical, 2016, 2018a, 2018b) and (Kobus Argent, 2018)) suggest that parts of the relevant aquifers are at least locally confined or partially confined in some areas. If the aquifer is confined or partially confined, it is overlain by a layer of low permeability material that inhibits rainfall infiltration over some parts of the aquifer, as illustrated in Figure 10. As a result, a confined aquifer with the same surface area as an unconfined aquifer may receive less recharge for the same direct rainfall. In most cases, unless there has been significant and detailed geological mapping, the area where semi-confined aquifers are recharged is often uncertain. This is addressed in the WSP by not permitting overlaps in the recharge areas of the confined and unconfined aquifers defined in the WSP. However, the variable presence of other confining layers (e.g. local confining clay layers) not being considered in the WSP introduces additional uncertainty in the recharge estimates.

It is unclear whether the percentage recharge rate used in the WSP refers to only the identified outcrops of the aquifers that make up the groundwater source or also the sub-crops beneath a confining layer. The variations in connectivity (permeability) in the different layers in the aquifer can cause local variations in recharge rates. Although, this is a ubiquitous issue for recharge studies, integrating the many layers into one lumped aquifer introduces some level of uncertainty as the fractured basalts are the dominant source for bottled water extractions.

Developing a better conceptual understanding of the geological strata in the WSP, possibly via a 3D geological modelling tool (e.g. Leapfrog Geo) where there is sufficient data would help to reduce the level of uncertainty in the estimated recharge values and assist in understanding whether the assumptions made in the WSP are appropriate. This would require a large scale detailed geological mapping survey or the collation of the existing core log data and geophysical measurements, where available. It is worth noting that this level of detail has not been typically undertaken in other WSPs of a similar nature for easterly flowing systems.

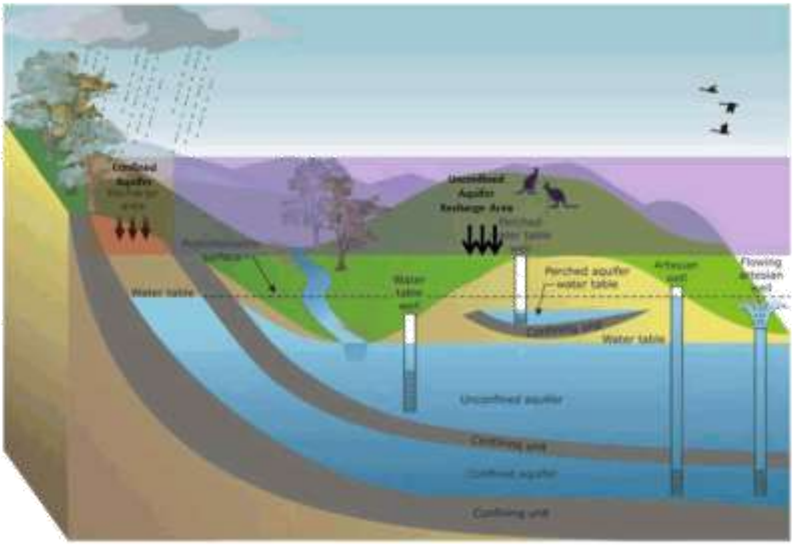

Figure 10: Recharge areas of confined and unconfined aquifers
Note: confined in red highlights; unconfined in purple highlights
Source: UNSW Sydney (2017)

3.2.3 Recharge Rate

The estimates of recharge provide the basis for Planned Environmental Water, LTAAEL or UEL in the WSP and are a source of uncertainty in the WSP (Table 7). While uncertainty in the recharge estimate may be acceptable if the estimates are suitably conservative, or there is limited consequence as a result of possible error bands, it is important to recognise how ambiguity may impact the plans. The systems considered in the WSP are considered to be 'less highly-connected groundwater sources' (DPI Water, 2016f), which means there is limited recharge through creek beds, and thereby, only recharge through rainfall was considered.

Recharge estimates in fractured rock are typically poorly understood due to the spatial variability and complexity of these environments (Crosbie et al., 2010). This may result in over (or under) estimation of recharge rates. Due to the practicality of treating the water sources as being homogenous, it is considered necessary to be conservative in the recharge rates assumed, to account for inherent inaccuracies and uncertainties in this calculation.

The values adopted for each of the groundwater sources considered in the WSP are typically based on estimates dependent on the hydrogeological type. The Coastal Porous Rock Rainfall Recharge Study showed that while the NSW default value of recharge rate in coastal porous rock is 6%, the values reported in calibrated models across the state ranged between 1 – 6%. This indicates that the NSW default value could potentially overestimate recharge in the porous rock groundwater systems in scope of this Review. The Clarence Moreton Basin adopted the value of 6% in lieu of other estimates.

Table 7: Recharge rates used in WSP for groundwater sources with bottled water extraction

Groundwater source	Recharge used in WSP (% of long-term rainfall)
Clarence Moreton Basin (porous rock)	6
New England Fold Belt Coast (fractured rock)	4
North Coast Volcanics (fractured rock)	8
Alstonville Basalt Plateau (fractured rock)	8

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More accurate estimates of rainfall recharge could be developed through multiple lines of evidence including field data analyses such as chloride mass balance calculations, water table fluctuation or base flow analyses. As the recharge rate is integral to the allocation of the LTAAEL and planned environmental water, the impact of the adopted values warranted further investigation and are considered further by the Review at Section 3.3.

3.2.4 Sustainability Index

The WSP, which is based on recommendations within DPI Water (2016f) and DPI Water (2015), acknowledges that regional estimates of recharge for large aquifers is not an exact science. As such, the WSP highlights that due to this uncertainty a precautionary approach is warranted. DPIE Water has advised that a precautionary approach was subsequently formulated using 0% recharge estimates for high environmental value areas, with no allowance for recharge other than direct rainfall and a sustainability index, which is further discussed below (DOI Water, 2019).

The sustainability index is a simple method for risk accounting that endeavours to manage the balance between environmental risk, economic and social growth. While the allocation of high, medium or low risk is subjective, the index is a measure that can be applied to all catchments with relatively limited information. Further work could be undertaken to assess whether the risk ratings given to specific catchments are appropriate, but the index appears to be a cost and time effective means to protect resources where limited information is available.

It would be useful to undertake sensitivity testing of the index to assess the implications of changing conditions or additional research that may result in a change in the risk ratings. Where this may result in the aquifer being over-allocated, more research may be required. Estimates of the risks associated with each groundwater source could be better detailed as information comes to hand.

3.3 TESTING THE WSP RECHARGE RATES AGAINST STUDIES AND OTHER APPROACHES

3.3.1 Relevant literature on recharge rates

A review of literature was undertaken to compare the recharge rates adopted in the WSP with existing studies in the same or comparable areas. This section provides an overview of the various approaches to calculating recharge rates in the region presented in the literature.

3.3.1.1 Coastal Porous Rock Rainfall Recharge Study

A primary source of information about recharge across NSW is the Coastal Porous Rock Rainfall Recharge Study prepared for NSW DPI Water (EMM, 2015). The data in that study are estimated from groundwater modelling studies, none of which are in the Tweed or Alstonville areas, or in the groundwater sources of interest, but rather the report considered advice from experts through interviews and a workshop. It also considered the Bioregional Assessment program (Raiber et al., 2016), which was then unpublished but in the process of undertaking recharge estimates for the Clarence Moreton bioregion.

The Coastal Porous Rock Rainfall Recharge Study recommended adopting 6% for the Clarence Moreton Basin groundwater source. It recommended that the ongoing work of the Bioregional Assessments should be considered (as published in 2016). Further, in high-risk locations (i.e. where a groundwater dependent ecosystem could be impacted or a surface water source influenced) and high-demand locations, the report recommended detailed recharge investigations.

3.3.1.2 The Bioregional Assessment

The Clarence Moreton Bioregion sits on top of the geological Clarence Moreton Basin. The Basin includes the Bundamba Group, overlain by the Walloon Coal Measures, overlain by the Lamington and Main Range volcanic rocks and alluvial aquifers. Other minor formations are present.

The Lamington Volcanics geological group encompasses the North Coast Volcanics. Both the Lamington Volcanics and Alstonville Plateau aquifers are fractured basalt aquifers within the Cenozoic basalt group. Based on this geology, recharge estimates for the Lamington Volcanics outcrops may be useful for North Coast Volcanics and Alstonville Plateau groundwater sources (although differences in climate, soils and vegetation are expected to play a dominant role in controlling recharge rates).

The Bioregional Assessment of the Clarence Moreton Bioregion used the chloride mass balance method to produce long-term average recharge estimates. The results from the Bioregional Assessment of the Clarence Moreton Bioregion are provided in Figure 11 (Raiber et al., 2016). The results are based on 3632-point estimates of groundwater chloride at points shown in Figure 12 below. The recharge estimates developed for these points are interpolated and extrapolated spatially over the bioregion, based on the identified relationship between long-term average recharge and long-term average rainfall, as detailed in Figure 13.

Averaging the 172 point estimates of recharge available for the Lamington Volcanics within the Bioregional Assessment data set, results in a 16% recharge rate. Based on Figure 11 and Figure 13, this appears to represent the spatially interpolated average for the Lamington Volcanics (the actual spatially interpolated value is not available from the report or the publicly accessible data set).

It is worth noting that the chloride measurements shown in Figure 13 provide minimal coverage of the groundwater sources of interest. Although 16 % is likely to be the best available estimate for the North Coast Volcanics and Alstonville Plateau groundwater sources, it cannot be used with confidence. Furthermore, while the chloride mass balance method is an established approach for approximating recharge. However, various assumptions inherent within the method mean that it is not generally considered an accurate approach. As such, these results are best complemented with alternative methods and should not be used as a single line of evidence.

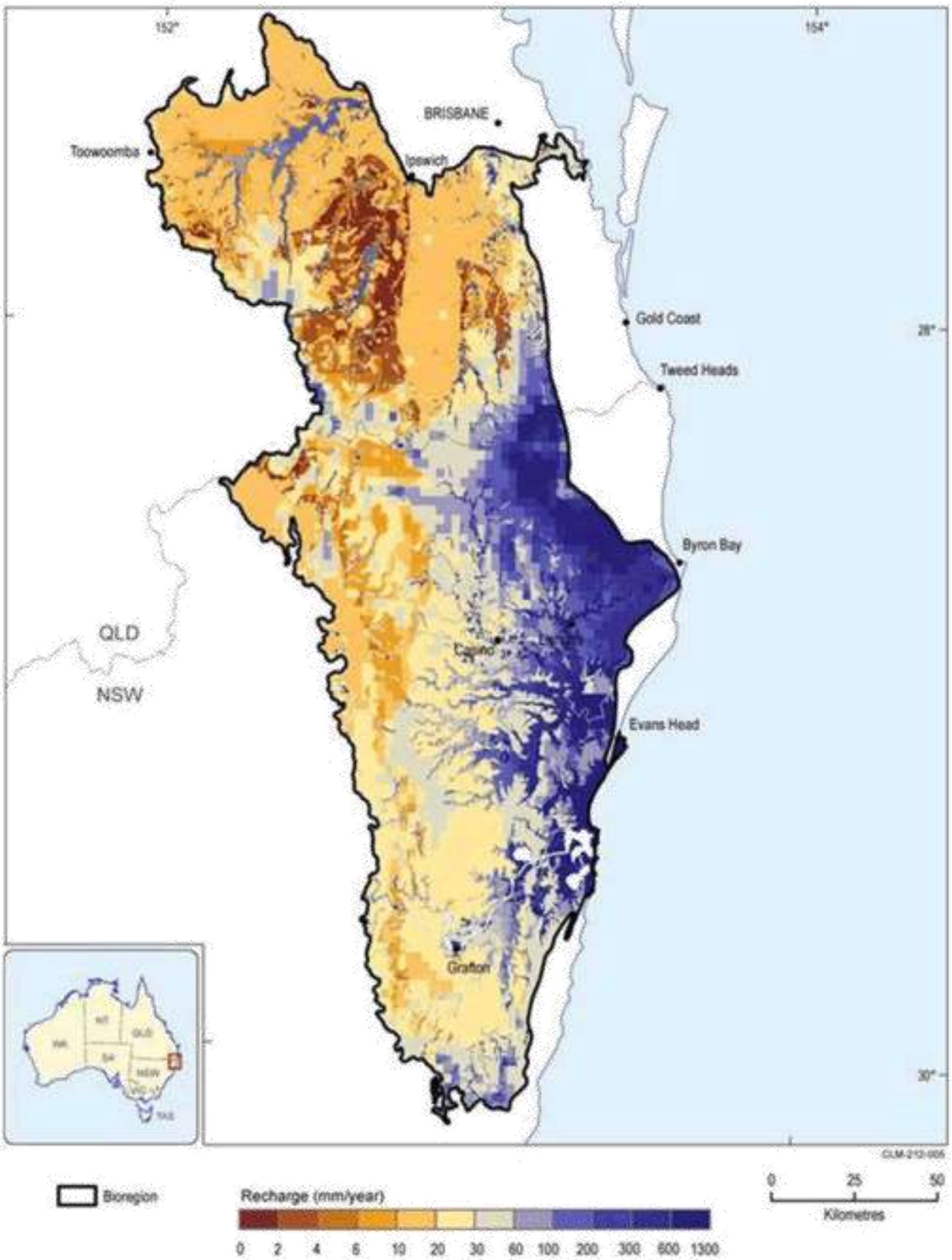

Figure 11: **Mean recharge estimates for the Clarence Moreton bioregion**
Source: Raiber et al. (2016)

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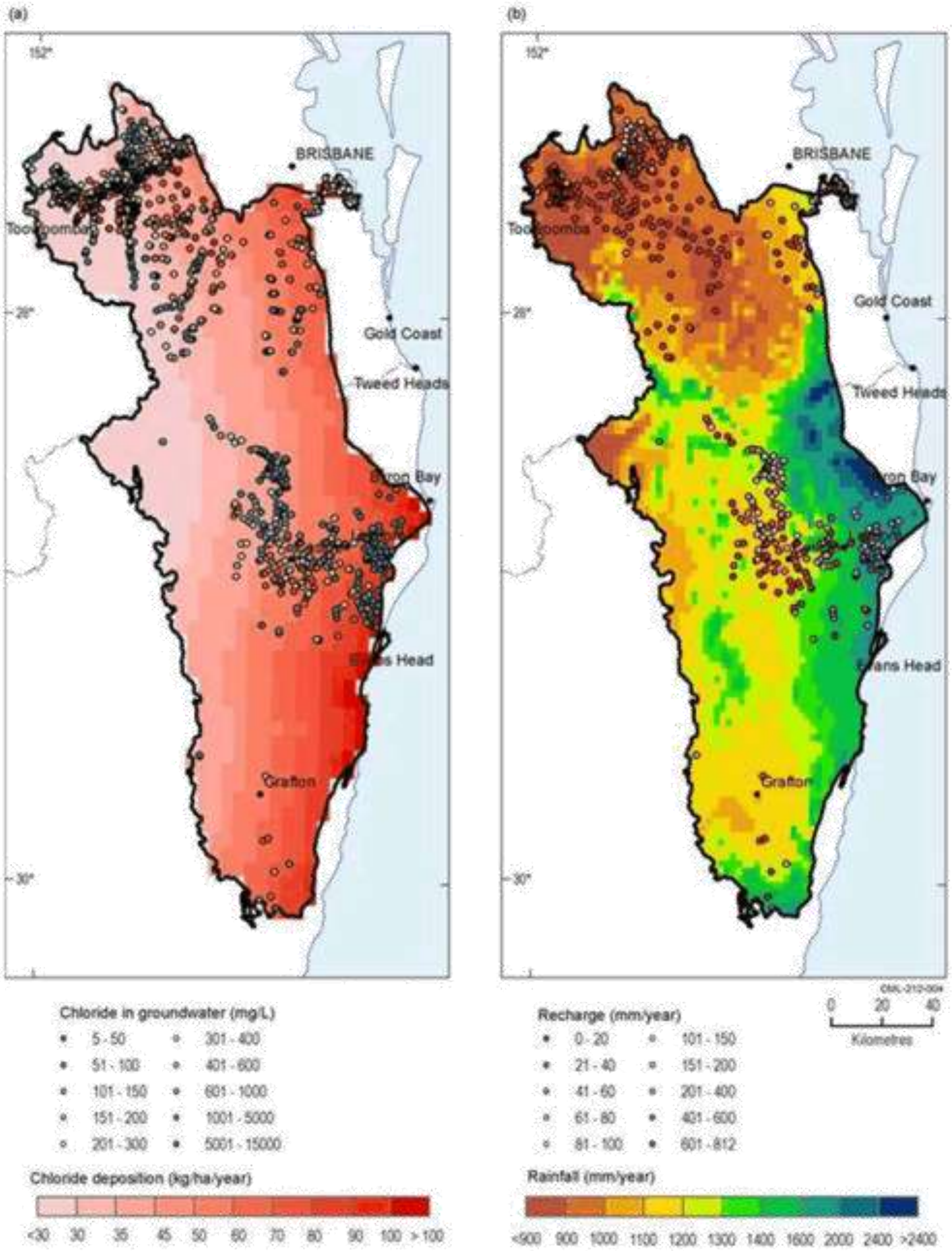

Figure 12: Data used for estimating recharge for the Clarence Moreton Bioregional assessments
Source: Raiber et al. (2016)

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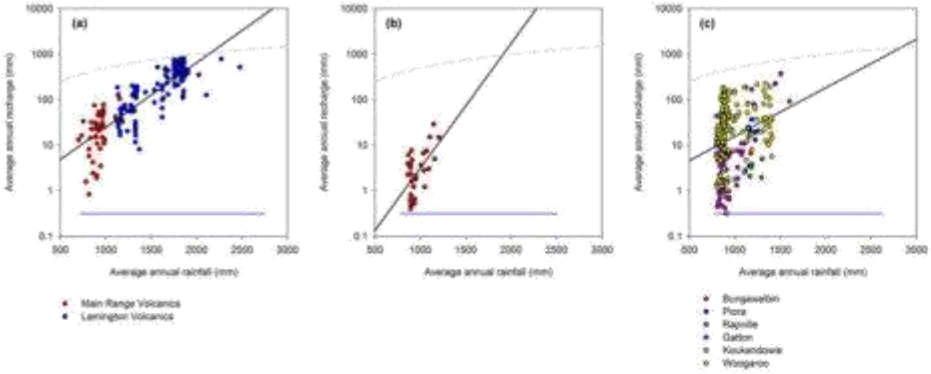

Figure 13: Relations between long-term average rainfall and chloride mass balance estimates of recharge for the hydrogeological units of the Clarence Moreton bioregion - (a) the Cenozoic Volcanics (Lamington Volcanics and Main Range Volcanics), (b) Walloon Coal Measures, (c) other sedimentary rock formations.
Note: The black line is the line of best fit through the data points, the dashed grey line is recharge as half of rainfall and the blue line is the range of annual average rainfall within the bioregion for the surface geology class Source: (Raiber et al., 2016).

The other groundwater source of primary interest, the New England Fold Belt Coast, is not clearly represented by the Clarence Moreton bioregion, as it underlays the Clarence Moreton Basin.

The Review concluded from the Bioregional Assessment:

- The 6% assumed in the WSP for the Clarence Moreton Basin groundwater sources is a reasonable basin-average estimate. However, there is large spatial variability of recharge within the Basin, and 6% should not be assumed a safe value for particular aquifers or locations.
- The results for the Lamington Volcanics indicate a spatial average recharge value of approximately 16% of rainfall. This is the best available published value to support the WSP values for fractured volcanic basalt aquifers including the Alstonville Plateau and North Coast Volcanics. However, the value of 16% is subject to the various uncertainties in the chloride mass balance method and is based on data points that are well outside the Tweed and Alstonville areas of interest.
- The other groundwater source of interest, the New England Fold Belt Coast, is not represented in the Bioregional Assessment results.

3.3.1.3 The University of Queensland recharge study

The University of Queensland undertook a study "Recharge estimation in the Surat Basin" (West et al., 2018). From discussion with the report authors, the study included recharge estimates in the Main Range Volcanics. These fractured basalt aquifers may be considered comparable in hydrogeological properties to the fractured rock aquifers of interest. However, the Main Range Volcanics are approximately 150 km north-west of the Tweed Valley, in a much drier region (approximately 700 mm annual average rainfall versus 1800 mm in the upper Tweed). Chloride mass balance and baseflow analysis methods were also used in this study and are provided below for comparison.

The recharge using the two methods, spatially averaged over the Main Range Volcanics subcrop, was estimated to be 0.7% and 0.9% of the long-term rainfall. The low values were attributed to relatively impermeable soils. Another recent estimate using the chloride mass balance method (DNRME, 2016) provided an estimate of 1.2%. Further, a broader review of previous recharge studies in this region (West et al., 2018) suggested that recharge results range from 1.9 to 2.3% of rainfall. This range of estimates (from 0.7% to 2.3%) are broadly consistent with the results found for the Main Range Volcanics in the Bioregional

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Assessment of the Clarence Moreton Bioregion (the point estimates provided for the Bioregional Assessment ranged from 0.2 to 6.3% with an average of 2.4%). The relatively low percentage values in the Main Range Volcanics compared to the Lamington Volcanics are expected due to the high sensitivity of recharge to the rainfall and potentially attributed to different soil and vegetation covers. While it can be concluded that The University of Queensland recharge study results are not comparable to the aquifers of interest for the Tweed and Alstonville areas, the results illustrate the range of approaches that may be undertaken to estimate recharge in hydro-geologically comparable aquifers.

3.3.1.4 Australian Landscape Water Balance

The Australian Landscape Water Balance website of the Bureau of Meteorology includes a Australian Water Resources Assessment Landscape model (AWRA-L) which is the near-surface component of Bureau of Meteorology's national water balance modelling system. One of the AWRA-L outputs is deep drainage, which is the water moving vertically downward at a depth of 6 m. In most situations, this can be considered to be an estimate of groundwater recharge.

AWRA-L focusses on surface hydrology and is calibrated to river flow gauges. Its accuracy for recharge estimation has been assessed by CSIRO although not specifically for aquifers of interest (Shi, Vaze, & Crosbie, 2015). It was concluded that "*overall, the groundwater recharge assessment in this report indicates that AWRA is able to provide reasonably reliable spatial and temporal (e.g. annual) estimates of recharge across Australia*".

Deep drainage results for the Tweed River catchment and surrounding region are shown in Figure 14. The mapped results are for 2018, which has a modelled deep drainage close to the long-term median value, therefore may be considered typical. The modelled median deep drainage for the catchment is approximately 40 mm/year, or 2.2% of long-term average rainfall. Due to the grid sizes, it is not practical to pick out particular values for the groundwater sources of interest.

It may be concluded from this study that surface water modelling tools, which represent the effects of soil and vegetation and calibrated to surface flows, may give significantly lower recharge rates than assumed in the WSP. The difference between the recharge rates estimated by AWRA-L and the WSP suggest that additional investigations are needed to ensure that the rates used in the WSP are not over-estimated or the AWRA-L are not underestimated.

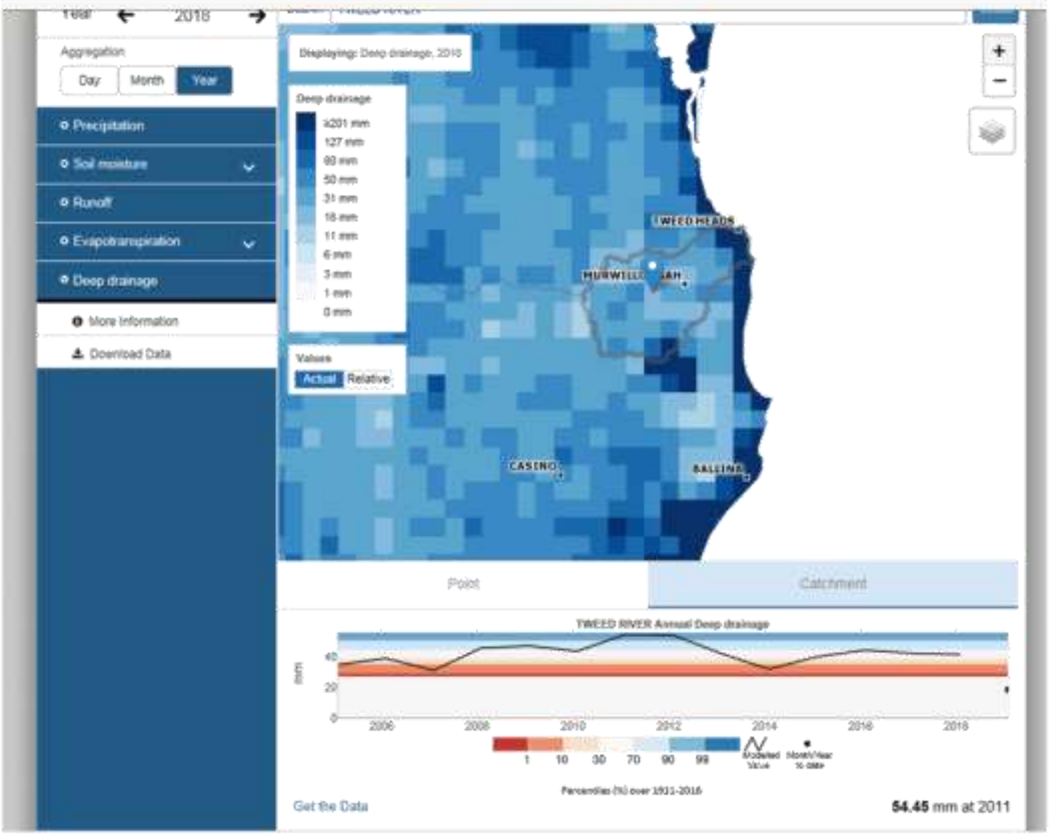

Figure 14: Screenshot of AWRA-L deep drainage results, showing map for typical year 2018
Source: BOM (2019)

3.3.1.5 The National Review of Recharge Studies by CSIRO

In 2010, CSIRO conducted a review of previous recharge studies in Australia (Crosbie et al., 2010). The NSW studies included in the review were for Coastal Alluvium, Inland Alluvium and the Western Slopes of the Great Dividing Range. None of these are relevant to the groundwater sources of interest. Fractured rock aquifers were found to be very poorly represented in the available data.

Vegetation type and soil type were found to be critical determinants of recharge. Relating recharge to surface geology had mixed results. It may be concluded from this review that there is likely to be high uncertainty in generalising recharge rates from surface geology (as used in WSP), especially in fractured rock aquifers.

3.3.2 Application of methods to local area

There is a range of different techniques available to quantify recharge, with the choice of method dependent on the goal of the study, the spatial and temporal scales, and level of information available. Each approach has uncertainties so often multiple techniques are used to increase the reliability of the outputs (Scanlon, Healy, & Cook, 2002)

Two methods were used to estimate groundwater recharge within this Review. These are application of the chloride mass balance method to chloride measurements from the proponents' hydrogeology reports; and filtering baseflow from available surface flow measurements. Both methods have considerable assumptions and uncertainties.

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3.3.2.1 Application of chloride mass balance

The chloride mass balance method (Anderson, 1945) is a simple method for estimate groundwater recharge from rainfall based on the following assumptions (Wood, 1999):

- Chloride in groundwater is only sourced from rainfall
- Chloride is conservative in the system (no sources or losses).
- The chloride flux does not change over time (steady state conditions).
- There is no recycling of chloride in the system.

Then,

$$R = \frac{1000\ D}{(Cl^{-})_{gw}}$$

where R: recharge [mm/year];

D: Chloride deposition rate [kg/m^2/year];

$(Cl^{-})_{gw}$: Chloride concentration in groundwater [kg/m^3].

The chloride mass balance method was applied to the area under study using values of chloride deposition estimated from the Bioregional Assessment (assuming no Chloride losses) and chloride concentration in groundwater from the proponents' hydrogeology reports (when available).

Long term recharge estimations obtained were averaged per aquifer system and are presented in Table 8. Table 8 also shows WSP values for comparison.

Table 8: Groundwater sources, recharge rates used in WSP and recharge estimated locally

Groundwater source	Recharge used in WSP (% of long-term rainfall)	Recharge estimated locally (% of long-term rainfall)
New England Fold Belt Coast	4	31
Clarence Moreton Basin	6	10
Alstonville Plateau	8	(*)

Note (*): No local data was available for the Alstonville Plateau.

The estimates based on the local chloride measurements are considerably higher than those used in the WSP, however, it should be noted that:

- there is uncertainty in these estimates because they are based on a very small number of chloride measurements
- if losses of chloride due to surface runoff are considered, these values would be lower, but there were no available data to include them
- if the source aquifers are confined, these estimates may be interpreted as estimates at the outcrop of the aquifers
- if the source aquifers are not confined the recharge may come from overlying aquifers and/or surface water sources.

3.3.2.2 Baseflow filtering as an estimate of recharge to the Northern Rivers bottled water industry

Baseflow is the sustained contribution to river flows. Conceptually, baseflow is often considered to be the groundwater contribution to river flows, although may contain other sustained flow contributions. Where baseflow may be assumed to be the groundwater contribution, and considered as the outflow from the groundwater reservoir, it provides an alternative estimate of recharge, although will only provide estimates of recharge to aquifers that discharge upstream of the gauge. Long-term stream flow gauges are needed, like those maintained by the DPIE Water.

At catchment scale, the stream flow components can be broadly grouped in classes based on the different orders of magnitude of the subflow responses to rainfall. Most stream flow series show quick flow and slow flow components (Willems, 2009). The slow flow component corresponds to baseflow.

Baseflow filtering is a data analysis technique that allows users to numerically separate out baseflow contributions from total measured/gauged river flow (Tallaksen, 1995). The method excludes any recharge that does not appear as baseflow at the gauge, and thus may exclude recharge that feeds deep groundwater systems and excludes recharge through the river bed that does not re-emerge before the gauge.

Baseflow filtering was used to estimate groundwater recharge at a number of flow gauging stations within the area of interest. The filtering method used is described in Appendix 4. Figure 15 shows the location of flow monitoring points and groundwater sources.

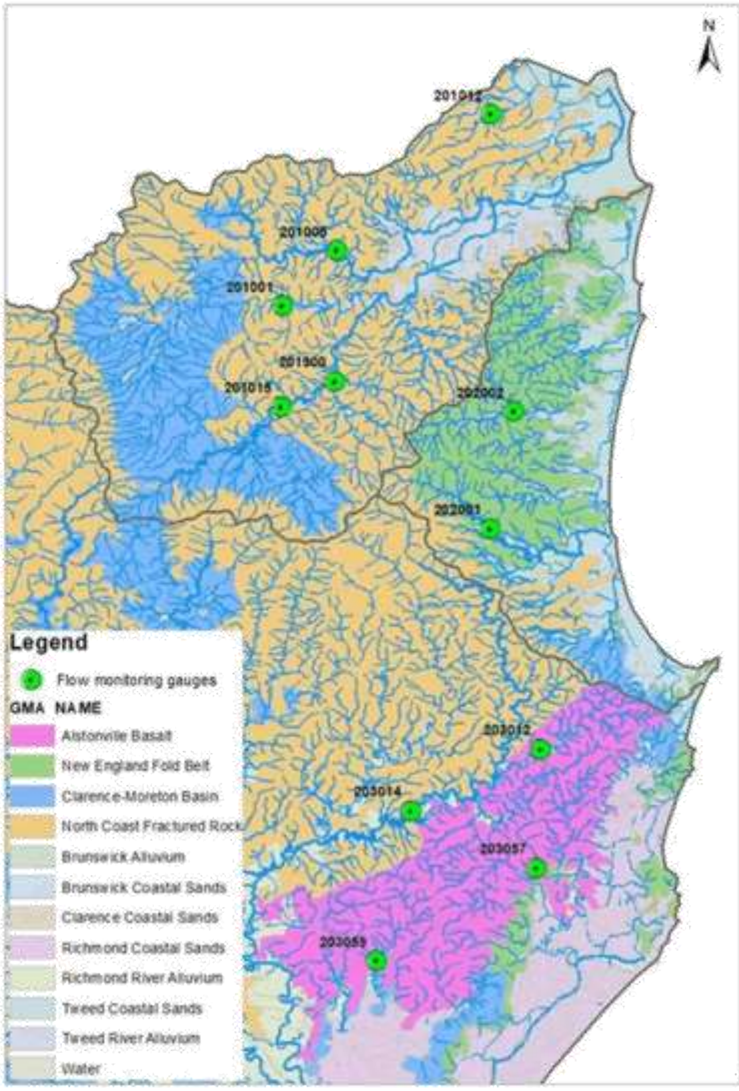

Figure 15: Flow monitoring points in the Northern Rivers region and groundwater management areas

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Table 9 shows the flow gauges in the Tweed and Alstonville Plateau Areas. The daily flow time series for monitoring points in Figure 15 and Table 9 were obtained from the BOM. Rainfall is from daily SILO (Scientific Information for Land Owners) data downloaded from (Queensland Government, 2019), SILO uses mathematical interpolation techniques to infill gaps in gauged rainfall time series and constructs spatial grids, and for the current purpose is equivocal to the alternative BOM gridded rainfall data. Rainfall falling over each gauged catchment was averaged from all SILO cells within or overlapping the drainage area.

Table 9: Flow gauges in the Tweed Area and Alstonville Plateau

Code	Area	Name	Latitude	Longitude	Catchment Area km^2
201001	Tweed	Oxley River at Eungella	-28.3537	153.2931	213
201005	Tweed	Rous River at Boat Harbour No. 3	-28.3096	153.336	111
201012	Tweed	Cobaki Creek at Cobaki	-28.200871	153.458926	10
201015	Tweed	Tweed River D/S Palmers Road Crossing	-28.433857	153.291908	156
201900	Tweed	Tweed River at Uki	-28.413522	153.334927	275(**)
202001	Brunswick	Brunswick River at Durrumbul (Sherrys crossing)	-28.531174	153.458183	39 (*)
202002	Brunswick	Burringbar Creek at Burringbar	-28.43774	153.476761	39 (*)
203012	Alstonville	Byron Creek at Binna Burra	-28.706611	153.497897	39
203014	Alstonville	Wilsons River at Eltham	-28.755574	153.394827	223
203057	Alstonville	Houghlahans Creek at upstream Teven	-28.801169	153.494846	10 (*)
203059	Alstonville	Maron Creek at Graham Road	-28.874925	153.36741	39 (*)

(*) Catchment areas with * were estimated (**) Influenced by upstream reservoir so lower value for baseflow analysis

Appendix 4 presents aggregated monthly baseflow for the available period of data for these flow gauges, together with the rainfall over the catchment.

For each monitoring point, aggregated annual values are also presented in millimetres for rainfall, total streamflow (Q) and baseflow (BF). Ratios BF/Rainfall and BF/Q are calculated, and their tendency is analysed by calculating a 5-year moving average. Table 10 shows the average BF/rainfall ratios over the available data periods.

Table 10: Fraction Baseflow/Rainfall for flow gauges for period 1960-2018

Code	Area	No of years with information	Average Baseflow/Rainfall
201001	Tweed	59	0.08
201005	Tweed	37	0.09
201012	Tweed	36	0.10
201015	Tweed	9	0.05
201900	Tweed	37	0.05**
202001	Brunswick	47	0.05
202002	Brunswick	9	0.08
203012	Alstonville	40	0.22
203014	Alstonville	58	0.17
203057	Alstonville	8	0.14
203059	Alstonville	7	0.14

** Influenced by upstream reservoir so lower value for baseflow analysis

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From the figures in Appendix 4 and data in Table 10, it is observed that fractions of baseflow:rainfall and baseflow:total streamflow are variable annually. Long-term baseflow:rainfall ratios are in the range of 5-15% in the Tweed, 5-10% in Brunswick and 10-25% in the Alstonville system. These values may be interpreted, with considerable uncertainty, as recharge rates of aquifers that discharge upstream of the gauging locations.

Given that these values are likely to be under-estimates of total recharge because they only capture the groundwater that is discharged above the gauge, and due to the uncertainty in the filtering method, it is concluded that there is no evidence here that the WSP values of recharge are not conservative

3.3.3 Impact of reducing the recharge rates

Despite the available data or research, there is likely to always be some uncertainty in the extraction limits and planned environmental water calculated in any WSP. One approach to assess whether the current level of uncertainty is acceptable is to undertake sensitivity analyses of the results. Sensitivity analyses examine 'what-if' cases for a range of possible values for an attribute in question. In the case of the WSP, a sensitivity analysis could be undertaken to see whether a change in the recharge or sustainability index might result in the aquifers being stressed at the current level of extraction or at the prescribed level of allowable recharge.

For example, in a scenario where recharge was just 20% of that calculated in the WSP, however there was no change to the LTAAEL or current assignment of water, the recharge amount reserved for the environment (RRE) would be as shown below in Table 11.

Table 11: Hypothetical example scenario - reducing recharge to 20% of the estimated recharge in the WSP

Groundwater Source	Hypothetical Recharge - 20% of WSP value (ML/yr)	LTAAEL (ML/yr)	Current Assigned Water (ML/yr)	RRE* (ML/yr)	RRE as a percentage of estimated recharge	Assigned Water as a percentage of recharge
New England Fold Belt Coast	396,000	60,000	35,468	336,000	85%	9%
North Coast Volcanics	62,000	13,000	5,907	49,000	79%	10%
Alstonville Plateau	10,016	8,895	8,895	1,121	11%	89%
Clarence Moreton Basin	115,200	300,000	4,562	-184,800*	-160%*	4%

*RRE is calculated as Average Recharge (ML/yr) - LTAAEL. A negative RRE implies the extraction limit is greater than the expected recharge.

As shown in Table 11, if the recharge rate was reduced to 20% of the WSP value, the RRE in the New England Fold Belt Coast and the North Coast Volcanics remains relatively high (approximately 80%) and the present LTAAEL is likely to remain reasonable. In the Alstonville Plateau, RRE (as a percentage of recharge) would be significantly reduced if the recharge rate had been overestimated. However, there is a network of monitoring bores (piezometers) within the Alstonville aquifer which can be inspected to assess whether there has been any long term changes in water levels throughout the groundwater system. The availability of this data provides a way to scientifically evaluate long term trends in aquifer water level and to identify signs of the aquifer becoming stressed (e.g. systematic decline of water levels over a significant time period).

Table 11 also shows that the reduced recharge would result in the LTAAEL being larger than the annual recharge. However, extraction in this region is presently very low. If there is significant concerns that the recharge rate in this region has been overestimated, the LTAAEL could be reduced without significant impacts to current license holders.

3.4 MONITORING DATA FROM ALSTONVILLE BASALT

The NSW Government operates 29 monitoring piezometers on the Alstonville Plateau (including two in North Coast Volcanics) which continuously measure water levels in various locations at multiple depths throughout the region. Analysis of this data provides a useful way to understand the groundwater system, as well as to identify periods in which water supplies in the aquifer may be stressed.

This section is separated into two distinct parts based on the time of monitoring:

- Pre 2009, a number of reports were released that analysed the existing monitoring data to date;
- Post 2009, the Review hasn't found an updated status report on the groundwater levels. As such, monitoring data was accessed by the review team to provide comment on groundwater levels in the Alstonville Plateau over the last decade.

3.4.1 Alstonville monitoring network and aquifer levels to 2006 and 2009

In 2006, the Department published a status report on the groundwater levels in Alstonville. At the time, the monitoring network consisted of 11 monitoring piezometers measuring both the deep and shallow aquifers, across five sites at Alstonville. This report included the development of conceptual models for the Alstonville GW sources showing the system comprises two major aquifers – a shallow unconfined aquifer (less than 50 metres deep) and a deeper semi-confined/confined aquifer (generally >50 m) (Green, 2006; DECCW Water, 2011).

Green (2006) stated that the shallow unconfined aquifer is rapidly recharged by rain, while the deeper semi-confined/confined aquifer takes longer to recharge after rainfall events. While the deep aquifers do experience periods of drawdown and recovery, the recovery period can be substantially longer than that observed in the shallow aquifers, most likely due to the limited and slow recharge processes associated with these semi-confined systems.

Green (2006) specifically addresses groundwater levels during a drought period in the early 2000s. During this period, surface water runoff was minimal and groundwater extractions were high. As a result, the deep groundwater levels were at some of their lowest observed levels and the aquifer was noted in several reports as stressed over this period of time (Green, 2006; DECCW Water, 2011). While limited monitoring data is available to quantify groundwater extractions during this period, Green (2006) speculated that this was likely associated with the over-extraction of groundwater due to limited surface water availability during the drought. The drawdown covered an area more than 3 km wide with drawdown levels varying from 8 to 19 metres (Green, 2006). An embargo on new licences was also imposed on the Alstonville aquifer in 2000 to prevent further stress on the aquifer (DPIE Water 2019, pers comm., 30 October).

From early 2003 onward when the drought ceased, the levels in the deep aquifer system started to recover. From that time until the data was analysed for the 2006 status report, the deep aquifer levels rose by 8 to 25 metres across the aquifer (Green, 2006; DECCW Water, 2011). By 2009, the Department noted that groundwater levels had recovered to levels seen in the 1980s when monitoring commenced. In addition to rainfall slowly providing recharge to these aquifers, it is likely that extraction of the groundwater reduced significantly when surface water became more plentiful. However, as groundwater use in the Alstonville region is largely un-metered, conclusions about the impact of pumping and climate are difficult to differentiate in the deeper aquifers.

3.4.2 Alstonville monitoring data between 2006 – 2018/2019

In 2005-2006, after completion of the groundwater status report discussed in the section above, the Department expanded the monitoring network to consist of 29 monitoring piezometers across 13 sites measuring both shallow and deep aquifer levels. While no additional reporting had been undertaken analysing the Alstonville Plateau data since the detailed 2006 report (Green, 2006) and a brief update in 2009 (DECCW Water, 2011), groundwater level data has been continually collected on the expanded monitoring network.

A basic analysis of the data from the previous thirteen years (2006-2019) has been undertaken by the Review to provide insight into the state of the Alstonville aquifer today and the impact of environmental variables (e.g. rainfall and seasons) on groundwater levels in the region. Data was accessed for all 29 monitoring piezometers in the Alstonville Plateau. The location of each piezometer (including depth) is summarised in Figure 16 and Table 12.

In summary, the analysis detailed below shows, during the period from 2006 onward, the readings from shallower piezometers, tend to be more variable and show increases following periods of rainfall. The deeper piezometers (depths around 50m+) tend to be more stable, showing a tendency towards a steady upward trend over time. The analysis below has identified lagged rainfall as an important variable for understanding piezometer water levels in the Alstonville Plateau, especially in shallow piezometers and deeper piezometers that are indicating connection to surface waters and upper aquifers. There were no strong seasonal effects shown on water levels or pressures, but almost all the piezometers showed temporal effects.

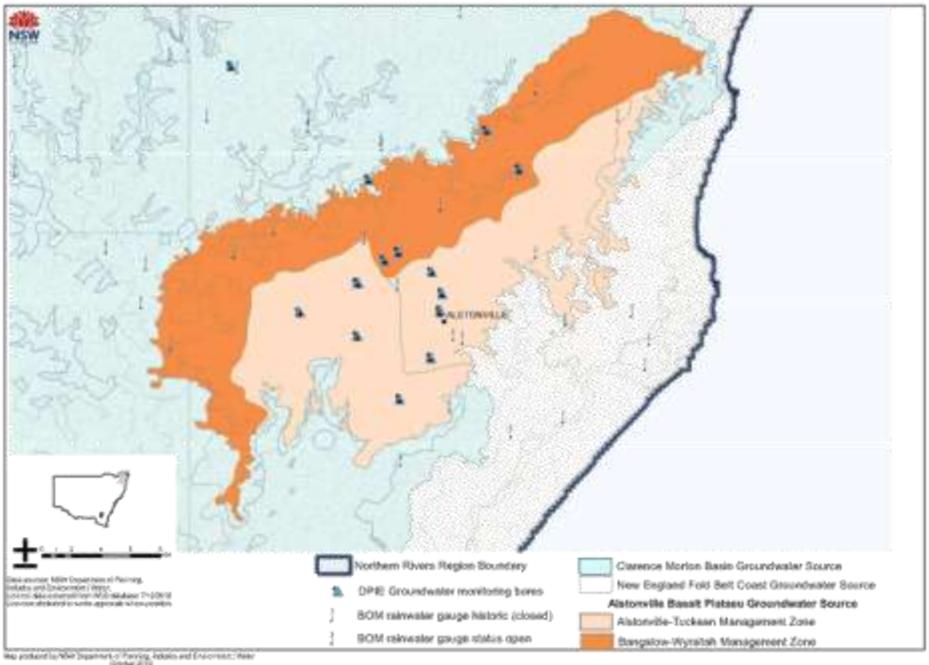

Figure 16: Map of Alstonville showing the 13 sites for the Alstonville monitoring piezometer network

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Table 12: DPIE groundwater monitoring piezometer network at Alstonville
Shows depth classification (shallow, medium or deep)[1], year drilled, the amount of variability of the levels explained by rain, season and time through a GAM analysis.

Piezometer ID	Hole	Pipe	Depth[1]	Year drilled	Lag (days) &	Variance Explained (post 2006) #		
						Rain	Season	Time
GW040999	1	1	Shallow	2005/6	30	57%*	8%*	10%*
GW040999	2	2	Deep	2005/6	40	1%	7%	98%*
GW041001	1	1	Shallow	2005/6	30	68%*	8%*	8%*
GW041001	2	2	Deep	2005/6	40	3%	2%	99%*
GW041002	1	1	Deep	2005/6	200	61%*	5%	75%*
GW041003	1	1	Shallow	2005/6	30	39%*	11%*	8%
GW041003	2	2	Deep	2005/6	180	63%*	5%	19%*
GW041004	1	1	Shallow	2005/6	150	50%*	11%*	8%
GW041004	2	2	Deep	2005/6	150	51%*	11%*	8%
GW041005	1	1	Shallow	2005/6	30	53%*	3%*	5%*
GW041007	1	1	Medium	2005/6	100	55%*	7%	19%*
GW041007	1	2	Deep	2005/6	120	51%*	7%	22%*
GW041008	1	1	Shallow	2005/6	120	56%*	10%	37%*
GW041008	1	2	Deep	2005/6	150	58%*	16%*	36%*
GW041000	1	1	Deep	2005/6	280	17%	2%	94%*
GW041000	1	2	Deep	2005/6	280	20%*	3%	95%*
GW081005	1	1	Deep	1999	280	2%	1%	99%
GW081006	1	1	Shallow	1999	120	44%*	5%	42%*
GW081002	1	1	Deep	1999	280	45%*	7%	71%*
GW081003	1	1	Medium	1999	150	66%*	14%*	35%*
GW081004^	1	1	Shallow	1999	NA	NA	NA	NA
GW081000	1	1	Shallow	1999	150	47%*	4%	15%
GW081001	1	1	Deep	1999	280	2%	11%	99%
GW036702	3	1	Shallow	1987	150	49%*	4%	8%
GW036702	2	2	Shallow	1987	280	29%*	21%*	18%*
GW036702	1	4	Deep	1987	NA	NA	NA	NA
GW036701	1	1	Shallow	1987	240	33%*	11%	41%*
GW036701^	1	4	??	1987	NA	NA	NA	NA
GW036701	2	2	Deep	1987	280	8%	3%	97%

& Lag associated with the best predictive power
# variance explained corresponds to the percentage of variability in the data that can be explained by a GAM model that includes all three factors (rain, season and time) compared to a model that leaves each respective factor out.
* Significant at $p<0.05$ based on a likelihood ratio test with block bootstrap
^ This piezometer had only limited data and none past 2006
[1]Classifcation of shallow, medium and deep provided by DPIE Water. Generally DPIE Water are classified shallow with screen interval up to approximately 25 m, medium 25-40 m and deep 40m onwards, with the deepest having a screen interval 150-168 m. The conceptual model indicated the shallow aquifer runs to approx. 50 m with the deep aquifer >50 m

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The monitoring data alone will not separate the effects of extraction from climate, but analysis of rainfall patterns over the period can give some indication of the impact of climate variability on groundwater levels. This complements the qualitative analysis of how long-term river baseflows relate to climate in the Initial Report, which found a strong and consistent influence of climate but no evidence of other influences.

The analysis in this section is not intended to be an in-depth hydrogeological analysis, but rather an empirical statistical analysis to assess the long term changes in water levels in each piezometer. The water levels in the piezometers over the last decade are shown in Figure 17 and Figure 18. Piezometer levels here refer to the distance (in metres) from the measuring point to water.

Figure 17 and Figure 18 also shows interpolated rainfall sourced from the SILO database (Queensland Government, 2019) to improve the understanding of the relationship between rainfall and groundwater levels. As evident in these two figures, the groundwater level data is not continuous at every monitoring station, with several extended gaps in a number of the monitoring wells, especially in the earlier periods. There are also several notable dips in the levels from two deep pziemometer. The Review was unable to confirm the cause, but it was speculated that these may have been due to measurement error, periods when the data from the logger was being downloaded or the logger was down.

The shallower piezometers are more variable and appear to be recharged regularly with rainfall. Figure 18 shows that the deeper piezometers (depths around 40-50m+) tend to be quite stable, with a tendency towards a steady upward trend over time.

The Review team undertook some statistical analyses to consider these observations in more detail. In particular, a statistical technique called the Generalized Additive Model or GAM (Hastie & Tibshirani, 1990) was used. GAMs have become very popular as an exploratory data analysis tool that allows one to assess the relationships between variables of interest without having to impose strong modelling assumptions such as linearity. They are popular for modelling environmental data where non-linear effects arise often and where it is desirable to use analysis tools that let the data drive the results rather than imposing strong assumptions.

For the purpose of this investigation, the Review team developed GAM models that predict piezometer level (in metres below measuring point) as a function of time, rainfall and season. The purpose of this analysis is to investigate how much of the variability in groundwater levels in each piezometer is associated with each of these three components. The Review explored a range of options for how to best incorporate rainfall into the model. It found that 'lagged rainfall' averages, where rainfall is reported for each day as the average rainfall over the previous x days (where x was allowed to range from 10 days up to 240 days) provided a better explanation of variability in the piezometers than daily rainfall. While other lagged rainfall distributions may be suitable, for the purpose of this simplified analysis, the unweighted average over the x days is used. For each piezometer, the Review team re-ran the GAM models to identify the most appropriate lagged rainfall average(x). The sixth column in Table 12 shows the best identified rain lag variable value for each piezometer.

Following this analysis, the extent to which each component contributes to the variability of each piezometer was calculated. To ensure that the significance tests were appropriately adjusted for autocorrelation induced by the time-series nature of the data, a technique called the block bootstrap (Kunsch, 1989) was used, which has been implemented using the *boot* package in the statistical programming environment, R (Canty & Ripley, 2019). This analysis is an alternative to using the Seasonal Kendall Trend test, which is popular in hydrogeology.

Table 12 shows the percentage variability in measured piezometer levels that can be explained by lagged rainfall, season and time (shown in columns 7, 8 and 9 respectively). The data is analysed from 2006 onward in order to boost statistical power to detect effects. These figures were computed by running models leaving out each factor and comparing the deviance explained by that model to the deviance explained by the model with all three factors in included. Statistical significance was assessed through use of a likelihood ratio test, using the block bootstrap to adjust for autocorrelation. Numbers that are statistically significantly different from 0 at $p<0.05$ are indicated by an asterix. A higher percentage indicates that the water levels in that piezometer are more highly correlated to that particular variable.

Table 12 suggests quite a lot of variability between piezometers and locations. In some cases, for example piezometer number GW41008, shown in Figure 19, rainfall averaged over the previous 120 to 150 days could explain quite large amount (>55%) of the observed variability in day to day piezometer levels. The strong association between the lagged rainfall and measured piezometer level is visually quite striking in Figure 19. In general, lagged rainfall was found to explain 30% - 70% of variance in shallow piezometers, which is consistent with the findings of Green (2006) who noted that these shallow aquifers are rapidly recharged through direct rainfall. The Review had anecdotal information that groundwater extraction may be higher during dry periods; this analysis indicates the impact of low rainfall periods on groundwater levels may be from a variety of factors.

The correlation between rainfall and water level variance in deeper piezometers was less consistent. Rainfall was observed to account for more the 50% of variability in some deeper piezometers (such as GW410002_1_1, GW410003_2_2, GW410004_2_2). This indicates that some of the deeper piezometers have some connection with surface waters (possibly through upper aquifers) and are unlikely to be within confined aquifers. However, rainfall effects were less significant in other deep piezometers (see GW040999_2_2, GW041001_2_2, GW041000_1_1, GW041000_1_2, GW081005_1_1, GW081001_1_1, GW036702_1_4, GW036702_2_2). This suggests that these aquifers are confined (or semi confined) as per the observations of Green (2006). Further work could be undertaken, based on this analysis and existing geological mapping, to potentially identify confined aquifers, but this analysis has not been undertaken as part of this review.

The majority of the piezometers showed no significant seasonal effect after adjusting for rainfall. However, almost all the piezometers showed significant temporal effects. By this we mean that including time in the model provided a statistically significant improvement compared to models that did not include time. We undertook further analysis to determine whether these time effects could be described as linear or non-linear. For the most part, we found significant non-linear effects, though visually these effects were not strong. For the majority of deep piezometers, the overall time-effect explained the majority of variation in observed levels. The significance of the time variable may reflect other factors not incorporated into our modelling, for example changes in patterns of extraction or other aspects of rainfall not adequately captured with the lagged rainfall variable tested in the GAM analysis.

The three panels in Figure 19 provide more detail on the GAM analysis for a single piezometer (GW041008) to further illustrate the outcomes of this analysis. Panel a) reveals a strong and fairly linear relationship between lagged rainfall and piezometer water levels. This suggests that as rainfall occurs, piezometer water levels respond. As such, there is a possible recharge mechanism of the rainfall to the aquifer and the aquifer is unlikely to be fully confined.

Panel b) shows the relationship between piezometer water levels and time. While there does appear to be some correlation between time and water level, the pattern is not particularly linear or systematic (in terms of either a general increase or decrease). As stated above, this is likely to reflect other environmental factors (e.g. extraction or surface water connections) that have not been considered in the analysis. Further analysis would be required to identify other factors that may be significantly impacting groundwater levels throughout the Alstonville Plateau.

Panel c) shows the relationship between piezometer water levels and seasonal effect. While technically this particular piezometer shows a statistically significant seasonal effect (in terms of having a p-value less than 0.05), it is not a strong effect and no clear pattern can be visually discerned. The contribution of seasonal effects to piezometer water level variability was generally found to be small for most of the piezometers considered in this analysis. Even in cases where the analysis revealed a statistically significant seasonal effect, the magnitude of change in piezometer levels over a season tended to be very modest (after accounting for rain and overall time effects). This suggests that the season has a relatively minor impact on piezometer water levels in the Alstonville Plateau. Similar detailed analysis for all piezometers is provided in Appendix 5.

The availability of reliable monitoring data on these piezometers from the Alstonville region provides an invaluable tool for stakeholders who wish to understand how patterns might be changing over time or in response to rainfall and other factors. While the simple empirical analyses presented above are by no mean a replacement for more sophisticated hydro-geologically based models and might be improved by further or modified inputs, they are a useful tool for planning and monitoring. This analysis has identified lagged rainfall as an important variable for understanding piezometer water levels in the Alstonville Plateau, especially in shallow piezometers and deeper piezometers that are well connected to surface waters and upper aquifers.

Water levels in these piezometers should continue to be regularly assessed to ensure periods of sustained water level decline are identified early. If further analysis can identify how changes in extractions relate to trends in groundwater decline and recovery, it may be appropriate to set trigger values for water levels in key deep aquifers that allow for adaptive management of groundwater extractions (e.g. once water levels fall below a certain level, restrictions may be placed on extractions in that area).

Figure 17 and Figure 18 were created using an on-line tool created by the Review team that can be used to interactively view hydrographs similar to those reported by Green (2006) and showing the piezometer levels over time, along with a graphical display of rainfall levels over the same time period. The online hydrograph tool allows the user flexibility in terms of which piezometers to plot as well as whether to display daily rainfall or lagged averages (discussed above). The hydrograph tool also allows flexibility in terms of zooming in to a particular time period of interest. While this tool does not offer the same breadth of information as available in Groundwater Explorer, it has the advantage of being simpler to use and is also much quicker to run. The Review will explore the possibility with DPIE Water of the interactive hydrograph tool being made more widely available.

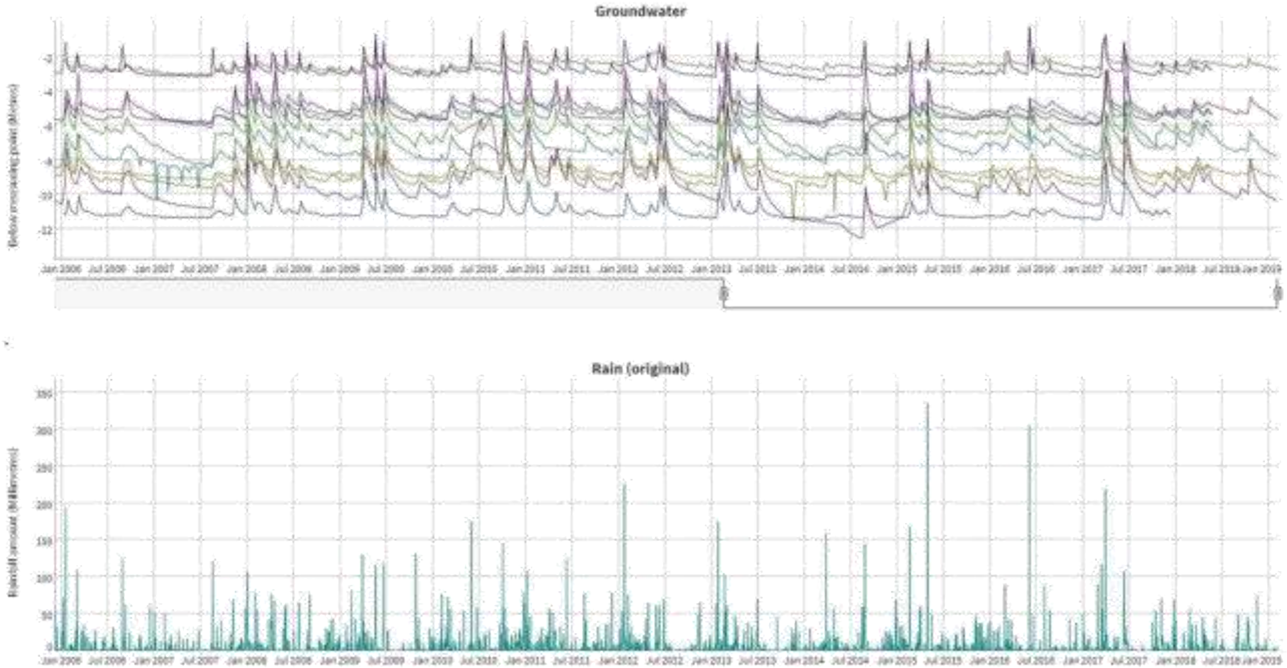

Figure 17: Hydrographs showing the levels of 12 'shallower' piezometers in the Alstonville Plateau from 2006 to present.
These include GW040999.1.1, GW041001.1.1, GW041003.1.1, GW041004.1.1, GW041005.1.1, GW041008.1.1, GW081006.1.1, GW081004.1.1, GW081000.1.1, GW036702.3.1, GW036702.2.2, GW036701.1.1. The vertical axis in the top panel shows the distance from measuring point to water for each piezometer while the x-axis shows date. The bottom panel shows daily rainfall associated with the Alstonville Tropical Research Station.

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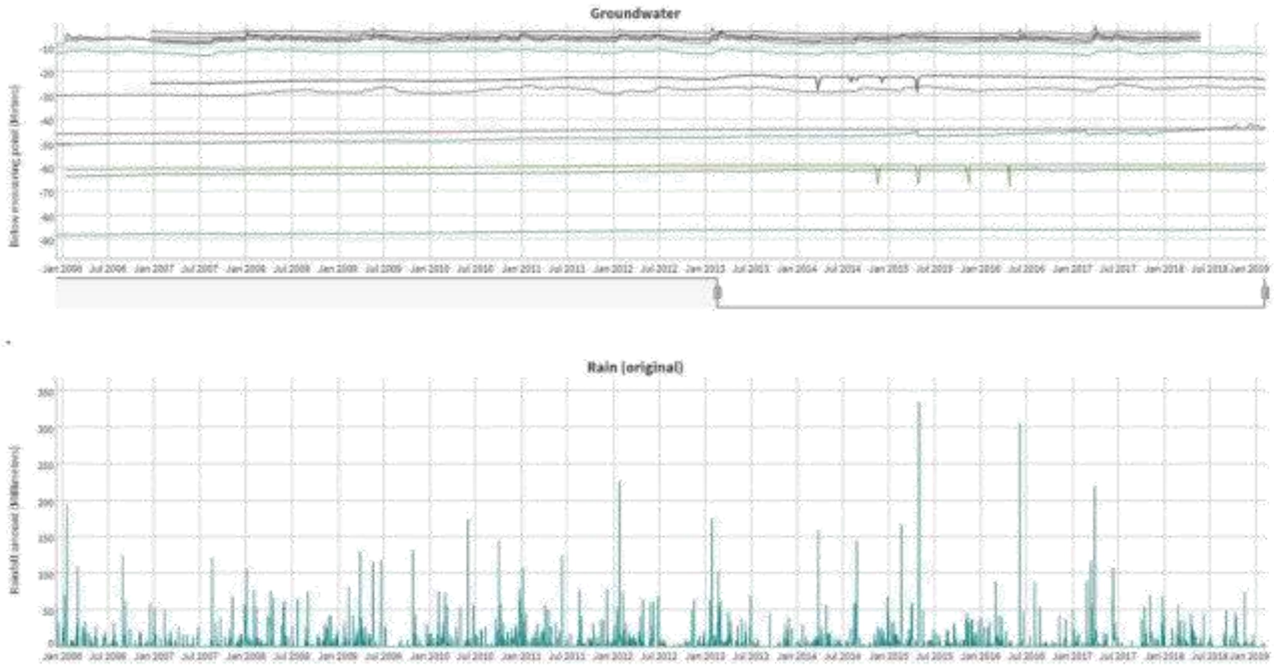

Figure 18: Hydrographs showing the levels of 16 'deeper' piezometers in the Alstonville Plateau from January 2006 to present.
These include, GW040999.2.2, GW041001.2.2, GW041002.1.1, GW041003.2.2, GW041004.2.2, GW041007.1.1, GW041008.1.2, GW041000.1.1, GW041000.1.2, GW081005.1.1, GW081002.1.1, GW081003.1.1, GW081001.1.1, GW036702.1.4, GW036701.1.4, GW036701.2.2
The vertical axis in the top panel shows the distance from measuring point to water for each piezometer while the x-axis shows date. The bottom panel shows daily rainfall associated with the Alstonville Tropical Research Station.

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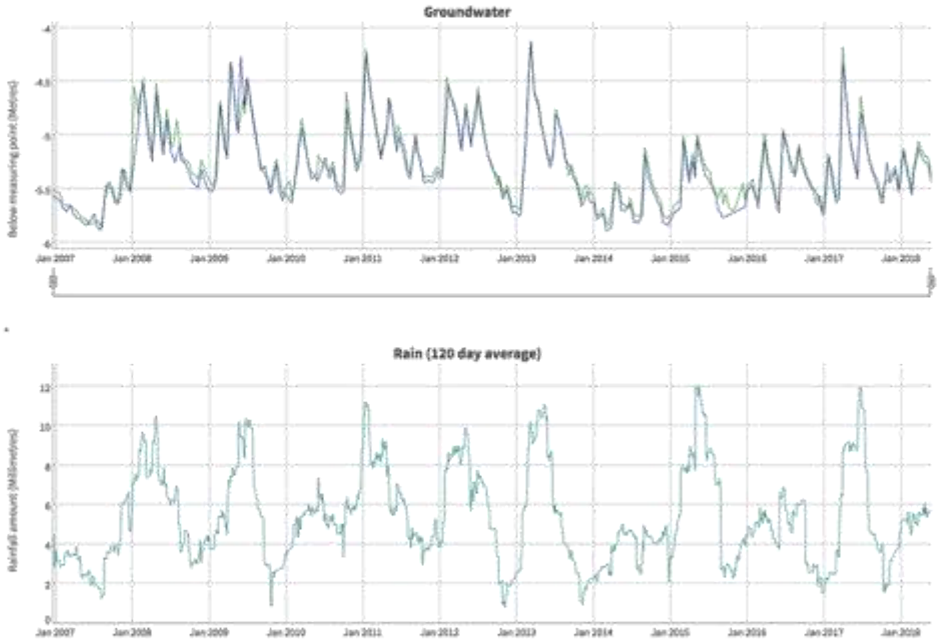

Figure 19: Hydrograph for Piezometer GW041008, Hole 1, Pipes 1 and 2 with 120 day rainfall average plotted in the lower panel.

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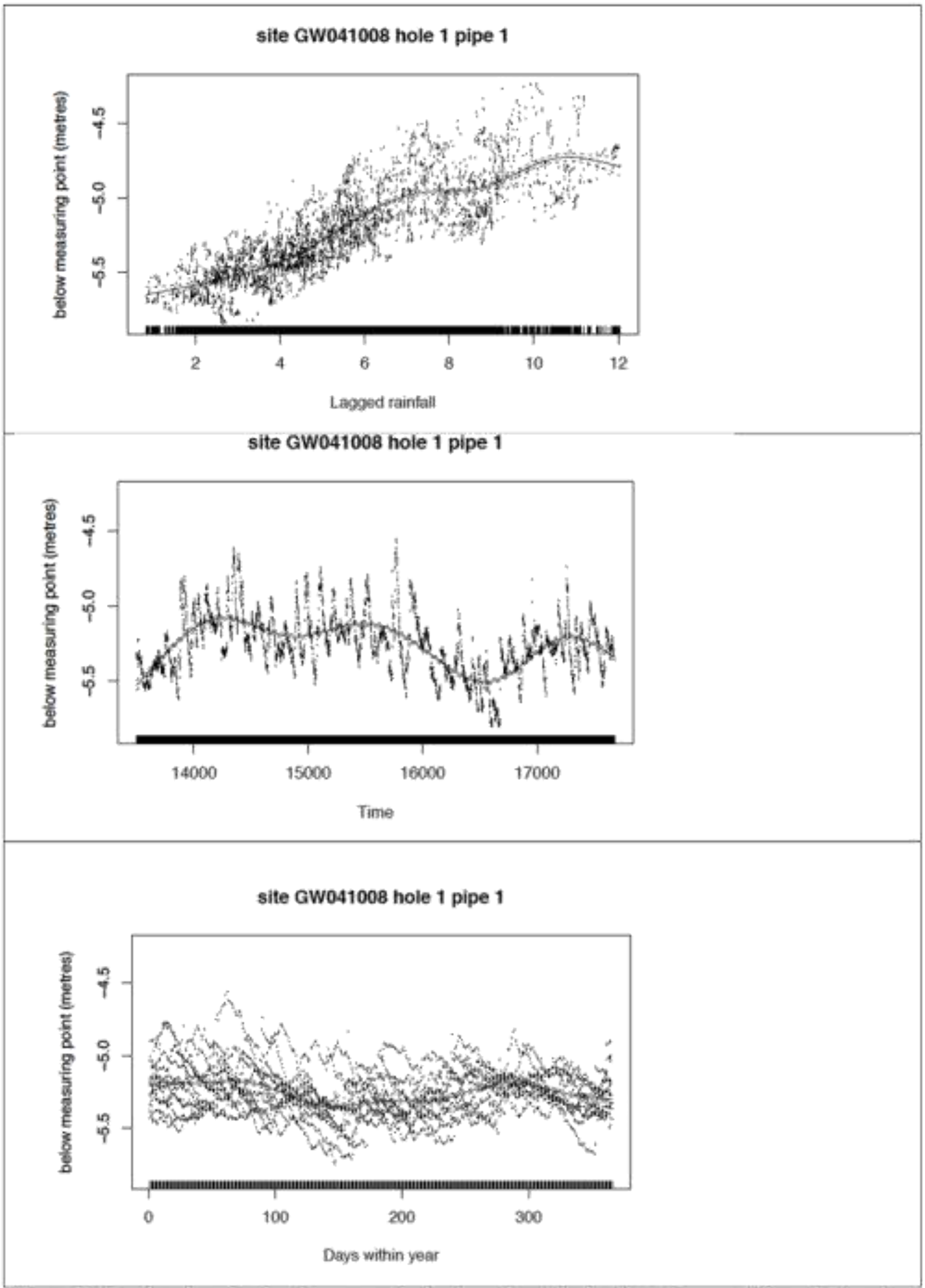

Figure 20: Panels a, b and c showing, respectively, the estimated rain effect, the overall time effect and the seasonal effect estimated from fitting a GAM model

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3.5 CONCLUSIONS

The WSP aims to set sustainable extraction limits for the groundwater sources through consideration of a number of parameters, including rainfall over the area, recharge rates, areas of high and non-high environmental value and a sustainability index. These variables are subject to a level of uncertainty associated with the predictions and a precise value may not be achieved due to the complex and heterogeneous nature of groundwater movement. This is particularly evident in fractured rock systems that are difficult to fully characterise. Given this, a range of practices have been used in developing and managing the WSP to account for, or reduce, uncertainty – conservative calculations, adaptive management, sensitivity testing, examining multiple lines of evidence.

The recharge rate, in particular, was considered in detail in this Review as a key technical variable in the determination of the extraction rates. This was done through a review of literature of recharge rates on comparable aquifers and application of alternative techniques as a basis for recharge rates (chloride-mass balance and baseflow filtering).

WSP assumptions

- In groundwater studies and management, there will always be a level of uncertainty associated with predictions (e.g. recharge rates) and a precise value may not be achieved due to the complex and heterogeneous nature of groundwater movement. This is particularly evident in fractured rock systems that are difficult to characterise fully.
- The WSP plan was developed based on the best available data at hand and followed a standard procedure. The assumptions made in the WSP are practical, reasonable and in agreement with standard practice. In general, the WSP incorporates a reasonable level of conservatism for extraction limits based on the risks identified.
- The rainfall data used and the methodologies are sound and apply limited uncertainty to the extraction rates.
- The portion of the estimated recharge value available for extraction is a function of rainfall recharge over low environmental value areas together with an assessment of environmental and socio-economic risk.
- Calculating recharge is complex due in part to the variability and complexity of the hydrogeology and limited knowledge of the systems. Based on the analysis, the Review considers the recharge rates used in the WSP are reasonable and conservative. This statement is made with a relatively low level of confidence due to lack of data for the groundwater sources of interest.
- In practical terms the groundwater sources are treated as geologically homogenous which adds uncertainty and would benefit from further work. The Review recognises that the complexity of the geology makes it difficult to incorporate heterogeneity into the WSP recharge calculations. Particular attention should be given to the effects of geological variability within groundwater sources, and soils and vegetation overlying aquifer outcrops. The Review acknowledges the conservatism incorporated into the current WSP through the allowable allocation figures.
- There is evidence to suggest that for the WSP recharge variable, there is a wide range of values that can be applied as well as a number of different approaches to calculate it. Limited field data is available to support a single estimate and best practice is to use more than one estimation method to reduce uncertainty if possible.
- Recharge rates applied to the four groundwater sources in scope in the WSP ranged from 4% - 8% with studies and alternative methods indicating, with considerable uncertainty, levels between 1% and 31%. The calculations by the Review using CBM and baseflow filtering for recharge rates had results mostly above the values used in

the WSP. The Review noted the important contribution that surface conditions and soil could make to the recharge of the underlying geology.

- The Review tested a scenario in which the recharge rates were reduced by 80%. It found the recharge reserved for the environment for the New England Fold Belt Coast and North Coast Volcanics would remain at around 80% of recharge. For Alstonville, it would be reduced, but the network of monitoring bores provides the ability to monitor long-term changes in levels. For the Clarence-Moreton Basin, with a relatively low volume water allocated, the LTAAEL could be reduced with no impact on licences.
- Based on the analysis, the Review considers the recharge rates used in the WSP are reasonable and conservative. This statement is made with relatively low level of confidence due to lack of data for the groundwater sources of interest.
- The application of the sustainability index appears to be a cost and time effective risk tool that is applied as an additional means to protect resources where limited information is available.
- The WSP incorporates a reasonable level of conservatism for the extraction limits when the groundwater sources are not fully allocated and where they are fully allocated at Alstonville, monitoring is applied.
- Additional monitoring in strategic locations in the Tweed would help inform gaps in knowledge on a regional scale and provide a path towards better conceptual understanding of aquifer flows.
- The overall system is managed with some level of adaptive management, including an annual determination of the volume of water per licence share and WSP are subject to an interim review at five years with a full review at ten years.
- Impacts of climate change should be considered in future WSP methodologies. A warming climate can lead to increases or decreases in rainfall at a location, variations in the timing and frequency and strength of rainfall events, and increases or decreases in evapotranspiration. The development by the NSW Government of Regional Water Strategies will provide further insights into the impact that climate change could have on the region and catchments over the coming decades, which can further inform management approaches for the region's water resources.

Sustainability of WSP extraction limits

- Due to limited extraction levels (where known allocations in the Tweed region are much lower than the extraction limits contemplated in the WSP), limited data and uncertainties described regarding the WSP parameters, it is not possible to conclude whether the extraction limits are currently sustainable. However, the Review found no evidence at this point in time that current WSP extraction limits are not sustainable.
- For the Alstonville Basalt Plateau Groundwater Source, which is fully allocated, and there is a network of monitoring piezometers, data from 2006 onwards was analysed by the Review, which concluded:
  - The deeper piezometers (depths greater than around 25 m) showed a greater stability and a steady upward trend over time of groundwater levels and/or pressures. In contrast, the shallower piezometers showed greater variability and appear to be recharged more regularly with rainfall.
  - Lagged rainfall is an important variable for understanding piezometer water levels in the Alstonville Plateau. This was observed in shallow-sited piezometers and in deeper piezometers sited in systems that are well connected to surface waters and upper aquifers.

- There is limited amount of information available on current actual extraction volumes. The Review notes that enhanced metering requirements will come into force in the region in 2023 for eligible groundwater extractors. Given this lack of data on extraction volumes, it is difficult to separate the effects of environmental variables (such as rainfall) from the impacts of human extraction (which tends to increase during dry periods).

Methodological improvements

- The Review considers there is room for improvement in the future assessment of the variables underlying the extraction limits.
- Impacts of rainfall patterns in the region on recharge should be considered in future WSP methodologies, including changing patterns associated with climate change.
- Particular attention should be given to assessment of groundwater recharge rates across broad spatial areas and the associated need to distinguish between confined versus unconfined aquifers.
- Developing a better conceptual understanding of the geological strata in the WSP to reduce the level of uncertainty in the estimated recharge values. This could possibly be undertaken via a 3D geological modelling tool (e.g. Leapfrog Geo) where there is sufficient data and should include some soil mapping. This would require a large scale detailed geological mapping survey or the collation of the existing core log data and geophysical measurements, where available. The Review notes this level of detail has not been typically applied in similar WSP for easterly flowing rivers and would require allocation of time and resources.
- Sensitivity testing could be undertaken to see whether a change in the recharge or sustainability index might result in the aquifers being over allocated or stressed.
- Further work could be undertaken to assess whether the risk ratings given to specific groundwater sources are appropriate.
- Water levels in the Department's piezometers should be regularly assessed to ensure periods of sustained water level decline are identified early. With further analysis, it may be appropriate to set trigger values for water levels in key deep aquifers that allow for adaptive management of groundwater extractions (e.g. once water levels fall below a certain level, restrictions may be placed on extractions in that area).
- Where the system is fully (or near fully) allocated, additional monitoring/sampling and routine data analyses could be applied, as was undertaken at Alstonville, within an adaptive management framework.

4 EXTRACTION IMPACTS: UNDERSTANDING, ASSESSMENT AND MANAGEMENT

The focus of this Chapter is on the mechanisms that cause impacts and consequences; the complexities in measuring local scale impacts from bore extraction; the hydrogeological assessments that form part of the development application and licencing processes; associated assessment challenges and potential management solutions; and additional information that would help to understand the systems better.

4.1 EXTRACTION IMPACTS AND CONSEQUENCES

For this Review, an impact refers to the physical change that occurs from an action (such as groundwater extraction), while a consequence (following the analogy) may be the temporary or permanent loss of water access or loss of environment for GDEs and associated flora and fauna. An example would be if groundwater extraction results in reduced pressure heads and groundwater discharge to a local creek (impact), which then affects flora or fauna dependent upon that water source (consequence). Risk refers to the level of potential consequence combined with its likelihood of occurring.

4.1.1 Impact mechanisms

There is an extensive volume of literature detailing the impact mechanisms from a bore (or bore field) on the surrounding aquifer or connected waters. Readers are directed to Acworth (2019) for a recent and detailed description of processes in Australia. In brief, groundwater extraction from an aquifer (via a groundwater bore) reduces hydrostatic pressure heads at the bore, creating a differential pressure gradient that induces water flow towards the lower pressure area (i.e. towards the bore). The area influenced is called the 'zone of influence' or 'cone of depressurisation' or 'cone of depression' surrounding the bore (Figure 21). The size of this zone, and the nature and degree of the pressure head change and resultant flow paths, depends on the hydrogeological properties of the rock or soil matrix, as well as on the rate and duration of the extraction(s).

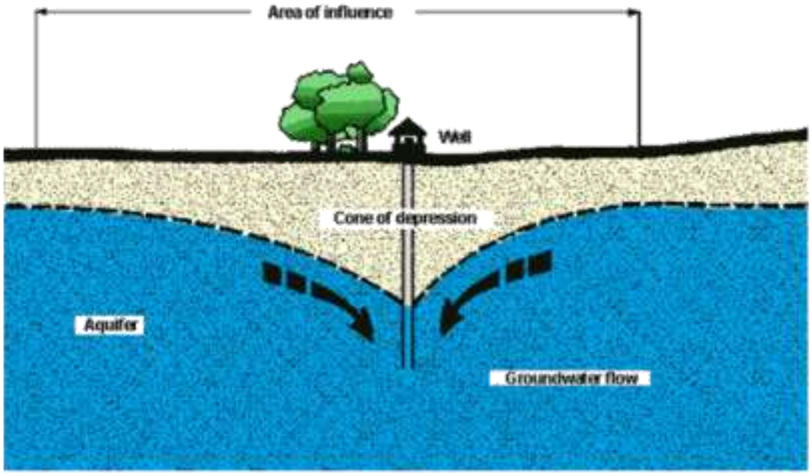

Figure 21: Area of influence and cone of depression in the aquifer due to groundwater pumping
Source: Oregon State University (2019).

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The primary means to calculate flow in porous media is Darcy's Law. This equation states that flow is a function of the differential pressure heads across an area and the saturated hydraulic conductivity. The saturated hydraulic conductivity is a measure of how water flows through an aquifer and its value varies widely – over at least 10 orders of magnitude - depending on the rock or soil type, integrity and structure. Large variations in hydraulic conductivity may apply even in the vicinity of a single zone of influence. Whereas pressure heads can be directly measured via piezometers, assumptions are often made (based on our geological understanding) to determine broad acre values of hydraulic conductivity.

In many locations the subsurface geology is complex and difficult to characterise. Natural geological structures may be heterogeneous, with variations in geology, identity, structure, and physical properties both laterally and with depth. This can result in important regional and local-scale variations in saturated hydraulic conductivity and other properties. To overcome these uncertainties, a variety of field techniques have been developed, including geophysical methods, to derive local-scale values of hydrogeological properties. The most commonly used field method is the well pump test, where water is extracted from a bore for an extended period and adjacent piezometer pressure heads are measured before, during and post the pumping period (which may be 12 hr, 24 hr, 48 hr or longer periods depending on the extraction rate and geologic properties). Other commonly used methods to calculate hydraulic conductivity include slug tests, direct pressure testing or core analysis.

In locations where the aquifer is connected (either directly or indirectly) to other systems, drawdown may reduce water yields in adjacent bores or induce diversions from other aquifers. Further, if any adjoining aquifers are unconfined, a decline in the water table elevations may decrease groundwater discharge to connected surface waters and potentially influence groundwater dependent ecosystems (GDEs). The induced flow between aquifers or from surface water may also result in water quality impairments. Importantly, if the zones of influence of two or more bores overlap, then the drawdown impacts are cumulative.

Mechanisms of impacts in practical terms are different between porous rock (e.g. Clarence Moreton Basin Groundwater Source) and fractured rock aquifers (e.g. Alstonville Basalt Plateau, North Coast Volcanics and New England Fold Belt Coast Groundwater Sources). Flow through fractured rock is dominated by discrete fractures and complex folds that formed through volcanic activity often tens or hundreds of millions years ago. In these fractured rock environments the extraction point (the bore location and pumped depth) depend on the fracture network that intersects that point. This network is difficult to accurately map without extensive hydrogeological investigations and, in many cases, cannot be explicitly determined. This means that extractions in fractured rock aquifers may be unpredictable and do not comply to Darcian theory (i.e. flow is a function of fracture size and fracture connectivity, versus pressure gradients and hydraulic conductivity). In contrast, flow through porous rock better conforms to drawdown prediction models and hence, local impacts may be more accurately predicted.

In either circumstance, expert interpretation of bore logs and pump test results is typically required to determine aquifer hydrogeologic behaviour. In a practical sense, this variance suggests that fractured rock aquifers require more investigations as they have higher uncertainty, although this should not be used as rationale to limit data gathering in porous systems. Further considerations are addressed below.

Extraction impacts are assessed in the hydrogeological assessment process for some new water extraction approvals (for example, in water access licence dealings or water supply works approvals). The range of impacts assessed and the standards for acceptable impacts are discussed below.

4.1.2 Extraction consequences

Bore water extraction can potentially impact connected water within the same aquifer, within a connected aquifer, or within a connected surface water body, leading to possible changes in water quantity or water quality.

The range of impacts described in the DOI (2018a) document includes those on the groundwater source itself (both in terms of quality and quantity), on groundwater dependent ecosystems (GDEs), surface water, culturally significant sites, and other water supply bores, as well as the compaction of sediments, and cumulative drawdown from existing approved water supply works and entitlements (DOI, 2018a). For the purposes of the Review's report, for ease of explanation, physical impacts (such as on groundwater quantity and quality) are distinguished from consequences (such as on culturally significant sites). Depending on the magnitude and extent of the impact, these changes can result in environmental consequences both within and outside the aquifer.

GDEs are a type of ecosystem which can be impacted by groundwater extraction. GDEs are generally recognised as "*ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services*" (Kuginis et al., 2016). Not all GDEs draw on groundwater directly and not all are solely reliant on groundwater, and the groundwater dependence of GDEs will vary due to climate, geology and land use.

The extraction of groundwater can harm GDE ecology if it impacts the amount of water entering wetlands and water courses, may lead to alteration of the ecosystem and loss of ecosystem services (Eamus et al., 2006). For example, where extraction increases the depth to groundwater, the availability of water within the root zone of terrestrial groundwater dependent vegetation will be reduced, which could lead to stress and the potential loss of vegetation (Eamus et al., 2015). Further monitoring and studies are required to improve understanding of tolerance thresholds; and the relationships between drawdown, changes to the groundwater environment and impacts on biota. Impacts to GDEs are considered in the hydrogeological assessment process for groundwater extraction approvals. This process seeks to minimise impacts on groundwater levels associated with GDEs and prevent unacceptable consequences on GDEs.[47]

4.2 COMPLEXITIES IN MEASURING LOCAL SCALE IMPACTS FROM BORE WATER EXTRACTION

4.2.1 Variability of fractured and porous rock systems

There are well established methods for measuring and/or predicting local scale groundwater and surface water impacts. However, in the complex systems of interest here, considerable technical challenges and costs are expected. Addressing these challenges can lead to conservative generalisations or assumptions that idealise the system features, which may or may not be conservative. A brief discussion of these challenges is provided in this section.

The region of interest is characterised by complex geology, with three fractured rock systems (New England Fold Belt Coast, North Coast Volcanics and Alstonville Basalt Plateau) and the Clarence Moreton Basin porous rock. As noted above, fractured rock systems may be highly variable and it is often difficult to assess the size, shape or connectivity of the fracture network. Typically, this uncertainty cannot be resolved via field data collection and assumptions are required to predict sustainable yields.

In contrast, the Clarence Moreton Basin generally consists of porous rock aquifers that are easier to conceptualise. Nevertheless, aquifer property variability within the Clarence

[47] Other potential activities that can impact GDEs include contamination, salinisation, vegetation clearing and filling or draining of wetlands.

Moreton Basin can lead to fractured rock-like behaviour. Overall, the complexities, challenges and costs involved when working in these hydrogeologic systems must be recognised when considering new monitoring guidelines or requirements.

There are considerable challenges in measuring impacts from groundwater extractions. Spatial and temporal variability means that existing groundwater pressure monitoring is unlikely to be sufficient, and monitoring should consider the need for an adequate number of appropriately located measurements. Analytical or numerical modelling may be required to extrapolate the measured pressure drawdowns to the asset locations but these models are only as sufficient as the data used to conceptualise the system. Therefore, it is not a trivial decision to request or require comprehensive assessments/modelling especially where there is already available field (including local) information to indicate that the risks are low.

4.2.1.1 Spatial variability of hydrogeology

Spatial variability in aquifer hydrogeology exists over both regional and local scales. Over regional scales, there will be significant variability in the source aquifer properties and their overlying (potentially confining) layers. This suggests that broad-scale generalisations about aquifer properties, and their degree of confinement (including those made in the WSP), cannot be directly applied to a local scale impacts assessment. Similarly, using hydrogeological properties measured in other water catchments and aquifers, even those of the same classification, is of limited value. Over local scales, fractures and other variations in hydrogeological properties in the area around an extraction bore mean that single or even multiple observations of hydrogeological properties or drawdowns (e.g. during pump tests) may not adequately characterise the Representative Elementary Area (REA). The concept of the REA suggests that the area under observation should be of sufficient size to adequately represent the broader characteristics. In porous media the REA can be relatively small, whereas in fractured rock areas the REA must be much larger to be equally representative.

Another key factor is the connectivity between deep and shallow aquifers. Bore logs showing clay layers (aquitards) between shallow and deep aquifers are sometimes used to support the view that shallow aquifers and surface water are unlikely to impact one another (e.g. aquitards or aquicludes). Moreover, while it may be correct that this supports the argument that there is no connectivity along the profile of the bore log, the spatial continuity of the aquitard is typically uncertain and the area in question may not be characteristic of its REA.

The local-scale spatial variability means that consequences for GDEs and water supply works will not necessarily be at the locations closest to the proposed extraction point. Further, flow pathways between the extraction point and the assets may deviate substantially from straight lines. It is therefore challenging to determine appropriate monitoring locations for measuring depressurisation as the extraction point propagates in various means towards the assets at risk.

The complexities of evaluating and ascertaining potential connections between the deeper groundwater system, the shallower aquifers and impacts on local assets, as a result of spatial variability, is detailed in a case study of town water supply bores at Lumley Park and Convery's Lane which draw from the deeper aquifer in the Alstonville Basalt Plateau Groundwater system. This case study is included at Appendix 6.

4.2.1.2 Temporal variability

Temporal variability of groundwater pressures and surface flows is related to climate, extractions and potentially other human influences. These influences on pressures and flows can have time-lags varying between minutes to years and have complex interactions that make measurements difficult to interpret. This complexity is illustrated in the analysis of the Alstonville groundwater data in Chapter 3. In many cases (but not confined aquifer systems), there is a cone of depressurisation that encompasses assets, but there may also be assets where the impact or consequence is present but more difficult to detect and unambiguously attribute to the extraction. Continuous monitoring technology such as weather stations, pressure transducers and extraction meters facilitate detailed analysis of responses and potential drivers/influences. However, months, years or even decades of data may be required to desegregate the various influences at sites of interest.

4.3 EXISTING TECHNICAL APPROACHES TO MEASURING LOCAL SCALE IMPACTS

4.3.1 Groundwater pressure monitoring

Groundwater pressure or level monitoring is fundamental to impact monitoring. This requires the drilling and construction of monitoring bores called piezometers. This technology is well established. Generally, costs increase with the depth and numbers of bores. As much of the cost is associated with hiring a drill rig and operator, installing additional monitoring bores may not induce significant additional costs when other bores are being drilled simultaneously. Nonetheless, the location and depth of the piezometer should be based on the potential impacts being assessed and the hydrogeological conditions.

Monitoring of groundwater pressures continuously in time is undertaken in two main ways:

1) Conventional water level monitoring. Slotted pipes are installed at the required monitoring depth, whereby the groundwater stabilises to a level equivalent to the water pressure head in the aquifer. A pressure transducer installed below this level or ultrasonic transducer installed at the top of the casing can accurately measure the groundwater level at a desired time interval. This is an accurate method and has a secondary benefits as it can also be used as a sampling piezometric well to collect water quality data;

2) Vibrating wire piezometers allow pressure heads to be monitored at multiple depths, but with lower accuracy, higher cost and limited flexibility regarding the function of the bore. In any case a traditional monitoring bore would also be required to take validation measurements. Hence, conventional technology is typically more applicable in small-medium enterprises, although in principle, the later would be useful if costs reduce and accuracy rises.

4.3.2 Chemical and temperature tracers of water flow

Chemical and temperature tracers to identify groundwater flow patterns are sometimes used to supplement groundwater pressure data. The presence of multiple drivers of water pressures and flows (climate, extractions and potentially others) means that there is often ambiguity in the cause-effect relationship. In hydrogeology, this is often addressed by investigating water chemistry. For example, if the river water chemistry changes from the typical background surface water chemistry to include components of a local aquifer's groundwater chemistry, this may signal a groundwater discharge point. Vice-versa, the chemistry can be used to identify where surface water is being drawn into (recharging) groundwater.

Temperature may also be used in the same way, since groundwater temperatures are usually distinct from surface water temperatures. In this context, the chemistry or temperature are called 'tracers' of water flow. The combination of pressure data and tracers provides further lines of evidence to suggest connectivity between aquifers, or between aquifers and the surface water. Many tracers are straightforward and low cost to implement (although isotope tracers that provide more precise results and give additional information about groundwater age require specialist methods). Indeed, Radon (222Rn) is a commonly used natural environmental tracer as it provides an indicator of the volume of groundwater within a surface waterbody or it can be used to identify groundwater sources.

4.3.3 Numerical modelling

Numerical modelling is often employed where limited field data is available to make adequate predictions. In these cases, hydrogeological, surface hydrology and ecological numerical models may be used based on monitored sites/periods. Numerical models may also be used to simulate scenarios that test the effects of a single existing or proposed extraction bore field if sufficient data is available to adequately characterise the aquifer properties. The use of numerical models introduces many new technical challenges including:

- the value of the numerical model is dependent on the accuracy of the underlying conceptual model and the numerical calibration and validation process,
- the quality of the model depends on the quantity, quality and relevance of available measurements; and,
- the time, data and expertise required for numerical modelling can increase assessment costs.

The limited existing conceptual models and data sets to support modelling is a particular challenge in the Northern Rivers and even more so in the Tweed Shire due to limited previous projects that have warranted the investment. The cost of developing complex numerical models means that they are generally used for larger projects where the potential risks are considerable and the data is limited.

4.3.4 Surface water monitoring

Surface water levels can be measured continuously in time in a similar manner to groundwater. For rivers, the water levels can be converted to flow rates using a rating curve. Unless a hydraulically suitable natural site can be found, achieving accurate rating curve will require an intrusive structure (weir or flume) to be built in the river as well as calibration and regular maintenance.

Alternative non-intrusive river flow measurement technologies are also available. Another limitation of using flow measurements to detect impacts of groundwater extractions is that river flows tend to be dominated by climate influences. Along with the accuracy limitations of the flow gauge, this can make it more difficult to discern the impacts of extractions unless they are large compared to river flows. Extractions near to headwater streams may be relatively large; however further downstream the catchment (where most existing flow gauges are situated) the impacts of extractions of the magnitude relevant to this Review are unlikely to be discernible.

4.3.5 Groundwater dependent ecosystems (GDE) monitoring

Assessing the potential impact of an extraction bore relies on monitoring data measuring the local groundwater level or pressure heads. Applying information about the groundwater level to a terrestrial GDE requires an understanding of the GDE's groundwater use from surficial and deeper aquifers. In many cases there is limited information available to know the exact water requirements of the species of concern.

Methods for monitoring terrestrial GDEs include soil moisture, evapotranspiration and various ecological indices (Richardson et al., 2011). Various technologies and theoretical approaches combined with other data sources can be used to measure soil moisture and evapotranspiration. Both soil moisture and evapotranspiration can be highly variable in space and accurate estimates at one measurement do not always mean sufficient representation of potentially impacted areas. Terrestrial GDE studies conducted in other areas of NSW have generally used a multiple lines of evidence approach combining various monitoring approaches.[48] However, it is rare for this full range of monitoring approaches to

[48] Including measuring the stress of groundwater dependent vegetation through tree growth point dendrometers (stem gauges that monitor tree growth increment at small timescales), sapflow gauges and isotopic analysis of leaf samples (Eamus et al., 2015)

be considered in impact assessments except when high priority GDEs are considered to be at risk.

4.4 ASSESSMENT OF POTENTIAL IMPACTS

The WSP requires hydrogeological reports for certain extraction and development applications. This section provides further detail on the assessment processes associated with these hydrogeological reports. The next section considers the substantive content of these hydrogeological reports.

4.4.1 Applications that require hydrogeological assessment

Hydrogeological assessments may be required under the *Water Management Act 2000* for applications that will change the authorised groundwater extraction volumes from new or existing bores, for example, applications for water supply works approval or applications for water licence dealings. The types of applications that may require a hydrogeological assessment are summarised in Table 13 below.

Table 13: Types of applications under the *Water Management Act 2000* that may require hydrogeological assessment

Application type	Description
s 92: Water supply works approval	Approval to construct a new or additional groundwater work
s 71P: Subdivision and consolidation of access licences	Division of a licence into two or more licences (usually so a portion can be sold); or combining of licences
s 71Q: Assignment of rights under access licence dealing	Reduction of the share component on a licence and the increase by the same amount on another (previously referred to as a permanent trade)
s 71R: Amendment of share component of access licence	Cancel an access licence and grant a new licence in another water source or management area
s 71S: Amendment of extraction component of access licence	Change the times or rates at which water can be extracted (not generally applicable to groundwater)
s 71T: Assignment of water allocations	Reduction of allocation in a licence account and increase by the same amount in another (previously known as a temporary transfer)
s 71U: Interstate transfer of access licences	Same as 71Q dealing except it is between two interstate access licences
s 71V: Interstate assignment of water allocations	Same as 71T dealing except it is between two interstate access licences
s 71W: Nomination of water supply works to access licence	Nomination of a works removed from or added to an access licence, irrespective of ownership and location.

Source: (DOI, 2018a)

Note: Applications for interstate transfer of access licences (s 71U) or water allocations (s 71V) will not require a hydrogeological assessment if they do not impact bores in NSW.

4.4.2 Process for applications requiring hydrogeological assessment

Applications for water access licence dealings or water supply works approvals are lodged with WaterNSW.[49] WaterNSW may refer these applications to DPIE Water for hydrogeological assessment if required. DPIE Water has the necessary expertise to conduct hydrogeological assessments of applications as required. Figure 22 outlines the DPIE Water process for assessing applications for water access licence dealings or water supply works approvals.

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[49] WaterNSW is responsible for responsible for granting and managing water licences and approvals for rural landholders, rural industries, developments which are not SSDs or SSIs. However, NRAR is responsible for granting and managing water licences and approvals for government agencies, state owned corporations, water utilities, licensed network operators, mining companies, irrigation corporations, Aboriginal communities, floodplain harvesting, state significant developments (SSD), state significant infrastructure (SSI), schools and hospitals

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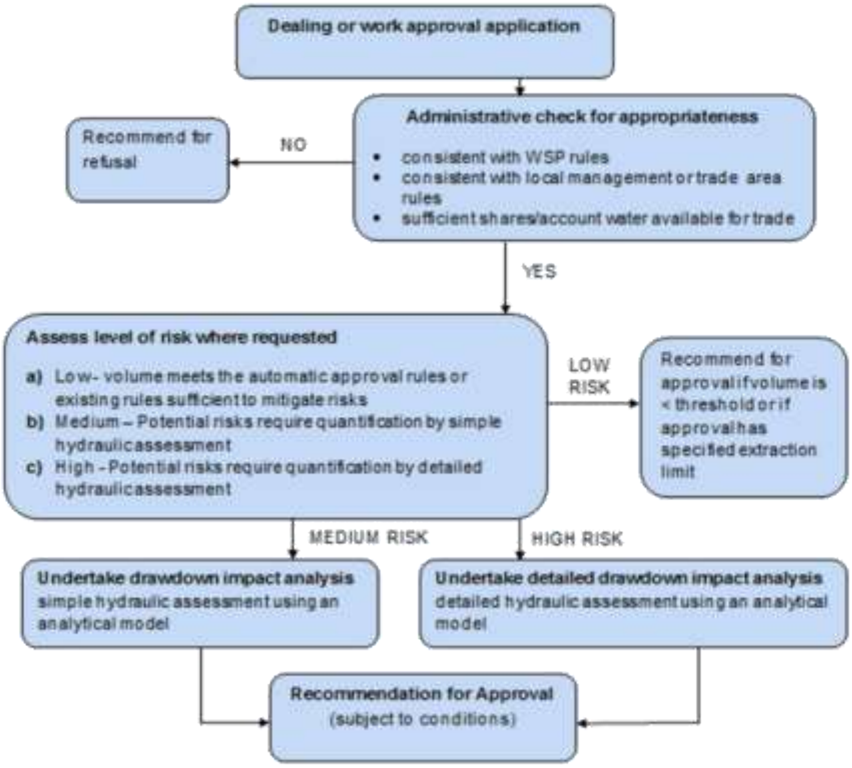

Figure 22: Process for assessing applications for new water supply works approvals and water licence dealings

4.4.3 Applications must satisfy minimum set of conditions

Prior to determining if a hydrogeological assessment is required, all applications must firstly satisfy a minimum set of conditions including:

- **Consistency with the WSP rules** – for example, the WSP may specify conditions on minimum distances to certain environmentally sensitive features (refer to Appendix 7 for further detail);[50]
- **Local management or trade area rules** – for example, certain water dealings may be subject to additional restrictions;[51] and
- **Sufficient water for trading** – for example, the seller must have sufficient shares/account water to trade.

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[50] For example, the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 40-3 specifies rules for minimum distances between water supply works to minimise interference.

[51] For example, the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 48(1)-(2) specifies prohibitions on trading between groundwater sources in the WSP and on certain assignments of rights from an access licence in the Alstonville Basalt Plateau (Bangalow-Wyrallah) Management Zone to an access licence with an extraction component that specifies the Alstonville Basalt Plateau (Alstonville-Tuckean) Management Zone. Note that this prohibition only applies if it would cause the sum of the share components of all access licences in the Alstonville Basalt Plateau (Alstonville-Tuckean) Management Zone to exceed the sum of the share components of all access licences in the Alstonville Basalt Plateau (Alstonville-Tuckean) Management Zone at the commencement of this Plan.

The *Access Licence Dealing Principles Order 2004* also specifies general principles and rules for managing dealings in rights and allocations under water access licences. The core principles expounded in the Order focus on minimising negative interference with other water users and the environment, and maximising the value to society gained by extracting the water. These principles include:

- Dealings should not adversely affect environmental water, water dependent ecosystems, or geographical and other features of indigenous, cultural, heritage or spiritual significance.[52]
- Dealings should not adversely affect the exercise of basic landholder rights.[53]
- Dealings should have no more than a minimal effect on the ability of a person to take water using an existing approved water supply work and any associated access licences.[54]
- Dealings should maximise social and economic benefits of access licences to the community. Access licence dealings rules should allow maximum flexibility in dealings to promote this objective.[55]

4.4.4 Applications are subject to a risk assessment

Applications that satisfy minimum conditions are then assessed by DPIE Water for risk to determine what level of hydraulic analysis is required to support the application. Applications can either be considered to be:

- **Low risk** – no further hydrogeological impact assessment is required;
- **Medium risk** – assessment of drawdown impacts using a simple analytical hydraulic model undertaken; or
- **High risk** – assessment of drawdowns using a detailed analytical hydraulic model a is undertaken (DOI, 2018a).

As a general rule, applications which request approval to take larger volumes of water,[56] or which are proximate to other bores, groundwater dependent ecosystems, or other sensitive areas will generally require hydrogeological evidence to support them and validate that the impacts will be acceptably minor. For example, the WSP rules require a hydrogeological report to establish evidence of acceptably minor impacts to approve proposed bores within certain minimum distances from GDEs, groundwater dependent culturally significant sites, other water supply works, and contamination sources (see Appendix 7).[57]

4.4.5 Applications may be subject to a hydrogeological assessment

Based on the risk assessment process, medium and high risk applications are subject to hydrogeological assessment.[58] To inform this hydrogeological assessment, the applicant seeking approval for a dealing or water supply work should supply a hydrogeological report. These reports are prepared by a groundwater consultancy, and will generally comprise a pump test (see further detail below) and a hydrogeological study that includes a technical

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[52] Access Licence Dealing Principles Order 2004 cl 7, 8.
[53] Access Licence Dealing Principles Order 2004 cl 9(1).
[54] Access Licence Dealing Principles Order 2004 cl 9(2).
[55] Access Licence Dealing Principles Order 2004 cl 10.
[56] The Review notes that the licences entitlements for bottled water operators in the region cover a broad range from 5 ML up to greater than 100 ML/year, with some operators drawing on their licences from multiple bores.
[57] *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* cl 40-3. Note that the standard of acceptability varies depending on the protected feature the works would be proximate to, for example another bore versus a GDE or an environmentally sensitive area versus a source of contamination. WSP applies minimum distances determined by Water Management Committees based on aquifer type and technical advice from the Department (DPIE, 2019a). The Department is developing a fact-sheet detailing the assessment process including assessment of potential impacts on GDEs (DPIE, 2019a). Minimum distance rules may also be influenced by the application of more accurate GDE mapping, developed from the PCT vegetation mapping (DPIE Water, 2019a).
[58] Note that applicants submitting applications for low risk dealings or works would generally not required to provide a hydrogeological report or conduct a pump test.

analysis of the pump test data; and assesses the potential drawdown of the proposed extraction on neighbouring water uses and environmental assets.

4.4.5.1 Applications over 20ML/year will require a pump test

A pump test is required to support an application for approval to construct and use a bore to extract over 20ML/y of water from a groundwater source within the coastal management area of NSW, including areas within the WSP, for irrigation, industrial, recreation or other commercial purposes. This pump test should be conducted by a groundwater consultant and form part of the hydrogeological report consistent with WaterNSW guidelines (see Table 15), including providing a "*technical analysis of the pumping test information; and identification of the potential drawdown impacts of the proposed operation on neighbouring users and surrounding sensitive environmental assets*" (WaterNSW, 2017).

Pump tests will generally require a test bore licence from WaterNSW prior to drilling, and must be conducted in accordance with Australian Standards. The proposed volume of water extraction will determine the minimum duration of pump testing,[59] and drawdown and recovery measurements from observation bores may be required (WaterNSW, 2017).

4.4.5.2 Applicability of the Aquifer Interference Policy (AIP)

The NSW Government's AIP focuses on proposed high risk aquifer interference activities where the purpose of water extraction is for disposal, not for use, for example, mine and construction project dewatering involving hundreds of megalitres. WaterNSW and DPIE Water have advised the Review that they consider all applicable policies when considering applications for licences and approvals or providing hydrogeological advice, respectively. However, they do not refer to the AIP for activities that are not defined as high risk under the AIP or do not involve large volumes of water.[60]

4.4.6 Relevant impacts considered in the hydrogeological assessment

As discussed above, the hydrogeological assessment consider the potential drawdown impacts of the proposed water dealing or works on neighbouring water users and environmental and cultural assets. This includes impacts:

- on the groundwater source in question,
- on groundwater dependent ecosystems (GDEs),
- on connected surface water sources,
- on culturally significant sites,
- on neighbouring water supply bores,
- on groundwater quality,
- of compaction of sediments,
- of cumulative drawdown from existing approved water supply works and entitlements (DOI, 2018a).

A key consideration is the impact of any drawdown on GDEs and culturally significant sites. This reflects the objectives of the *Water Management Act 2000*, including to "*protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality*" as well as to recognise and foster social and economic benefits from the sustainable and efficient use of water.

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[59] For applications seeking a 21 to 50ML/year entitlement, a minimum one day pumping duration and recovery will be required. For applications seeking a 51 to 100 ML/year, a minimum seven day pumping duration and recovery will be required. For applications seeking more than 100 ML/year entitlement, a minimum 70 day pumping and recovery will be required (WaterNSW, 2017)

[60] See Appendix 4, Initial Report.

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4.4.6.1 Groundwater dependent ecosystems (GDEs)

To be able to protect and monitor the health of GDEs, knowledge of their broad-scale distribution, location and vulnerability to changes in groundwater level is required. The NSW Government has undertaken work to identify groundwater dependent ecosystems to meet its legislative requirements under the WMA and WSPs, which require spatial mapping of GDEs to apply the minimum distance rules as discussed above.[61]

The report used remote sensing analysis, including vegetation and groundwater mapping data to identify a model for high, medium and low probability terrestrial vegetation GDEs. However due to the conservative nature of the decision rules, the report acknowledges that some GDEs may have been inadvertently filtered out.[62] The GDE model generated was refined and tested against other existing literature, knowledge of underlying geology and environment, and ground-truthing in other areas of NSW.[63] This mapping will be further updated for the coastal region of NSW following an update of the underlying vegetation classification scheme, resulting in more accurate GDE maps (DPIE 2019, pers. comm., 02 August).

While the probability GDE mapping layers are used by DPIE, the GDE mapping used in the WSP is a point layer map that is not electronically available and only recognises GDEs considered 'high priority'[64]. DPIE has indicated that new WSPs under development or being re-made in NSW will refer to a full dataset of all GDEs identified by NSW DPIE and link to the National GDE Atlas (DPIE 2019, pers comm., 23 October).[65] The WSP allows for the list of high priority GDEs to be amended after year five of the plan as further GDEs are identified, or during the life of the plan following approval by the Minister (DPI Water, 2016f).

4.4.6.2 Culturally significant sites

Six different Aboriginal nations occupied the NSW north coast prior to European settlement due to the high diversity and abundance of natural resources in the area, particularly around the Northern Rivers region. The Tweed and Northern Rivers region is the traditional home of the Bundjalung Nation. The area has a number of culturally significant coastal sites, special meeting places, middens, campsites, hunting and gathering sites, crafting sites, and ceremonial places. The water and vegetation in the area provided the people with critical resources including flora and fauna.

The WMA and hydrological assessment process recognise and protect culturally significant sites and aim to foster social and economic benefits to culture and heritage. The WMA specifically aims to recognise and foster "*benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water*."

These objectives are reflected in the WSP, which recognises the multidimensional relationship Aboriginal people have with land and water – including spiritual, customary and economic. This means that not only should certain sites be protected because of their spiritual and environmental significance, but also because the ecosystems and flora and fauna they support should be preserved to enable ongoing traditional practices including hunting, fishing and gathering. The WSP recognises this multidimensional relationship by establishment and prioritisation of Native Title rights within Basic Landholder Rights as well

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[61] This work is summarised in the report, *Methods for the identification of high probability groundwater dependent vegetation ecosystems* (Kuginis et al., 2016).
[62] This technique recognised some but not all wetlands; other potential GDEs such as stygofauna (groundwater invertebrates important to maintaining water health) and groundwater baseflow contributions to surface water were not included.
[63] Note that this mapping will be updated to provide a more comprehensive and accurate GDE map for the coastal region of NSW following an update of the underlying vegetation classification scheme (DPIE Water, 2019b)
[64] Identified in 'The GDE Map' attached in Appendix 10 of WSP Background Document (DPI Water, 2016f) and Appendix 3 of the WSP
[65] The Atlas includes data obtained through a national assessment process as well as NSW. GDEs will be prioritised according to the High Ecological Value Aquatic Ecosystem (HEVAE) Framework developed as part of the Aquatic Ecosystems Toolkit (2012).

as permitting Aboriginal communities to apply for a WAL for cultural purposes or community development purposes. The WSP identifies a number of groundwater sources that represent areas of spiritual and cultural significant to Aboriginal people.

The hydrogeological assessment process also recognises and protects culturally significant sites, including sites of significance to Aboriginal people, by considering the potential drawdown impacts of proposed water dealing or works on these sites (including with respect to the traditional uses of these sites). As discussed above, the WSP specifies minimum distance rules to groundwater-dependent culturally significant sites to avoid unacceptable impacts on these sites. These rules apply not only to sites of significance to Aboriginal people, but also to other sites of cultural and heritage significance.

Information on groundwater-dependant culturally significant sites is constantly updated by DPIE through engagement with Aboriginal peoples (DPIE 2019, pers comm., 25 September). This is an ongoing activity as even once a site has been identified, further information may be required to understand the cultural significance of the site, its interrelationship with the groundwater source and the associated water requirements of the site.

4.4.7 Defining the level of acceptable impacts

For different groundwater sources, the magnitude of acceptable impacts currently applied by DPIE Water for groundwater dealings and water supply work approvals on water drawdown varies. Table 14 details the acceptable impacts on the water table and groundwater pressure for most porous and fractured rock groundwater sources in NSW.[66] These criteria apply to all four groundwater sources within the scope of this Review.

Table 14: Acceptable level of impacts for porous and fractured rock groundwater sources

Type of impact	Level of acceptable impacts
Impact on water table (unconfined aquifers)	1. Less than 0.1 metre cumulative drawdown in the water table 40 metres from any: a. High-priority, groundwater dependent ecosystem, or b. High-priority, culturally significant site. 2. An additional drawdown of not more than 10% of the pre-development Total Available Drawdown (TAD) to a maximum of 2 metres at any: a. 3rd or higher order surface water source measured at 40 metres from the high bank. b. Water supply works (excluding those on the same property), subject to negotiation with impacted parties. 3. A cumulative drawdown of no more than 10% of the pre-development TAD of the unconfined aquifer at a distance of 200 metres from any water supply works including the pumping bores.
Impact on groundwater pressure (confined/semi-confined aquifers)	1. A cumulative drawdown of not more than 40% of the pre-development TAD at a distance of 200 metres from any water supply works including the pumping bores. 2. An additional drawdown of not more than 3 metres at any water supply works (excluding those on the same property) subject to negotiation with impacted parties.

Source: (DOI, 2018a)

When assessing expected impacts against the acceptable level of impacts, the impact period considered varies from one year for temporary trades,[67] to 10 years for permanent trades.[68]

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[66] Except for porous and fractured rock groundwater sources within the Great Artesian Basin for which different criteria apply.

[67] For example, assignment of water allocation to another licence under s 71T of the *Water Management Act 2000 (DOI, 2018a)*

[68] For example, assignment of share component of a water access licence under s 71R or 71Q of the *Water Management Act 2000 (DOI, 2018a)*

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4.5 MANAGEMENT OF IMPACTS AFTER APPROVAL

The primary mechanisms for managing the impacts of groundwater extraction under existing groundwater entitlements are conditions on works approvals or access licences, conditions on development consents through the councils, water allocations (or 'available water determinations') and temporary water restrictions.

4.5.1 Conditions imposed on approvals (WALs and works approvals)

Approvals may be subject to conditions, including:

- 'Mandatory conditions' – conditions imposed by the *Water Management Act 2000*, *Water Management Regulations 2018*, or the relevant WSP,[69]
- 'Discretionary conditions' – conditions specific to the particular approval and location, for example to give effect to agreements between an applicant and an objector, or to protect the environment.[70] These conditions would be informed by the hydrogeological assessment that may identify particular areas of risk that can be managed through conditions of approval.

Mandatory conditions prevail over discretionary conditions to the extent of any inconsistency between them.[71] The applicable conditions are specified in the relevant licences or approvals. Common conditions on water access licences and works approvals for groundwater extraction include:

- Installation, maintenance and operation of appropriately configured water meters.
- Installation, maintenance and operation of a data logger.
- Recording of pumping activities in a logbook.
- Provision of data, records and reports to the Minister and/or the Department covering water quantity, water quality, application of water, etc.
- Permitting the Department access to the site to inspect and test the works.
- Duty to notify the Minister or Department of breaches.[72]

4.5.2 Conditions of development consents

Bottled water operators in the Northern Rivers region generally require a development consent under the *Environmental Planning and Assessment Act 1979* (EP&A Act) to construct or expand the necessary facilities to extract water for bottling purposes. To obtain the necessary consent, the operator submits a development application to the local council. Historical development consents for water bottling firms operating in the region date back to 1993.

It is within council's remit to apply conditions and performance measures to the consent, which can be in relation to impacts and consequences of the development. These may require the operator to develop a plan for monitoring and reporting their performance against these conditions. For example, a recent consent (issued late 2018), imposed conditions related to water take (specifically, the volume in ML/y of water permitted to be extracted), a requirement to use a daily log book, and the transport of that water (specifically, maximum truck movements and daily hours of operation permitted). Conditions provide a mechanism for councils to set standards and outcomes for protecting certain environmental values and to monitor and assure compliance. Conditions may be varied subject to an application by a proponent to modify the consent, but only in relation to the subject area of that modification application.

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[69] *Water Management Act 2000*, s 100(1)(a) and s 100(1AA)
[70] *Water Management Act 2000*, s 100(1)
[71] *Water Management Act 2000*, s 100(1)(a) and s 100(1AA)
[72] A search was conducted of conditions of water access licences and water supply works approvals for bottled water extraction operations in the Northern Rivers region.

The Review considered a number of development consents for bottled water operators in the Northern Rivers region. While the scope of conditions contained in these consents was broad, the Review did not identify conditions that related to local impacts on aquifers or groundwater, or potential environmental consequences associated with those impacts.

Tweed LEP 2014 required the Council to be "*satisfied that development will not have an adverse impact on natural water systems or the potential agricultural use of the land*"[73] and under the EP&A Act, to consider the likely environmental impacts of the development.[74] As a result, Tweed Shire Council has informed the Review that it expects more detailed hydrogeological information to be submitted during the assessment process for development approvals for the bottled water industry, including seeking information on conceptual models, testing and ongoing monitoring plans.

The Review also notes that these expectations around hydrogeological assessment also need to be seen in the context of a regulatory framework that places significant responsibility for hydrogeological assessment and licence or works approvals with the state government.

Tweed Shire Council has informed the Review that where the extraction of water has been subject to the hydrogeological assessment and approval by the state government, the Council historically focused on assessing and imposing conditions on other environmentally relevant matters not covered by conditions of the water licence or works approval – for example, noise, truck movements and hours of operation.

However given the LEP, there was a question as to the extent to which the Council needed to or should undertake its own hydrogeological assessment.

Given the implications of the overlap between development consent conditions and water licences or works approvals, further work should be undertaken to ensure consistency, to avoid duplication of effort, and to address any gaps in the assessment and approvals process.

4.5.3 'Water allocations' or 'available groundwater determinations'

WSPs provide a mechanism, a 'water allocation' or an 'available water determination' (AWD), to control water take for each licensed water user each water year. The AWD is intended to ensure that water take is managed to the extraction limit, to prevent impacts on the water source and other users or consequences to GDEs, and to provide certainty to water users regarding the amount of water that can be taken and under what conditions.

The AWD process for groundwater sources determines the available water in the coming water year by considering the LTAAEL,[75] water entitlements under access licences and basic landholder rights, and actual water take. The AWD assigns a portion of the available water to each licensed water user based on their water entitlement. While the AWD is conducted each water year, the focus of the AWD is to manage sustained growth in actual water take to the LTAAEL, which is a long-term measure.[76]

On 26 June 2019, DPIE Water issued an *Available Water Determination Order for the North Coast Costal Sands and the North Coast Fracture and Porous Rock Groundwater Sources 2019* for the 2019-20 water year commencing 1 July 2019. The statement allocated local water utility and aquifer licence holders covered by the WSP groundwater sources an allocation of 100 percent of their entitlement, or 1 ML per share unit.

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[75] The LTAAEL represents the extraction limit of a particular groundwater source over the long term, expressed as an average.
[76] For example, the standard water allocation for licensed water users is 1ML/unit share, but Clause 29(2)-(3) the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 specifies that where growth in water take is assessed to have increased more than 5 percent above the LTAAEL extraction limit over a three-year period, the water allocation may be reduced to less than 1ML/unit share.

4.5.4 Temporary water restrictions

Under section 324 of the *Water Management Act 2000*, temporary water restrictions can be imposed in the public interest.[77] These restrictions can prevent or impose restrictions on the taking of water from a specified water source and area for a specified period:

- to maintain or protect water levels,
- to maintain, protect or improve water quality,
- to prevent land subsidence or compaction,
- to protect groundwater dependent ecosystems, or
- to maintain pressure or to ensure pressure recovery.[78]

The majority of Temporary Water Restriction Orders that have been enacted are for regulated river systems. Fewer Orders have been enacted for groundwater sources.[79]

4.5.5 Collaborative data and approach

The Natural Resources Commission's 2005 Standard for Quality Natural Resource Management established 'Opportunities for collaborations' as one of seven components of the Standard, and the subsequent 2013 NRC review of the 2004 WSP was undertaken in view of this Standard (NRC, 2005). The 2013 review identified a number of examples of collaboration and further opportunities, including sharing spatial information between agencies, with licence holders on operational matters; to ensure shared data is used; and ensure NSW Government's various regulatory frameworks, investments and interventions complement each other (NRC, 2013).

This Review (by the NSW Chief Scientist & Engineer) has also identified opportunities for enhancements in the way that agencies and council collaborate on data sharing and their various roles in the water management process including with respect to the bottled water industry. These include the need for relevant authorities to:

- Develop a shared understanding of the data, modelling and information needed by each agency in decision making
- An agreed and documented set of standards for data capture, sharing, storage (frequency, metadata requirements, computational and program requirements, data sharing protocols including in relation to commercial data)
- When potentially new measurement and monitoring technologies or regimes are introduced, an approach to discuss (and reach agreement on) the most effective measures to roll out new monitoring to maximise the utility and outcomes for the group of agencies
- Where new performance indicators are identified through the WSP or performance measures conditioned on proponents, a shared understanding by agencies of which legal instrument these measures should be attached to, and how data on these measures is communicated with relevant agencies for the purpose of compliance, or measuring cumulative impacts, or providing for research activities. Where new performance measures are required of proponents, a forum to discuss between

[77] *Water Management Act 2000*, s 324(1).
[78] *Water Management Act 2000*, s 324(2)
[79] On 21 February 2018, temporary water restrictions were imposed for the Botany Sands Groundwater Source in response to a threat to public health and safety, see NSW Government Gazette No 23 of 23 February 2018, 816. On 1 September 2009, temporary water restrictions were imposed for the Mid Murrumbidgee Groundwater Management Area 013 in response to a threat to public health and safety, see NSW Government Gazette No 136 of 25 September 2009, 5229. On 17 August 2009, temporary water restrictions were imposed for the Upper Namoi Zone 11 – Maules Creek Groundwater Source to protect water levels in an aquifer and to protect groundwater dependent ecosystems, see NSW Government Gazette No 113 of 18 August 2009, 4815. On 25 June 2009, temporary water restrictions were imposed for the Lower Murrumbidgee Groundwater Sources and Lower Murray Groundwater Source in response to a water shortage, See NSW Government Gazette No 95 of 26 June 2009, 3797-8. On 14 March 2009, temporary water restrictions were imposed for all aquifers or parts of aquifers underlying the Blue Mountains City Council Local Government Area to protect groundwater dependent ecosystems, see NSW Government Gazette No 52 of 20 March 2009, 1431.

agencies where there are potential contradictory measures, and the most appropriate instrument to reflect conditions in a way that prevents duplication.

4.6 OBSERVATIONS ON PAST HYDROGEOLOGICAL REPORTS

Hydrogeological reports dating from 2007 to 2019 were made available to the Review by seven operators (or proponents) of bottled water extractions in Tweed Shire and Ballina Shire. These represent a large proportion of the industry hydrogeological reports that are being used to support recent licence or development applications related to the bottled water industry. Two reports that did not support license or development applications are discussed in this section in general terms only. The Review notes that a small number of operators have historical licences and documentation was limited.

This section summarises the reports' purposes and contents, public and government responses to the reports, and general observations regarding the comprehensiveness of the assessment and alignment with currently available guidelines. The purpose of this analysis is to identify general challenges that emerge in developing reports (versus a full technical assessment) that are sufficient to inform license assessments or development applications.

The hydrogeological reports, in most cases, assess hydrogeological impacts of proposed developments on surface flows, GDEs and surrounding groundwater bores. Some of the hydrogeological reports have additional purposes including assessing the commercial viability of the bores. One report focusses solely on the water quality risks to the bore. One report is an update of a historical report, including supplying updated water quality results, without supporting a current development or entitlement application.

The focus and style of the reports varies depending on the purpose and the identified or perceived risks. Six of the seven reports are presented in conventional consultancy report format; one is presented as a letter to the proponent.

4.6.1 Review of the available hydrogeological reports for the industry

The collective content of the hydrogeological reports is reviewed here against the *Groundwater Consultancy Requirements - Hydrogeological investigation report standardised table of contents* in the "Coastal groundwater: Test pumping groundwater assessment guidelines for bore licence applications". This guideline is specific to pump tests for supporting license applications and does not provide a definitive guideline for the hydrogeological reports in question; however, it provides a useful, established template for this review (Table 15). Other relevant comments regarding the content of the hydrogeology reports, for the purpose of supporting development applications, are listed below.

4.6.1.1 Level of detail in the hydrogeological reports commensurate with the risks and requirements of applicable guidelines and policies

All reports refer to the WSP. Identification of specific relevant requirements of the WSP is variable between the reports.

The main public policy document referred to in the hydrogeology reports is the WSP. This policy stipulates minimum distances of extractions from high priority GDEs, high banks of a river or stream, culturally significant sites and water supply works. There is provision for changing these distances on a site specific basis if risks can be shown to be low, implying additional investigation would be required. In most of the existing/proposed bottled water sites, these minimum distances are reportedly met, and so there is no explicit requirement in the WSP to conduct further hydrogeological investigation.

In cases, there are rivers/creeks within the stipulated minimum distance (40 m) of the extraction sites, and in all cases there are rivers/creeks within a few hundred metres; therefore there is an onus on the proponent to demonstrate there is no (or very low)

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hydraulic connectivity between the target aquifer and the surface water. This is done with reference to the regional-scale classifications of connectivity in the WSP, to bore logs that show confining layers, to results of pump tests, and, in cases, to differences in water chemistry between the aquifer and surface water and anecdotal evidence of stable surface water responses.

During consultations in the Review, concern was expressed over the lack of objective, local-scale evidence to demonstrate low connectivity between the target aquifer and surface water. This is reflected in hydrogeology report conclusions by use of subjective terms such as "unlikely to cause impacts", which are considered by some stakeholders as lacking an evidence base.

Beyond the WSP requirements, the purpose of the reports includes satisfying the council requirements that the hydrogeological risks are acceptable. Meeting the minimum distance requirements of the WSP and the largely qualitative analysis of connectivity undertaken in the reports is not necessarily sufficient to meet this purpose. The absence of detailed modelling or significant monitoring of assets at potential risk means impacts and risks are unquantified. The cost-benefit of additional modelling and monitoring where this is not explicitly required by the WSP or other published guidance is predominately based on judgement and is disputable even among hydrogeology experts .

The hydrogeology reports all recognise that lack of data hinders understanding. In most cases the reports include recommendations for further investigation, although they do not explicitly recommend this is required prior to approval. Two reports recommend further pump tests to confirm sustainable extraction rates, two recommend additional monitoring during bore operations, and one recommends monitoring shallow groundwater with an associated cease-to-pump trigger. The review of the hydrogeology reports also noted that in some cases uncertainties and data limitations were identified in the report; however these were not always well reflected in the report's conclusions or executive summary.

Table 15: Contents of five bottled water industry hydrogeological reports from the Tweed and Ballina Shire compared against standardised table of contents in the coastal guidelines

Hydrogeological investigation report standardised table of contents		Included in report	Extent of detail
Certification	Groundwater consultant (qualified)	Yes, in all reports	
Introduction	Property location, identification of the proposed development	Yes, in all reports	All reports provide maps showing property location. All reports include a map or maps showing key features of the property (~1 km); all but one show the location of the property with respect to locality features (~5-10 km); and most also show location on the regional scale (~50-100 km scale). Quality of maps is variable.
	Purpose for which the licence is being sought	Yes, in all reports	Sufficient
Geology	Geological description of the property and surrounding region	Yes, in all reports	All reports describe the site's geological context. The level of detail in all reports is constrained by lack of available regional and local scale geological data. All full reports contained one or more bore logs that describe geology over the depth of the bores. Only one report provides a regional geological map, although the value of this is debatable, and other reports refer to relevant published maps.
	Stratigraphic boundaries or structural features that may influence groundwater availability	No	Available data does not permit this, although it is likely to be relevant to at least some of the sites
Hydrogeology	Setting: Description of the type of aquifer and a summary of typical water bearing zones encountered in test bores in the vicinity of the property	Yes, in all reports	In some reports the information could be improved using existing sources of data
	Licensed: Details of licensed water supply bores within 1km of the property including works purpose and likelihood of being impacted should the proposed development proceed	All reports identify nearby water supply bores, but not all use a 1 km radius; all assess likelihood of impacts	The likelihood of impacts is addressed with support from pump test results, water quality data, bore logs, regional hydrogeology data, the thresholds specified in the WSP and in some cases the AIP, and in two cases other (unsubstantiated) local hydrological observations. Due to absence of monitoring and modelling at the potential receptor bores/GDEs and pathways from the extraction to these receptors, the analysis of likelihood is subjective.
	Environment Identification of ecosystems likely to be groundwater dependent, surface water systems that could be affected by reductions in discharge with prolonged pumping	Yes, in all reports	The identification of GDEs in most cases relies on the High Priority Groundwater Dependent Ecosystem (GDE) Map in the WSP and the National GDE Atlas webtool supplemented by site visits.
	Particular identification of sensitive ecosystems of special conservation value	Yes, in all reports	One report is vague about criteria used for determining presence of GDEs.
Field work	Test bore establishment: Details of the drilling and construction of the subject bore, identifying the test bore licence under which it was authorised. A statement of compliance with the Minimum Construction Requirements for Water Bores in Australia – Second Edition 2003 or	Information about the bores is provided in all cases although the level of detail is	The pump test bores in all cases are existing pumping and monitoring bores (piezometers). I.e. they were not drilled for the purpose of the reported pump tests. The available details on bore establishment are variable. In most cases bore logs are provided. A statement of compliance is made in only one case.

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Hydrogeological investigation report standardised table of contents		Included in report	Extent of detail
	subsequent equivalent guideline.	variable.	In all cases but one, other relevant observations of the local hydrological and land use context made during field visits are described.
	Test pumping and recovery: Measurements and graphical analysis documentation of drawdown and recovery data for pumping and observation bores. Calculated aquifer transmissivity and storativity values, together with bore efficiency estimates. Details of the water quality tests (compliant with requirements; National Uniform Drillers Licensing Committee, 2012) undertaken to demonstrate the groundwater is suitable for the intended purpose.	Pump test data are provided in all cases. In all cases water quality information is provided to show fitness for purpose although compliance is not stated.	As stated above, the observations make use of available bores rather than being drilled specifically for the tests. In one case an observation bore was not used (it was recommended if the approval was given). In all cases but that one, aquifer transmissivity and storativity values are estimated, together with bore yields. Water quality assessment is extensive due to its commercial importance. Sufficiency of pump tests (including location of monitoring bores (piezometers) and length of test) is questionable in cases, and further pump tests are recommended in some cases.
Impact assessment	Sustainability: Predictions of the impacts of pumping of the subject bore on neighbouring licensed users and potential groundwater dependent ecosystems based on the required controlled test pumping, together with the predicted effects on groundwater levels for the region surrounding the subject property and the potential to affect discharge to surface water systems	All reports undertake this to some extent	The level of quantitative analysis presented is variable, depending on the availability and quality of pump test data for identifying a zone of influence. In most cases expert judgement is relied upon, including caveats about lack of data. The potential to affect discharge to surface systems is not assessed because aquifer discharge locations are unknown but are not thought to be local based on the regional-level connectivity descriptions in the WSP. Connectivity of the target aquifers with shallow groundwater and surface water is assessed using regional scale knowledge supplemented by bore logs and water quality.
	Trigger levels: Identification of the threshold drawdown levels adopted to prevent impacts on neighbouring bores or ecosystems, and estimations of the maximum drawdown impact on neighbouring bores, monitoring bores (piezometers) and ecosystems with and without trigger levels being active	One report recommended a shallow groundwater trigger level	Only one report recommends a trigger. In all cases, risks to neighbouring bores and GDEs are concluded to be low, and it may be assumed that triggers were not considered appropriate (cease-to-pump triggers are generally only used as part of groundwater licensing in high-risk projects such as mining).
	Management Responses: Actions to be taken if threshold levels are reached or exceeded, including reporting to regulatory authority, cease-to-pump conditions, and provision of water to affected users		
Operation	Schedule identification of the proposed operating regime including discharge rate and hours of pumping	All reports refer to pumping volumes.	All reports refer to licensed volumes; some also refer to proposed annual volumes; and some to hours of pumping that can be sustained at a given pumping rate. None refer to the specific operating regime, which is likely to be unknown at the time of the analysis.

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Hydrogeological investigation report standardised table of contents		Included in report	Extent of detail
	Monitoring Descriptions of the location of monitoring bores (piezometers), the frequency at which monitoring is to be undertaken and the type of data to be collected	Monitoring piezometers and the monitoring used during pump tests are described	Most reports recommend continual monitoring of drawdowns at existing or new monitoring bore (piezometers).
	Reporting Details of the timing of reports, the type of information to be reported to the regulatory authority, the number and nature of exceedances and response times between an occurrence and management actions being implemented, and methodologies to be adopted to mitigate impacts should they be ongoing	This is not included in the hydrogeology reports	The reports are not written in the context of an adaptive regulatory regime, since this does not typically apply to low risk extractions. Most reports recommend continued monitoring to inform sustainable extractions.
Constraints	Identification of any consent conditions imposed by council or other regulatory authority that would prevent the requested entitlement being realised in full for the purpose for which the licence is being sought. In particular, conditions limiting the supply of water to other parties are to be identified	All reports describe current relevant licenses	The reports identify the status of license and development applications and relevant constraints. In most cases licenses exist and the application is about a change of bore use and/or a council development application.
References	Citations of all documentation referred to within the report.	Yes, in all reports.	There are cases where the referenced documentation must be inferred, rather than being properly cited.
Figures	All diagrams referred to within the report, including a locality map, a plan of the property identifying separation distances between the subject bore and site boundaries or other features (especially suspected groundwater dependent ecosystems, licensed works and surface water bodies), geological map and sections, together with a plan illustrating the extent of predicted drawdown during the proposed pumping operation	All reports include maps	The maps vary from excellent quality showing all relevant available information, to poor quality and of questionable completeness.
Appendices	Raw data and additional diagrams or text required to provide background or support to the findings of the investigation	All reports (except that in the format of a letter) provide appendices with further data	All relevant raw data are not included in all reports, and in cases where it was provided, there was no accompanying interpretation or description of methods used to obtain the data.

Source: (WaterNSW, 2017)

4.6.1.2 Accessibility of the hydrogeological reports to a non-technical audience

The hydrogeology reports are necessarily highly technical are not comprehensible to non-experts. In most cases the Executive Summary and/or Conclusions sections of the reports are more accessible; however these alone cannot be relied upon to make approval decisions since they do not always reflect the full detail of the report including any particular uncertainty in the local hydrogeological conditions and limitations of the tests and data employed.

During consultation, some councils commented on their limited internal hydrogeological capacity and reliance on guidance by WaterNSW/DPIE Water and/or external consultants and hydrogeologists when necessary. Documents show that significant assessments are made to support the Council by WaterNSW (using technical advice from DPIE Water). It is important that the reports retain the highly technical content given the complexity of groundwater assessments in general, but particularly in complex systems like those in this region and the risk of losing vital information. Clarity around this could be improved through the application of standardised table of contents like the one in the Coastal Groundwater guidelines.

4.6.2 Public responses to the hydrogeology reports

In three cases, the Review team has seen responses by public interest groups and/or their expert advisors, where concerns about the methods and conclusions of the hydrogeology reports are raised. The concerns mainly relate to:

- *The lack of measured data to support assessment of local impacts.* In particular, the responses from experts and interest groups argue the lack of characterisation of the connectivity between the proposed extraction point and nearby creeks. Recommendations are made by academics, commissioned to peer review the reports, to: measure shallow and confined groundwater pressures to understand the connectivity; conduct shallow groundwater monitoring over different depths between the creek and target confined aquifer to measure responses to pumping; and to measure creek flow responses to pumping including in low flow periods that are most vulnerable to impacts. In one case, the expert presents calculations that demonstrate the potential for large impacts on creek flows if a high degree of connectivity is present. In another case, water quality data are re-interpreted by an expert as signifying the potential for a connection between the targeted aquifer and the creek.
- *The over-reliance on aquifer-scale generalisations to support local scale assessment.* This relates to assumptions about connectivity taken from regional generalisations in the WSP. While the low levels of the proposed extractions compared to the extraction limits in the WSP are recognised by the expert, this is considered to be an insufficient indicator of local impact risk. Cumulative impacts due to future potential extractions are also raised as a concern.
- *Uncertainty.* Following from the above points, the experts and interest groups argue that some conclusions of the reports are unreasonable given the level of uncertainty in the assessment.
- *Perceptions of factual errors.* In one case the interest group notes that there are bores near the proposed site that are omitted from the report. In a later response, the hydrogeology consultant noted that these bores could not be identified from publicly available databases and welcomed further information about them.

4.7 FURTHER INFORMATION TO UNDERSTAND SYSTEM IMPACTS FROM BORE WATER EXTRACTIONS

As discussed, there are considerable challenges in measuring and managing local impacts from groundwater extractions due to numerous factors, in particular the spatial and temporal variability of hydrogeological systems, and imperfect monitoring technologies and modelling methodologies. However, further improvements could be made to assist in measuring, assessing and managing the impacts of groundwater extraction within acceptable limits. While some of these improvements could pose resourcing challenges for proponents and government, a set of potential improvements is discussed below.

4.7.1 Investment in monitoring and technological advances

One of the challenges associated with assessing potential impacts from extractions is the limited amount of field data available, particularly in the Tweed systems. At present there are very few monitoring piezometers in the Tweed, although this is not the case with the state monitoring network in the Alstonville region. Improving piezometric monitoring is needed, at multiple complementary locations where there is perceived risk and/or lack of knowledge of groundwater responses and flow. However, investment in additional monitoring should balance the resources required to install and maintain equipment, and record and interpret the data against the value of expected improvements in data availability and quality. This should be informed by the characterisation of the risk level that the system is in – systems at greater risk would be prioritised over locations and systems at lower risk.

Another important development is the increasing ease at which sensing technologies can be deployed to the field at low cost. These technologies are variously commercially available or under development, and include improved traditional sensing technologies (for example, lower cost and more adaptive remote sensors), as well as advanced technologies offering novel capabilities (for example, quantum gravity sensors able to penetrate depth with significant accuracy).

4.7.2 Metering data

Water extraction metering supports the validation of actual groundwater extraction against licenced allocations and is an important improvement for water policy and management at a regional level (including the development of water sharing plans and available water determinations), as well as enforcement actions against individual licence holders. Access to extraction volumes would also help better determine impacts caused by extractions versus climate variability.

The Review notes that four of the bottled water operators in the region were required in December 2018 to install meters on their systems. The metering policy for qualifying groundwater systems will take effect in this region in 2023 (DOI, 2018b).

4.7.3 Improving clarity on NSW government's expectations of hydrogeological assessment reports

The evolving regulatory context has resulted in a number of policy and guidance documents that are potentially applicable.[80] These documents have led to a complicated array of guidance to proponents and consultants about what is required for a hydrogeological assessment.

As discussed above, hydrogeological assessment reports are variable in content and the level of contextual information, monitoring and data analysis included reflects the characterisation of the risk (Figure 22). Some of the hydrogeology reports this Review considered contain assessments of commercial viability of the bores as well as environmental assessments. In cases, the monitoring or methods used were not considered adequate by experts representing interest groups or by the agencies responsible for evaluating the reports. To a large extent this can be addressed by comprehensive and

[80] These include the WSP and its supporting documents, the AIP and its supporting documents, the 2018 Water resource Plans – Fact sheet – Assessing groundwater applications, and the Coastal groundwater test pumping assessment guidelines, among others.

consistent guidance on approaching the hydrogeological assessment as discussed above.[81] To help facilitate consistent contents of the reports, the environmental component could be a separate report or be clearly signposted.

These challenges have been addressed to some extent by the recent fact sheet (September 2018) that provides definitive criteria for acceptable levels of impacts (DOI, 2018a). The Review is also aware that DPIE Water is currently updating some pump test requirements. It is recommended that the relevant NSW government agencies should seek feedback from consultants on this document and its interaction with other policies, potentially leading to revised and integrated guidance. Similarly, feedback on applicable pump test guidelines could be sought and considered. The NSW government should continue to strive towards publicly available guidelines that reflect consistent internal assessment methods of agencies, and continue to provide access to its technical experts to provide any clarification needed to consultants.

4.7.4 Additional requirements concerning shallow groundwater drawdowns

The assessment of impact risks in the approvals process is presently based on minimum distances between extraction and assets, maximum permissible drawdowns in groundwater pressure heads at stipulated distances from assets, as well as guidelines on minimum requirements for pump tests and their reporting.

Currently there are no explicit requirements for the proponent to demonstrate that there are no detectable impacts at assets surrounding the site or detectable hydraulic connection between extractions from (assumed) confined aquifers and overlying shallow groundwater and surface water. However, monitoring of shallow aquifers is seen by many experts as a practicable method of measuring whether pressure drawdown at the extraction point has propagated towards assets at potential risk. In principle, this may be implemented as part of the pump tests, and/or as a requirement of the approval with an associated cease-to-pump criterion. This would require careful selection of appropriate monitoring points, which represent the potential hydraulic connection between the extraction and assets at potential risk, as well as a criterion for assessing acceptability of any observed effect. The requirement for an adequate period of baseline data would be an additional consideration.

In projects involving large groundwater extractions, it is common for shallow groundwater, surface water flow and/or GDE health indicators to be used to define triggers, whereby a defined level of impact would trigger a cessation of pumping. In practice, such monitoring is expensive to install and operate, requires a process for identifying acceptable impacts and triggers, a process for reporting and auditing, may require access to private land and increases investment risk for the proponent, due to increased uncertainty over continuity of operations. Therefore it is most appropriate in potential high risk cases. In the case of managing local impacts of high volume extractions on high-risk assets, a viable option may be to monitor easily measured parameters such as shallow groundwater levels on the property in question. However, in many cases the link between shallow groundwater levels and surrounding off-property assets such as GDEs will be arguable.

As well as providing an increased (although not comprehensive) safeguard against impacts, provide insight into factors like how the shallow system responds to rainfalls and the layering of the system at the local scale.

It is also important to consider the appropriate authority for any additional monitoring requirements. For example, if this monitoring is to be required as part of a development consent condition, local government should consider how risk tolerances should be balanced

[81] For example, the AIP comes with an application guide for consultants that includes a checklist, which allows the consultant to specify where in the hydrogeology report the AIP requirement is addressed. This might be considered for other applicable guidance.

against imposing further obstacles to development. Further, if the monitoring requirements for development consents are different from requirements of license dealings and works approvals, this would require a separate guidance documents for proponents and their consultants. Since the requirements regarding number, location and depth of shallow groundwater monitoring will be project-specific, the guidance is likely to be about the process, principles and general criteria rather than monitoring design.

4.7.5 Field verification

To address hydrogeological complexity, site investigations may be undertaken or required prior to designing an impacts assessment. This may include exploratory drilling, and/or the examination of drill logs from existing or new site bores before designing a pump test. This preliminary work may result, for example, in a recommendation for multiple monitoring bores (piezometers) in non-linear locations to understand better how depressurisation propagates in three dimensions. Intermittent review and iterative improvements to monitoring may be appropriate during this process.

Furthermore, temporal variability of groundwater pressures and surface flows means that adequate baseline data are essential to isolate effects of new extractions. Baseline data require foresight from project proponents, and also from asset owners/managers or the government if they wish to ensure that baseline data exists for valued assets. These baseline data requirements must balance the risks of the proposed extraction against the value of the extended baseline data required as collecting this data can require significant time and cost.

Methods to identify and classify vegetation can be designed to recognise GDEs and estimate the extent of impact. Vegetation assessment methodologies, such as the Bioregional Assessment or Biodiversity Assessment Methodology are useful approaches. However, engagement of an ecohydrologist consultant to undertake field verification on environmental assets would complement the assessment of potential impacts.

4.7.6 Improving data collection, accessibility and management

Data from the monitoring network at Alstonville is publicly available on the WaterNSW website (https://www.waternsw.com.au/waterinsights/real-time-data). This website provides real-time data on NSW river heights, streamflow, groundwater bores, meteorology and rainfall, as well as dam and reservoir levels and volumes.

It was noted above that extraction data is not readily available, but would greatly assist to better understand whether observed impacts on water levels and pressures are due to water extraction or climate variability.

For data that can be made publicly available, there are state managed environmental databases (e.g. SEED) that could be utilised.

The accessibility of any data is central and the preponderance of manual collection is an impediment in this regard. Advances in technology to provide robust and tamper-proof telemetering options that are commercially cost competitive would have a significant impact.

Current technology is also available to enable standardised templates and reports to be managed electronically. This would improve the flow of information to relevant agencies and other parties.

4.7.7 The potential role of local research studies

Knowledge of the groundwater requirements of GDEs is limited and research tends to be conducted on unconfined aquifers or systems that are simpler than fractured rock systems. Identification and requirements of subterranean GDEs and the contribution of groundwater to surface water baseflow is even more limited. Local impact studies that monitor groundwater drawdown on nearby GDEs may be considered where there is concern about the impacts (e.g. near Tweed World Heritage site or areas of high extraction) of drawdown on the local environment, surface water or other users.

Monitoring as part of a development consent or as a requirement of an approval can go some way to detecting local impacts or increasing confidence that they are acceptable or not, and to detecting local connectivity between deep and shallow groundwater at monitored locations. However, it is likely to leave gaps in knowledge about local (~0.01-0.1km^2) scale processes and conceptual models, and practical and cost constraints mean it is unlikely to provide new knowledge about catchment/regional-scale impacts (0.1-100km^2). For these, multi-year, multi-scale research projects would be needed.

Research should be encouraged, which monitors continuously at both the local scale and in the surrounding catchment to understand sources of groundwater water, the transmission of depressurisation due to pumping, and impacts on groundwater discharges. This would ideally require voluntary participation of a bottled water operator and surrounding landowners, including installation of continuous pressure transducers in pumped bores, monitoring piezometers and shallow water bores, and availability of metered pumping rates. It should also include tracer studies and surface flow monitoring, and potentially could include ecological indicators.

4.8 CONCLUSIONS

Impacts

- Based on the assessment of available information and analysis undertaken by the Review, there is no measured evidence that current bottled water extractions have impacts on other properties' bores, surface water or GDEs in the Northern Rivers region. This is at least partly due to the relatively low current levels of extractions, hydrogeological conditions and absence of monitoring capable of detecting these impacts.
- Alstonville is the location that has the greatest level of extraction and has monitoring that has been assessed, which provides confidence on the health of the groundwater source. In the case of the Tweed area, while this has minimal monitoring, it also has very low extraction levels for the water source overall – far below the allowable extraction limits.
- While all groundwater extractions have impacts, the magnitude of those impacts and potential consequences will vary. Whether these impacts are measureable, or are of a magnitude to have detrimental consequences on an ecosystem or environmental asset is the focus of monitoring and measurement that occurs both during the assessment phase, and also during the operational phase for approved operations.
- There are significant complexities in measuring local impacts from water extraction due to the spatial and temporal variability of the hydrogeology of fractured and porous rock systems
- While there are existing approaches to measuring and modelling local impacts, these have challenges in terms of accuracy, practicability and cost. Decisions about these investments are also typically done in light of the risk that is being addressed – risk likelihood and consequence.
- Bore water extraction can potentially impact water within the same aquifer, within a connected aquifer, or within a connected surface water body, leading to possible changes in water quantity and quality. The pump test is a common field technique, used in hydrogeological assessments, to derive local scale aquifer properties and to indicate proposed impacts of the extraction. In fractured rock systems, the fracture network that intersects the point of extraction will determine the response to pumping, which is complex and requires hydrogeological investigations and

interpretation of results in order to design the pump test. Impacts may be proximate to or at distance from the point of extraction, and occur vertically as well as horizontally.

- Noting the low level of current groundwater monitoring in three of the four relevant groundwater sources, there would be merit in reviewing the need for additional monitoring that will provide the baseline data, conceptual hydrogeological models and recharge estimates commensurate with potential future risk levels.
- At a regional scale, the cost of traditional monitoring bore infrastructure is likely to be an ongoing challenge. This is particularly the case in fractured rock systems subject to high hydrogeological variability. Emerging sensing technologies able to gather data over large areas and at depth may provide a step-change to the field, subject to cost and commercial availability. Whether at the local or regional scale the choice of monitoring will be informed by the level of risk and the cost-effectiveness of the monitoring. Local research studies may prove a useful adjunct.
- The assessment process for proposed extractions takes into account the risks of local impacts through a risk assessment process, requirements for some applicants for proposed medium and high risk extractions to submit a hydrogeological report to support their application, and criteria for acceptable levels of local impacts.
- Local scale monitoring during extraction operations can assist with better understanding of local hydrology and extractive impacts and consequences. This may include piezometric monitoring of the pathway between the point of extraction and locations where there is perceived risk. The cost of this monitoring is likely to be a challenge and its requirement should be justified by the risks as identified by an expert following analysis of pumping test data.
- Local scale monitoring during extraction operations could potentially support adaptive management, for example, through additional reporting and cease-to-pump rules related to observed groundwater pressures.
- The Review considered a number of past hydrogeological reports submitted to support proposed extractions by the bottled water industry in the Northern Rivers area as components of development applications. The hydrogeological reports, in most cases, assess hydrogeological impacts of proposed developments on surface flows, GDEs and surrounding groundwater bores. The focus and style of the reports varies depending on the purpose and the identified or perceived risks.
- Both industry and decision makers would substantially benefit from greater clarity, specificity and standardisation of requirements for hydrological reports. Current technology is available to enable standardised templates and reports to be managed electronically.
- Robust local assessment of potential connectivity between aquifer and overlying shallow groundwater and surface water should form part of pump tests and feature in hydrogeological reports. This is important, as observed in Alstonville, where deeper aquifers are not necessarily confined and may have connections to surface systems or shallower aquifers. It is important to increase understanding of how confined the aquifer is, as assessment criteria of allowable drawdown differs between confined and unconfined systems. In addition, field verification is an important part of the process.
- The Review received consistent reports from the community and sometimes neighbours of bottled water extractors about observed changes including environmental effects of drying watercourses and loss of water from previously productive bores. The Review has not identified scientific studies or other evidence establishing a causal link between these observed effects and extraction specifically

undertaken by the bottled water industry. Going forward, data from extraction bores, together with monitoring bores (piezometers), local studies and other sources of information should help improve knowledge of impacts from a range of sources.

Data

- Lack of extraction data is an impediment to establishing appropriate extraction limits for individual bores, measuring impacts, and at a regional scale, development of WSP and making determinations of available water. A state-wide metering policy for qualifying groundwater works with bore diameters of 200mm and above will take effect in the Northern Rivers region from 2023. Four of the bottled water extractors in the region are currently required by the regulator to have meters installed.
- The accessibility of any data is central and manual collection can be an impediment in this regard. Advances in technology to provide robust and tamper-proof telemetering options that are commercially cost competitive would have a significant impact.
- Making water extraction and monitoring data available in standardised formats through open databases would benefit decision-makers, researchers and the general public to better understand activities and impacts, including cumulative impacts at local and regional scale. Approvals by relevant state and local government authorities could include requirements that all hydrogeological data are published. There are state managed environmental databases (e.g. SEED) that could be utilised.

Decision-making

- As with any environmental, engineering, resource activity the proponents and decision makers and regulators operate in a realm of imperfect information. This leads to levels of uncertainty around data and information, however uncertainty need not prevent decisions being made.
- There are a number of approaches and tools employed to reduce uncertainty with regard to the assumptions, hydrological domain, impacts, consequences of water extraction. These include taking conservative estimates, using multiple lines of analysis, being judicious in decisions around the type and location of monitoring, employing adaptive management approaches.
- There is a lack of clarity around water planning, management and decision-making roles and processes at state and local government level and between relevant authorities.
- Given the implications of the overlap between development consent and water licences or works approvals, work should be undertaken to clarify roles to ensure consistency, avoid duplication and address any gaps in the assessment and approvals process.
- If Local government is to undertake hydrogeological assessment as part of the development application process, then it needs access to relevant expertise to interpret modelling and technical reports to inform its decision-making, including requirements for development applications.
- Access to government and industry water data through a common open platform housing standardised, well-curated and long-term data sets that can be expanded would assist assessment and decision-making of applications.

5 TECHNICAL APPROACHES TO SOCIO-ECONOMIC FACTORS

Term of Reference 3a requests advice on the scientific and technical approaches to examining socio-economic factors and impacts and possible solutions using locally relevant examples. These related primarily to concerns about the potential growth of the industry, issues associated with truck movements and the use of plastics. The first is dealt with in Chapter 2, the latter two here.

5.1 TRANSPORT (TRUCKS AND ROADS)

Heavy vehicles are used to transport water from the extraction site. These vehicles comprise either bulk water tank trucks or general-purpose freight trucks. The Initial Report also found a total of 128 return truck journeys per week for the bottled water industry in the Northern Rivers region.

Issues raised include: truck movements occurring outside of approved hours or number of trips; dangers from the presence of large trucks on small roads, including in school zones; potential for more significant harm from larger vehicles in the event of an accident; loss of visual amenity and stress from truck-associated noise; and the scale of road damage and maintenance requirements associated with large truck movements shouldered by the broader community.

5.1.1 Frequency and hours of operation

The Heavy Vehicle National Law (HVNL) prescribes a national regulatory framework for a nationally-consistent approach to heavy vehicle legislation (over 4.5 tonnes gross mass) (NTC, 2019). The HVNL is the result of a collaborative process between industry and government and is led by the National Transport Commission (NTC). In most states of Australia, including NSW, the HVNL establishes the Heavy Vehicle National Regulator (HVNR) as the regulator responsible for truck standards and on-road enforcement.

The HVNL regulates driver fatigue management by specifying heavy vehicle operations that require the maintenance of a work diary with driving and rest times. This requirement is linked to a heavy vehicle licence that is regulated in NSW through Roads and Maritime Services (RMS) and NSW Police. Outside of driver fatigue management, the HVNL and Regulations do not prescribe specific conditions that prohibit trucks moving within certain times of the day or how many times they can traverse a region.

Development consent is required for the extraction of water from groundwater systems for commercial bottling. In approving a development application, it is within the remit of local government to apply conditions related to trucks and truck movements, including permissible numbers of movements to and from properties and hours of operations, as well as to enforce compliance. For all new or modified development applications for water bottling, a traffic assessment may be required by council. Councils can only revoke or modify development consents on a limited number of grounds. Where applicants seek to modify conditions of approval, the conditions can be modified only on the issue the application seeks to amend.

A summary of conditions of approval for truck movements is provided in Table 16. Generally, approved truck movements occur between 7:00 – 18:00 on weekdays, with shorter hours on weekends. The number of truck movements per day is highly variable, ranging from two to twelve trips per day. Local Government authorities are responsible for compliance with conditions of development consents.

Table 16: Summary of conditions of approval for truck movements

Issue	Current measures	Responsibility of current measures
Timing	Range: 7:00-18:00 (Monday to Friday) and 8:00-12:00 (weekends)	Council (through the development consent)
Frequency	Range: 2-12 trips (Monday to Friday) and 4-8 trips (weekends)	Council (through the development consent)

If operational approval under the relevant development consent includes school zone times, trucks are legally entitled to operate during those hours. Trucks are held to the same speed conditions in school safety zones as other road vehicles, and these conditions are enforced by NSW Police.

Reviewing development applications currently pending, the Review identified conditions requiring traffic report assessments for the primary road that the water trucks enter and exit from the property, at major intersections and in swept paths within the immediate route of the extraction property. However, the Review has not identified traffic reports being required for historical water extraction licences at the time of assessment.

5.1.1.1 Potential solutions and technologies

Potential strategies available to councils to assist with ongoing monitoring of compliance with conditions of approval include use of written or digital logbooks and electronic tracking. Logbooks would enable collection of data such as odometer reading, location of operation and timing. Electronic products linking data to a database or a phone application could also facilitate accurate record keeping and ease of analysing results. Currently, the majority of development consents for bottled water extractors currently active do not require the use of logbooks to track specific truck movements in and out of the properties. However:

- An approval dating from 2016 stipulates "*an annual statement of truck movements to and from the subject site is to be supplied to council at the end of each financial year to the satisfaction of the General Manager or his delegate*".[82]
- A development application currently under consideration includes a draft condition that states "*The movement of trucks off the site in accordance with this development consent is to be maintained in a daily log which records the date and time of all inbound and outbound trucks from the subject site. At any time, Tweed Shire Council officers may request a copy of the log to be provided for audit of compliance with conditions of this development consent in regard to the times and frequency of truck movements in and out of the subject site…and is to be accompanied by a Statutory Declaration…declaring that the information contained in the log is true and correct*."[83]
- Tweed Shire Council advised that any new or modified applications for water extraction could have conditions requiring logbooks and the installation of security cameras (CCTV) to assist in the monitoring of truck movements (TSC 2019, pers comm., 20 September).

Alternative technologies for monitoring truck movements include active or passive vehicle tracking systems utilising GPS navigation devices and software to collect data for a comprehensive picture of vehicle movements.[84] These systems would be useful in collecting haulage logistics and transport data as they can provide precise and constant data on average speed, distance, fuel consumption, driver time and location.

[82] Development application DA06/1023 (condition 4.2; 10-20 Edwards Lane, Kynnumboon)
[83] Development application DA16/0936 (Rowlands Creek Road)
[84] Passive systems store data and are required to return to a predetermined point where the information from the device can be downloaded and analysed, whereas active systems transmit the date in near-real time via cellular or satellite networks to a computer or data centre for evaluation. Many modern devices will combine both active and passive tracking abilities so that if the cellular network becomes unavailable, the device will store the data to the devices internal memory.

Most devices are installed in the vehicle; however, new technologies also enable mobile phones to be used for tracking multiple variables. These tracking devices are readily available and relatively inexpensive, ranging from approximately $100-$400 (depending on functionality) plus monthly ongoing costs of $20-$30 per month for real-time tracking, history, odometer readings etc.[85]

Traditional approaches, such as traffic surveys, could be used to gather a broader picture about traffic, particularly on roads of concern. Traffic surveys have the capacity to collect data on traffic volumes, vehicle passing probability, road widths and swept paths and can be conducted as observational data during peak traffic times or conducted using Automatic Tube Counts (ATC).[86] Using ATC, data can be collected on the number of vehicles, speed, vehicle types and platoon data by time intervals.[87]

5.1.2 Truck noise

Noise standards for heavy vehicles are prescribed at a national level under the Australian Design Rules (ADRs). All Australian road vehicles must comply with the relevant ADR in place at the time of manufacture and supply to the Australian market. New noise standards for heavy vehicles took effect in 2005 and provide for a national standard for vehicle safety, anti-theft, lighting, noise, engine exhaust emissions and braking.

The National Transport Commission (Model Law on Engine Brake Noise Limits) Regulations 2009 also impose limits on the level of noise emitted by engine brake devices. RMS enforce these regulations through periodic inspections of heavy vehicles at testing stations to ensure that silencers are fitted and maintained and ensure they meet all other noise requirements as specified in the ADR and the HVNL. Current measures and responsible bodies surrounding truck noise is summarised in Table 17.

Despite the regulations, the NSW Environmental Protection Authority (EPA) reports a high instance of complaints from the broader NSW community regarding noise from engine or compression brakes from all types of heavy vehicles (EPA, 2013), and RMS have advocated for tighter vehicle noise stands. RMS and EPA report that noise from trucks braking can be intrusive and it is advisable that heavy vehicle drivers should avoid using exhaust brakes, engine compression or 'Jake' brakes near residential and noise-sensitive areas to help reduce the stress associated with excessive truck noise (EPA, 2013).

Currently, a national scheme is being implemented to impose noise limits from engine compression brakes using roadside noise 'cameras' as an aid to enforcement. There is currently no legislative basis to issue fines for noise from engine compression brake use in any jurisdiction in Australia. However these noise 'cameras' can be used to issue warning notices to truck owners whose vehicles exceed the national engine brake noise in-service noise standard (Parliament of NSW, 2012).

5.1.2.1 Potential solutions and technologies

Council can assist in controlling noise levels generated by trucks through the assessment process and conditions of approval. For all pending or future applications to modify development consents associated with the water extraction industry, a statement of environment effects is required, possibly including an Environmental Noise Impact Assessment. As vehicle noise regulations are set at a federal level, state and local authorities have limited powers to regulate low noise technologies on the vehicles themselves. However, other infrastructure technologies, for example sounds walls designed

[85] These devices are commonly used across haulage companies. In Australia, Linfox, one of the country's largest logistics and supply chain company deploys a GPS system to record a range of real-time data including road speed, engine RPM, fuel efficiency, vehicle location, kilometres travelled, driver identification and engine fault codes and warnings. The data is captured on a small digital recorder mounted in the front of vehicles, with data uploaded to a control room for analysis (Linfox, 2019)

[86] Automatic Tube Counts (ATCs) detect the axles of vehicles using a rubber pneumatic tube to measure vehicle movements.

[87] Platoon data measures the speed of groups of vehicles.

to reduce vehicle traffic noise in specific locations, are a technical option that could be considered.

Table 17: Summary of regulation relating to truck noise

Current measures	Responsibility of current measures
Restrictions on truck movement frequency, route and hours of operation	Council (through the development consent)
Engine noise standards during manufacture	Australian Design Rules
Heavy vehicle noise level limits	Heavy Vehicle National Law (National Transport Commission)
Heavy vehicle inspections	NSW Police, NSW Roads and Maritime Services

5.1.3 Truck size and road damage

A summary of development consent conditions related to truck size is provided in Table 18. The allowable truck size for water extraction under development consents varies across extractors, but generally ranges from 6 to 9 metre long B-double trucks and infringements can be issued if conditions are breached.

The NHVR classifies vehicles of this size as 'General Access Heavy Vehicles'.

Table 18: Summary of conditions of approval for truck size

Issue	Current measures	Responsibility of current measures
Safety	Range: 6m to 19m B-double truck	Council (through the development consent)
	Heavy vehicle standards on horns, mirrors, lights and reflectors	Heavy Vehicle National Law (National Transport Commission)
Damage	Registration cost for operating a heavy vehicle	Proponent/ NSW Roads and Maritime Services
	Road contribution plan Range: $1200 - $ 17536	Council (through the development consent)
	Road maintenance (state and council roads)	NSW Roads and Maritime Services and Council
	Heavy Vehicle Safety Stations	NSW Roads and Maritime Services

The NHVR provides specifications and standards for all heavy vehicles registered on NSW roads to ensure the safety of the trucks and other road users within the community. In terms of safety, these include specific standards on horns, vision mirrors and lights and reflectors. Water trucks are subject to the same regulation.[88] Under national mass and loading arrangements, General Access Heavy Vehicles have unrestricted access to the road system, except where a road or bridge is sign-posted otherwise. Provided these vehicles have current registration appropriate to the vehicle configuration, no specific access restrictions or additional safety precautions apply and no additional permits are required (RMS, 2019).

RMS also has a compliance program to inspect heavy vehicles that may be operating in an unsafe manner on NSW roads. Heavy Vehicle Safety Stations (HVSS) inspect the mass, dimension and loading of a heavy vehicle and ensure it is compliant with the vehicles registration.

The cost associated with road damage caused by heavy vehicles falls to State and Local Governments and the proponent of a development consent in accordance with the

[88] Note that although additional safety precautions are required for vehicles that are considered 'Oversize Over Mass (OSOM) Vehicles', the size of all approved water trucks across the LGAs within the Northern Rivers region meet the OSOM vehicle criteria (TSC, 2019a)

conditions. State registration charges for heavy vehicles aim to recover expenditure on roads from trucks and ensure safe roads for all road users. This registration fee, which includes a regulatory component, is collected through the RMS. The quantum of the fee depends on several factors including the number of axles, gross vehicle mass and what category of vehicle it falls into. These charges are contained in the Heavy Vehicle Charges Model Law.[89]

Although passenger cars account for a high proportion of vehicle-kilometres travelled in Australia, trucks make a greater contribution to pavement damage (Bureau of Transport and Communications Economics, 1997). Pavement damage attributable to a specific vehicle depends on a number of factors including roadway design as well as weight and axle configuration. A commonly agreed method to approximate the relative impact of different categories of vehicles on roads is through the 'Generalized Fourth Power Law', which predicts that the change in pavement damage is proportional to the difference in the vehicles axle weight to the fourth power (Freight on Rail, 2019). However, determining the number and types of wheel/axle loads that a particular pavement is subject to in any given time is more complex.

Road ownership generally determines the authority responsible for road maintenance charges. In the Northern Rivers region most roads are owned by local government, with only a few large inter-passes that are state owned. Some council roads that are strategic to traversing the region and have high use may receive a state contribution for their maintenance.

Councils can adopt Road Contribution Plans (RCP), as a mechanism to collect contributions from developers to support public road infrastructure. [90] The RCPs include an additional component relating to vehicle weight.[91] The Review found that development applications for bottled water extraction approved over the last decade include a contribution under the RCP. Tweed Road Contribution Plan modelling found that the Tweed Shire road network will experience considerable traffic growth, especially on the Tweed coast and in urban areas, as a result of the anticipated urban development and that most major urban road corridors will be required to carry considerably more traffic (TSC, 2016).

5.1.3.1 Potential solutions and technologies

Where feasible, increased council or police presence or random spot checks at extractors during operational hours may assist to regulate truck size compliance and alleviate community concern that larger than authorised trucks are being used. Technologies described in previous sections would also be relevant.

Councils can continue to exercise their powers in relation to truck size when approving development applications.

5.1.4 Conclusions

- There are technologies available that can provide accurate, consistent and real-time data on truck movements, which could be included as a condition of the development consent.
- Responsibility for governing truck safety, movements and size spans Federal, State and Local Government authorities. Each of the responsible bodies has measures to

[89] As implemented by each jurisdiction .The heavy vehicle registration fee is based on the pricing principles set by the Transport and Infrastructure Council and the Council of Australian Government (COAG) and undergoes annual adjustments (Transport and Infrastructure Council, 2017).

[90] Section 7.11 of the *Environmental Planning and Assessment Act 1979* is the principal legislation enabling Councils to levy development contributions for public amenities and services. A monetary contribution can be imposed by a way of a condition of development consent and can be in the form of a Road Contribution Plan.

[91] For example, the Tweed Road Contribution Plan (s 6.5) includes a heavy haulage fee based on a formula comprising the value and life of pavement.

regulate and monitor heavy vehicles through existing legalisation, approval of applications and technologies.

- Technologies and strategies are available to measure traffic volumes and impacts. Local government can levy heavy vehicle road users to contribute to the cost of road maintenance and repair.

5.2 PLASTIC BOTTLES

The Initial Report included concerns expressed during consultations about the environmental impacts of plastics used in the bottled water industry. These views were reiterated in submissions received by the Review.

The issue is international in scope and management of the impacts and solutions will be influenced significantly by factors and developments beyond the Northern Rivers region.

5.2.1 Extent and management of plastic

The main polymers that plastic bottles for drinking water are produced from are Polyethylene terephthalate (PET) and High density polyethylene (HDPE) (PricewaterhouseCoopers, 2008; Locock et al., 2017). PET and HDPE are predominately made of non-renewable sources such as oil or gas (CIEL, 2017) although recycling can collect waste PET and HDPE for reprocessing (recyclate). New plastic water bottles can contain PET recyclate (Locock et al., 2017).

Across Australia, 3.4 million tonnes of plastics were consumed (Envisage Works, 2019) in 2017-18 and approximately 58% of total plastic packaging generation was disposed to landfill from collection (Madden & Florin, 2019).[92] The recycling rate of PET in Australia has increased from 16% in 2016-17 to 21% in 2017-18 (Envisage Works, 2018, 2019).[93] In the same period, consumption increased from 345,600 tonnes to 355,300 tonnes, 32% of which was from NSW (Envisage Works, 2018, 2019).

NSW, together with the Commonwealth and other jurisdictions has committed to establishing a timetable and strategy to ban the export of key waste materials, including plastic; reduce plastics waste and diversion to landfill; and build capacity to recover value from waste and generate high-value recycled products (COAG, 2019). This follows a 2018 commitment for 100% of Australian packaging to be recyclable, compostable or reusable by 2025 and 70% of plastics to be recycled or composted (Waste Management Review, 2019). The Australian Packaging Covenant Organisation (APCO) manages the national product stewardship scheme for the delivery of the sustainable packaging pathways in Australia, and is leading the delivery of the 2025 National Packaging Targets.[94]

A nationally harmonised approach will facilitate implementation of NSW policies and initiatives. The NSW Circular Economy Policy Statement 'Too Good To Waste' was released in February 2019 (EPA, 2018), building on the NSW Waste Avoidance and Resource Recovery Strategy 2014–21 (EPA, 2014) and associated programs. These strategies are driven by the most efficient approaches for resource use, guided by the waste hierarchy to avoid and reduce waste in the first instance, followed by options to reuse and recycle waste, to recover energy and treat waste and finally to dispose of waste (EPA, 2014).

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[92] Consumption is defined as the Total use of product by Australian industry and consumers. It includes locally made and used product, imported product and locally utilised recyclate. Does not include locally made product that is exported for sale.
[93] The Recycling rate is determined from the extent of recyclate sent to plants domestically and internationally for re-processing
[94] APCO is a co-regulatory not-for-profit organisation administering the Australian Packaging Covenant, an agreement between Federal, state and territory governments and the packaging industry to reduce the harmful impact of packaging on the environment. Plastics in packaging accounts for 60% of the plastics waste stream. National Packaging Targets to be achieved by 2025 are: 100% reusable, recyclable or compostable packaging; 70% of plastic packaging being recycled or composted; 30% of average recycled content included in packaging and the phase out of problematic and unnecessary single-use plastics packaging (APCO, 2019d).

The NSW Government is currently developing a NSW Plastics Plan as well as a 20 Year Waste Strategy. In 2017, the NSW Government Return and Earn Container Deposit Scheme was introduced, resulting in the return of 750 million drink containers and a 33% reduction of eligible containers in the litter stream in one year (Blue Environment, 2018). Over January to June 2019, sorted PET plastic containers made up 28.1% of the volume collected across NSW, while HDPE made up 1.4%. A number of collection points are located in the Northern Rivers and there has been an increase in the return of containers since 2017 (Figure 23).

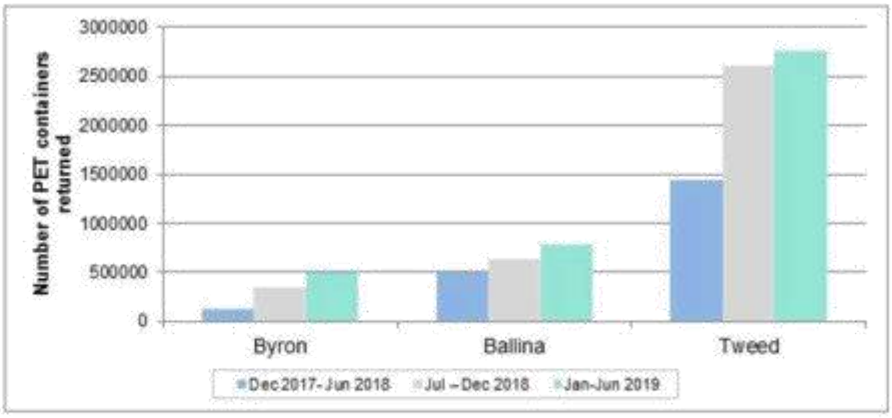

Figure 23: Return and Earn collection volumes of sorted PET plastics in select areas
Note: data includes Reverse Vending Machine, Automated Depot return volumes and disaggregated Over The Counter weekly return volumes collected through the Network Operator Exchange for Change

5.2.2 Bottled water industry – current practices and commitments

In the Northern Rivers region, proponents extracting water for the bottled water industry either sell the water on to a bottler and/or bottle the water themselves. Large companies, CCA, Asahi Holdings (Australia) Pty Ltd and Nu-Pure Pty Ltd account for over 70% of the market share of Australian bottled water products (IBISWorld, 2019). Both CCA and Asahi are signatories to the Australian Packaging Covenant, and were graded as level four (leading) out of five against the 13 criteria of the Sustainable Packaging Framework (APCO, 2019a, 2019b).

Coca-Cola Amatil has committed to reducing the amount of waste sent to landfill by making 100% of all packaging recyclable by 2030 (APCO, 2019b); has targets for increasing the recyclability of on-pack labelling, light-weighting bottles (i.e. reducing the amount of plastic used in containers) (APCO, 2019b); and increasing the amount of recycled plastic in PET bottles (Coca-Cola Amatil, 2018b). In 2019, the company announced seven out of 10 of its bottles manufactured for the Australian market would be 100% recycled plastic by the end of the year.[95] Asahi's Action Plan to meet the 2025 Targets include more than 50% of primary packaging to be recoverable, and improving material efficiency in up to 20% of products (APCO, 2019a). Asahi have commenced blowfill manufacturing to produce lightweight PET CSD bottles (Asahi Beverages, 2016). The Nu-pure spring water range uses 50% recycled PET (Nu-Pure, 2019).

There are smaller operators in the Northern Rivers who both extract and bottle, who use a range of plastic bottle products. While some use small plastic PET bottles (350-650ml); other operators are using options that may encourage minimisation of plastic production and waste. This includes use of large plastic containers designed for water coolers (up to 19L),

[95] This includes the Mount Franklin and Pump water brands. See https://www.marketingmag.com.au/news-c/news-coca-cola-recycled-bottles-2019/

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that are returnable or with a refundable deposit fee per bottle; use of plastic bottles with the addition of a compound (reverte) to encourage oxo-biodegradation and substitution of glass for plastic.

5.2.3 Opportunities and challenges

To achieve the 2025 National Packaging Targets, a whole of supply chain approach is required to focus on design, collection and recycling systems, reuse, materials circularity and consumer engagement (APCO, 2019f). It is anticipated that this period of transition for industry and consumers will see waste management initiatives implemented in a series of stages that are in line with a global shift to reduce waste entering landfill and improve recycling.

Globally, identified opportunities and challenges include improving design to avoid pollutant materials and minimise reprocessing challenges; improving recycling capability; increasing the quality and value of processed material; substitution and decoupling plastics from non-renewable resources (Ellen MacArthur Foundation, 2014; DEE, 2018).

APCO is leading a number of pieces of work on Australian used packaging volumes and resource recovery capabilities. Due for release later this year, these include reports on recycling infrastructure and emerging and at-market technologies to manage a range of waste streams, including plastics. These reports will provide a more granular picture than currently available at both national and state levels and will be a key input to strategies going forward.

Better characterisation of waste streams, understanding of material stream flows and establishing mechanisms to support market development will also underpin uptake of technologies.[96] The Institute of Sustainable Futures at the University of Technology Sydney was commissioned by APCO to provide a packaging material flow analysis (Madden & Florin, 2019) and developed a packaging sustainability framework that has been implemented as an online self-assessment tool for companies (Kelly et al., 2017).

Design choices at the manufacturing stage would help reduce contamination as recyclable containers that use different polymers for caps, adhesives and labels can present sorting challenges. Eliminating polymers and certain colours that are problematic for recycling would also improve recycling efficiencies as well as improving collection and sorting into clean single-polymer streams.

In Australia the majority of used plastic packaging that is disposed to landfill is not collected for recovery (Madden & Florin, 2019) and contamination also results in large volumes of recyclable plastics going to landfill (DEE, 2018). A large source of contamination is due to the handling and compaction of glass in co-mingled collections, causing the glass to break and producing glass fragments that are difficult to separate (Madden & Florin, 2019). Plastic bottles placed in co-mingled recycling bins for municipal kerbside collection are generally sent to Materials Recycling Facilities (MRFs) and are sorted into either a mixed-plastics grade, or more commonly three grades: PET, HDPE and other residual mixed plastics (DEE, 2018).

MRFs vary in technological sophistication, most using a mix of human, mechanical and electronic processes to sort co-mingled recycling, and lack capacity to sort highly contaminated waste (DEE, 2018). Of 12 reprocessing plants Australia-wide, three in NSW are reprocessing PET (DEE, 2018). There are opportunities to improve collection and processing infrastructure to reduce contamination and improve the quality and value of recycled materials, including through the use of automated optical sorting equipment (DEE, 2018).

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[96] In May 2019, the Federal Government committed $1.6 million to develop an online platform and marketplace and a further $9.2 million in August 2019 to advance innovation in plastics recycling under Round 8 of the Cooperative Research Centres Projects program (CRC-P).

PET recycling is mature technology and driven by markets for recycled PET overseas and locally. There is significant local capacity capable to recycle PET to food grade and there are projects in train that will increase this capacity. The capacity for recycling HDPE back into food grade remains limited compared to the volumes consumed.[97]

The market for recyclate is also influential, fluctuations depending on manufacturing capacity as well as oil and gas prices for the production of new plastic (Locock et al., 2017).

Many of the NSW Government 2018 *Waste Less Recycle More* grants will address the issues of increased restrictions on export of recyclate, cross contamination of recyclables; and will initiate opportunities to process recyclate for new purposes and update MRFs.[98]

5.2.3.1 Alternatives and additives

Alternatives to plastic bottles being explored by the global bottled water industry include glass and paperboard (Carton & Co Water, 2019). Substitution with glass may be influenced by market forces e.g. due to the lower cost of importing bottles (Meldrum-Hanna, Davies, & Richards, 2017; DEE, 2018), the quality of glass collected by municipal kerbside recycling (DEE, 2018) and higher transport costs (freight and energy) associated with glass (Meldrum-Hanna et al., 2017).

Bioplastics are produced from renewable sources, usually from vegetable fats or corn starch.[99] Currently, over 75% of bioplastics on the market are non-biodegradable (Australasian Bioplastics Association, 2019). Bioplastics can be designed to be either recyclable or compostable, but not both. Developing a consistent labelling system and avoiding compostable packaging contaminating the recyclables stream (and vice versa) has been identified as a priority (APCO, 2019c; Australasian Bioplastics Association, 2019). Most compostable bioplastics require specific conditions; as a result, the speed of biodegradation is different in industrial composting plants compared to home composts.

Plastic bottles may also be made with conventional polymers that have an oxidising additive to assist with degradation. These are referred to as oxo-degradable, hydro-biodegradable or oxo-biodegradable plastics (PACIA, 2007). Issues include establishing the timeframe in which complete degradation occurs in order for a biodegradable product to have an environmental benefit (European Commission, 2018) and concerns about oxo-degradable products (European Commission, 2015; Selke et al., 2015; European Commission, 2018). In Australia, APCO has identified working towards a ban on oxo-degradable plastics as a priority project as these plastics are included in problematic and unnecessary packaging to be phased out by 2025 (APCO, 2019e).

5.2.3.2 Emerging technologies

There are increasing examples of, and opportunities for, end of use applications for plastic where strong, light-weight material is required. Science and engineering advances in materials, chemistry and synthetic biology also have a role in improving design, substitution and reuse. While some developments are at early stages, many are in scale up to commercialisation stage. Research and development efforts to replace, repurpose and recycle plastics is a fast-moving and evolving space that is predicted to show significant growth within the next 5-10 years.

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[97] Australian manufacturers are required to comply with the Food Standards Code that outlines standards for plastic materials in contact with food. The Code refers to a voluntary Standard (AS 2070:1999) which states that post-consumer recycled material is not to be used in direct contact with food. However, it is understood the Code is currently under revision, and the reference is likely to be removed.

[98] Through this program, Lismore City Council will undertake technological updates to reduce cross contamination of recyclables at an MRF that services four council areas in the Northern Rivers region (DPIE, 2019b).

[99] Bioplastics can also be made from agricultural by-products, used plastic bottles and other containers using microorganisms.

This capacity for growth was highlighted in the 'Innovation in the NSW environmental goods and services' report. The report found that the environmental goods and services sector valued at $43.9 billion in 2017-2018, is growing at a rate of 7.1% per annum, faster than the wider economy, with exports worth $3 billion (NSW Innovation and Productivity Council, 2019).

Emerging research in materials engineering using Green Steel technology was invented at the Centre for Sustainable Materials Research and Technology (SMaRT) at UNSW. The Polymer Injection Technology substitutes coke with waste, using old tyres and plastics to provide a source of carbon to replace a significant proportion of the non-renewable coke used to make steel in electric arc furnaces. The SMaRT facility is also home to Green Microfactories™ designed to reuse and repurpose materials including transformation of plastic waste into high-quality 3D printing filaments. The recently announced ARC Research Industrial Transformation Research Hub for Microrecycling of Battery and Consumer Wastes opens up numerous new pathways to leverage high temperature process to access the wealth of resources embedded within complex wastes such as metals, plastics and glass. Instead of becoming landfill, they will be transformed into valuable materials and products, including metallic alloys, oxides and carbon.

In the field of Chemical engineering, the CSIRO Chemistry and Polymer Research Group is scoping projects to substitute materials for plastics, product development and the development of new materials (additives) to aid polymer reprocessing.

Licella and the University of Sydney have co-developed a technology called the Catalytic Hydrothermal Reactor, or "Cat-HTR", to chemically recycle End-of-Life Plastics. Cat-HTR breaks plastics down into smaller hydrocarbon components, using water at high temperature and pressure and a mix of catalysts to stabilize the break-down products, preventing the intermediate radicals from reacting with each other. The resulting liquid and gas products can be readily upgraded using existing hydrocarbon refining and blending infrastructure into useable products such as high-value waxes, lubrication oils, fuels, chemicals and gases. Since the hydrocarbon products closely resemble the crude oil from which the plastics were made, the Cat-HTR products can also be further cracked and refined to monomers from which new plastics can be made, providing a circular economy advantage to the technology. A large pilot plant with commercial scale reactor modules is established on the NSW Central Coast. The first commercial Cat-HTR plant is currently under development in Wilton (North East UK) and will convert 20,000 tonnes of End-of-Life Plastic annually. Similar commercial plants are under development in Australia.

Synthetic Biology is an emerging field where complex artificial biological systems are engineered. This research can be applied to the generation of plastics using genetically engineered microbes to replace polymers from petrochemical sources. A recently approved Australian Research Council Centre of Excellence in Synthetic Biology headquartered at Macquarie University is focusing on converting biomass from agriculture or waste streams to a range of products including bioplastics, building on work previously undertaken through the international Yeast 2.0 consortium.[100] While developments in this space may not be commercially viable in the short term, the university has industrial partners undertaking pilot projects to develop cost-effective manufacturing solutions at market scales.

5.2.4 Conclusions

- The presence and management of plastics is international in scope and management of the impacts and solutions will be influenced significantly by factors and

[100] *The Yeast 2.0 project is a global partnership focused on utilising synthetic biology tools to build the world's first synthetic eukaryotic genome".* See www.mq.edu.au/research/research-centres-groups-and-facilities/centres/synthetic-biology-consortium/our-projects.

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developments beyond those extracting water for bottling purposes in the Northern Rivers region.

- The NSW Government is developing a 20 year waste strategy and plastics plan in the context of broader Federal Government and inter-jurisdictional commitments to address waste and transition from linear to circular economies.
- There is a NSW Government container deposit scheme that has resulted in a one-third reduction across the state of eligible containers, including bottles entering the litter stream.
- Research and development efforts to replace, repurpose and recycle plastics is a fast-moving and evolving space that is predicted to show significant growth within the next five to ten years.

6 FINDINGS AND RECOMMENDATIONS

This Review has occurred during a period of widespread concern and public debate about extended drought and long-term water futures. The Review recognises the community concern about water allocations and use, and the desire for greater certainty and more definitive information to inform decision making.

Yet all decisions are made in the context of imperfect knowledge. In groundwater studies and management, there will always be a level of uncertainty associated with predictions and a precise value may not be achieved due to the complex and heterogeneous nature of groundwater movement. This is particularly evident in fractured rock systems that are difficult to characterise fully.

The question of how to manage risk and uncertainty optimally in relation to water resources is long-standing. Managing risk relies on efforts of the proponent, the regulator, state agencies and local government and other stakeholders. Policy and regulatory instruments provide a framework and strategies to help manage risk and reduce impacts. These include adaptive management, risk assessment of proposed developments and approval conditions for licences and development applications.

However, within these frameworks, judgements still need to be made. Relevant are risk appetite, context, available information, potential consequences and the degree of confidence in the assumptions made. Also important is access to tools that can be drawn on to reduce uncertainty and manage risk in a way that is cost effective and proportional to the level of risk.

6.1 FINDINGS

6.1.1 The bottled water industry

- Available industry data indicates that across Australia, over three-quarters of bottled water is sourced from underground wells, and the remainder from standard reticulated water supplies. Approximately 8% of Australian bottled water production is exported.
- The Review identified seven operators in the Northern Rivers region with allocations of 240.5 ML/y who are actively extracting for water bottling purposes, representing 0.55% of water licences and basic landholder rights (together defined in the WSP as 'total water requirements') and 0.008% of estimated total annual aquifer recharge in the four groundwater sources.
- Four further proposals, if approved, would amount to an additional 168 ML/y, being an additional 0.38% of estimated total water requirements and 0.006% of total annual aquifer recharge.
- Changing consumer preferences, trade imbalances, the availability of tap water and private ('no name') brands and population growth are expected to impact future bottled water production and consumption volumes.
- Scenario analyses conducted by the Review suggest the Australian bottled water industry is most likely to grow at a rate of less than 2% per annum to 2024 and that growth in the Northern Rivers region is likely to be consistent with this trend. Under most scenarios to 2024 considered, the 168 ML/y of additional proposed bottled water operations would be sufficient to meet fully projected growth in demand.

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- The Review also considered 'highly unlikely' and 'extremely unlikely' scenarios to 2034, being growth continuing at the current rate of 10% per annum and establishment of a major premium bottled water exporter in the Northern Rivers, respectively.
  - If the 'highly unlikely' scenario occurred, the bottled water industry would represent less than 2.3% of 'total water requirements' and 0.034% of estimated total annual aquifer recharge.
  - If the 'extremely unlikely' scenario occurred, the bottled water industry would represent less than 4.6% of 'total water requirements' and 0.069% of estimated total annual aquifer recharge.
- As the scenario analyses considered an unchanged regulatory and policy environment, these forecasts may be affected by regulatory intervention which directly or indirectly impacts the bottled water industry in this region.
- For the purposes of water extraction licensing, the bottled water industry is treated the same as other prospective commercial users. However, development consent under the *Environmental Planning and Assessment Act 1979* is required for water bottling activities. Approvals identified by the Review for bottled water extraction in the Northern Rivers region date from 1993.

6.1.2 Allocations

- The WSP determines the allowable extraction limit, set from the recharge value of each aquifer, with an amount of the recharge reserved for the environment and the reminder determining the Upper Extraction Limit or the LTAAEL
- Under the WSP, environmental water and basic landholder rights are given priority over licensed water extraction. Among licensees, priority is given to water utilities and licensed stock and domestic over commercial licensed purposes.
- At the commencement of the WSP for the four groundwater sources, 100% of storage is reserved for the conservation of the groundwater system.
- Water available for extraction is a portion of the estimated recharge value for each groundwater source. This is determined by the WSP. An amount of the recharge is reserved for the environment. The amount reserved for the environment equates to 97% of the estimated recharge value for New England Fold Belt Coast, 96% for North Coast Volcanics, 82% for Alstonville Basalt Plateau and 48% for Clarence Moreton Basin.
- The remaining amounts can be allocated for licensed purposes. Of these amounts, 38.0% of the New England Fold Belt Coast is allocated, 51.3% of the North Coast Volcanics and 1.7% in the Clarence Moreton Basin. Alstonville is fully allocated.
- These are average values over the groundwater source areas; which means that the environment is not protected to these levels in locally impacted areas.

6.1.3 Water Sharing Plan assumptions and uncertainty

- In groundwater studies and management, there will always be a level of uncertainty associated with predictions (e.g. recharge rates) and a precise value may not be achieved due to the complex and heterogeneous nature of groundwater movement. This is particularly evident in fractured rock systems that are difficult to characterise fully.

- The WSP plan was developed based on the best available data at hand and followed a standard procedure. The assumptions made in the WSP are practical, reasonable and in agreement with standard practice. In general, the WSP incorporates a reasonable level of conservatism for extraction limits based on the risks identified. .
- The rainfall data used and the methodologies are sound and apply limited uncertainty to the extraction rates.
- The portion of the estimated recharge value available for extraction is a function of rainfall recharge over low environmental value areas together with an assessment of environmental and socio-economic risk.
- Calculating recharge is complex due in part to the variability and complexity of the hydrogeology and limited knowledge of the systems. Based on the analysis, the Review considers the recharge rates used in the WSP are reasonable and conservative. This statement is made with a relatively low level of confidence due to lack of data for the groundwater sources of interest.
- In practical terms the groundwater sources are treated as geologically homogenous which adds uncertainty and would benefit from further work. The Review recognises that the complexity of the geology makes it difficult to incorporate heterogeneity into the WSP recharge calculations. Particular attention should be given to the effects of geological variability within groundwater sources, and soils and vegetation overlying aquifer outcrops. The Review acknowledges the conservatism incorporated into the current WSP through the allowable allocation figures.
- There is evidence to suggest that for the WSP recharge variable, there is a wide range of values that can be applied as well as a number of different approaches to calculate it. Limited field data is available to support a single estimate.
- Recharge rates applied to the four groundwater sources in scope in the WSP ranged from 4% - 8% with studies and alternative methods indicating, with considerable uncertainty, levels between 1% and 31%. The calculations by the Review using CBM and baseflow filtering for recharge rates had results mostly above the values used in the WSP. The Review noted the important contribution that surface conditions and soil could make to the recharge of the underlying geology.
- The Review tested a scenario in which the recharge rates were reduced by 80%. It found the recharge reserved for the environment for the New England Fold Belt Coast and North Coast Volcanics would remain at around 80% of recharge. For Alstonville, it would be reduced, but the network of monitoring piezometers provides the ability to monitor long-term changes in levels. For the Clarence-Moreton Basin, with only around 1.5% of available water allocated, the LTAAEL could be reduced with no impact on licences.
- Based on the analysis, the Review considers the recharge rates used in the WSP are reasonable and conservative. This statement is made with relatively low level of confidence due to lack of data for the groundwater sources of interest.
- The application of the sustainability index appears to be a cost and time effective risk tool that is applied as an additional means to protect resources where limited information is available.
- The WSP incorporates a reasonable level of conservatism for the extraction limits when the groundwater sources are not fully allocated and where they are fully allocated at Alstonville, monitoring is applied.
- Additional monitoring in strategic locations in the Tweed would help inform gaps in knowledge on a regional scale and provide a path towards better conceptual understanding of aquifer flows.

- The overall system is managed with some level of adaptive management, including an annual determination of the volume of water per licence share and WSP are subject to an interim review at five years with a full review at ten years.
- Impacts of climate change should be considered in future WSP methodologies. A warming climate can lead to increases or decreases in rainfall, variations in the timing and frequency and strength of rainfall events, and increases or decreases in evapotranspiration. The development by the NSW Government of Regional Water Strategies will provide further insights into the impact that climate change could have on the region and catchments over the coming decades, which can further inform management approaches for the region's water resources.

6.1.4 Sustainability of Water Sharing Plan extraction limits

- Due to limited extraction levels (where known allocations in the Tweed region are much lower than the extraction limits contemplated in the WSP), limited data and uncertainties described regarding the WSP parameters, it is not possible to conclude whether the extraction limits are currently sustainable. However, the Review found no evidence at this point in time that current WSP extraction limits are not sustainable.
- For the Alstonville Basalt Plateau Groundwater Source, which is fully allocated, and there is a network of monitoring piezometers, data from 2006 onwards was analysed by the Review, which concluded:
  - The deeper piezometers (depths greater than around 25 m) showed a greater stability and a steady upward trend over time of groundwater levels and/or pressures. In contrast, the shallower piezometers showed greater variability and appear to be recharged regularly with rainfall.
  - Lagged rainfall is an important variable for understanding piezometer water levels in the Alstonville Plateau. This was observed in shallow-sited piezometers and in deeper piezometers sited in systems that are well connected to surface waters and upper aquifers.
  - There is limited amount of information available on current actual extraction volumes. The Review notes that enhanced metering requirements will come into force in the region in 2023 for eligible groundwater extractors. Given this lack of data on extraction volumes, it is difficult to separate the effects of environmental variables (such as rainfall) from the impacts of human extraction (which tends to increase during dry periods).

6.1.5 Methodological improvements

- The Review considers there is room for improvement in the future assessment of the variables underlying the extraction limits.
- Impacts of rainfall patterns in the region on recharge should be considered in future WSP methodologies, including changing patterns associated with climate change.
- Particular attention should be given to assessment of groundwater recharge rates across broad spatial areas and the associated need to distinguish between confined versus unconfined aquifers.
- Developing a better conceptual understanding of the geological strata in the WSP to reduce the level of uncertainty in the estimated recharge values. This could possibly be undertaken via a 3D geological modelling tool (e.g. Leapfrog Geo) where there is sufficient data and should include some soil mapping. This would require a large scale detailed geological mapping survey or the collation of the existing core log data and geophysical measurements, where available. The Review notes this level of

detail has not been typically applied in similar WSP for easterly flowing rivers and would require allocation of time and resources.

- Sensitivity testing could be undertaken to see whether a change in the recharge or sustainability index might result in the aquifers being over allocated or stressed.
- Further work could be undertaken to assess whether the risk ratings given to specific groundwater sources are appropriate.
- Water levels in the Department's piezometers should be regularly assessed to ensure periods of sustained water level decline are identified early. With further analysis, it may be appropriate to set trigger values for water levels in key deep aquifers that allow for adaptive management of groundwater extractions (e.g. once water levels fall below a certain level, restrictions may be placed on extractions in that area).
- Where the system is fully (or near fully) allocated, additional monitoring/sampling and routine data analyses could be applied, as was undertaken at Alstonville, within an adaptive management framework

6.1.6 Assessment and management of potential impacts from water extraction

- Based on the review of available information, there is no measured evidence that current bottled water extractions have impacts on other properties' bores, surface water or GDEs in the Northern Rivers region. This is at least partly due to the relatively low current levels of extractions, hydrogeological conditions and lack of monitoring detecting these impacts.
- While all groundwater extractions have impacts, the magnitude of those impacts and potential consequences will vary. Whether these impacts are measureable, or are of a magnitude to have detrimental consequences on an ecosystem or environmental asset is the focus of monitoring and measurement that occurs both during the assessment phase, and also during the operational phase for approved operations.
- There are significant complexities in measuring local impacts from water extraction due to the spatial and temporal variability of the hydrogeology of fractured and porous rock systems
- While there are existing approaches to measuring and modelling local impacts, these have challenges in terms of accuracy, practicability and cost. Decisions about these investments are also typically done in light of the risk that is being addressed – risk likelihood and consequence.
- Bore water extraction can potentially impact water within the same aquifer, within a connected aquifer, or within a connected surface water body, leading to possible changes in water quantity and quality. The pump test is a common field technique, used in hydrogeological assessments, to derive local scale aquifer properties and to indicate proposed impacts of the extraction. In fractured rock systems, the fracture network that intersects the point of extraction will determine the response to pumping, which is complex and requires hydrogeological investigations and interpretation of results in order to design the pump test. Impacts may be proximate to or at distance from the point of extraction, and occur vertically as well as horizontally.
- Noting the low level of current groundwater monitoring in three of the four relevant groundwater sources, there would be merit in reviewing the need for additional monitoring that will provide the baseline data, conceptual hydrogeological models and recharge estimates commensurate with potential future risk levels.

- At a regional scale, the cost of traditional monitoring bore infrastructure is likely to be an ongoing challenge. This is particularly the case in fractured rock systems subject to high hydrogeological variability. Emerging sensing technologies able to gather data over large areas and at depth may provide a step-change to the field, subject to cost and commercial availability. Whether at the local or regional scale the choice of monitoring will be informed by the level of risk and the cost-effectiveness of the monitoring. Local research studies may prove a useful adjunct.
- The assessment process for proposed extractions takes into account the risks of local impacts through a risk assessment process, requirements for some applicants for proposed medium and high risk extractions to submit a hydrogeological report to support their application, and criteria for acceptable levels of local impacts.
- Local scale monitoring during extraction operations can assist with better understanding of local hydrology and extractive impacts and consequences. This may include piezometric monitoring of the pathway between the point of extraction and locations where there is perceived risk. The cost of this monitoring is likely to be a challenge and its requirement should be justified by the risks as identified by an expert following analysis of pump test data.
- Local scale monitoring during extraction operations could potentially support adaptive management, for example, through additional reporting and cease-to-pump rules related to observed groundwater pressures.
- The Review considered a number of past hydrogeological reports submitted to support proposed extractions by the bottled water industry in the Northern Rivers area as components of development applications. The hydrogeological reports, in most cases, assess hydrogeological impacts of proposed developments on surface flows, GDEs and surrounding groundwater bores. The focus and style of the reports varies depending on the purpose and the identified or perceived risks.
- Both industry and decision makers would substantially benefit from greater clarity, specificity and standardisation of requirements for hydrological reports. Current technology is available to enable standardised templates and reports to be managed electronically.
- Robust local assessment of potential connectivity between aquifer and overlying shallow groundwater and surface water should form part of pump tests and feature in hydrogeological reports. This is important, as observed in Alstonville, where deeper aquifers are not necessarily confined and may have connections to surface systems or shallower aquifers. It is important to increase understanding of how confined the aquifer is, as assessment criteria of allowable drawdown differs between confined and unconfined systems. In addition, field verification is an important part of the process.
- The Review received anecdotal information suggesting bottled water extractors were generally extracting water at an approximately evenly spaced production rate year-round compared with other commercial users who extract on a more periodic basis. The Review was not able to verify these observations. Further, all groundwater users are subject to future changing environmental conditions, which may influence their future patterns of use. The implementation of the NSW Non-Urban Water Metering Policy will provide information about use patterns in the bottled water industry and enable analyses of interactions and impacts.
- The Review received consistent reports from the community and sometimes neighbours of bottled water extractors about observed changes including environmental effects of drying watercourses and loss of water from previously productive bores. The Review has not identified scientific studies or other evidence

establishing a causal link between these observed effects and extraction specifically undertaken by the bottled water industry. Going forward, data from extraction bores, together with monitoring bores (piezometers), local studies and other sources of information should help improve knowledge of impacts from a range of sources.

6.1.7 Data

- Lack of extraction data is an impediment to establishing appropriate extraction limits for individual bores, measuring impacts, and at a regional scale, development of WSP and making determinations of available water. A state-wide metering policy for qualifying groundwater works with bore diameters of 200mm and above will take effect in the Northern Rivers region from 2023. Four of the bottled water extractors in the region are currently required by the regulator to have meters installed.
- The accessibility of any data is central and manual collection can be an impediment in this regard. Advances in technology to provide robust and tamper-proof telemetering options that are commercially cost competitive would have a significant impact.
- Making water extraction and monitoring data available in standardised formats through open databases would benefit decision-makers, researchers and the general public to understand better the activities and impacts, including cumulative impacts at local and regional scale. Approvals by relevant state and local government authorities could include requirements that all hydrogeological data are published. There are state managed environmental databases (e.g. SEED) that could be utilised.

6.1.8 Decision-making

- As with any environmental, engineering, resource activity the proponents and decision makers and regulators operate in a realm of imperfect information. This leads to levels of uncertainty around data and information; however, uncertainty need not prevent decisions being made.
- There are a number of approaches and tools employed to reduce uncertainty with regard to the assumptions, hydrological domain, impacts, and consequences of water extraction. These include taking conservative estimates, using multiple lines of analysis, being judicious in decisions around the type and location of monitoring, employing adaptive management approaches.
- There is a lack of clarity around water planning, management and decision-making roles and processes at state and local government level and between relevant authorities.
- State government agencies and local government should work to clarify roles and responsibilities to streamline assessment and approval processes, to avoid duplication of effort, and to address any gaps in the assessment and approvals process. The first step for this would be by February 2020 relevant officers from Water NSW, DPIE Water, NRAR and Tweed Council convene a workshop for Northern Rivers region bottled water to discuss and develop an approach between them. to:
    - Develop a shared understanding of the data, modelling and information needed by each agency in decision making
    - Documenting a set of standards for data capture, sharing, storage between agencies

  - Maximise the utility and outcomes for the group of agencies when new monitoring is being rolled out
  - Discuss gaps and overlaps in conditions between regulatory and compliance instruments of different agencies. Access to government and industry water data through a common open platform housing standardised, well-curated and long-term data sets that can be expanded would assist assessment and decision-making of applications.
- If Local government is to undertake hydrogeological assessment as part of the development application process, then it needs access to relevant expertise to interpret modelling and technical reports to inform its decision-making, including requirements for development applications.
- Regional Water Strategies will be developed over the coming months for the 12 catchment regions across the state and will assist to manage the regions' water resources. The Greater Hunter Regional Water Strategy is already in place. These will improve water security within each region and influence decisions about infrastructure, water reuse, water sharing including during droughts, protect the regions' environmental assets as well as addressing community and industry needs.

6.1.9 Truck movements and road impacts

- There are technologies available that can provide accurate, consistent and real-time data on truck movements, which could be included as a condition of the development consent.
- Responsibility for governing truck safety, movements and size spans Federal, State and Local Government authorities. Each of the responsible bodies has measures to regulate and monitor heavy vehicles through existing legalisation, approval of applications and technologies.
- Technologies and strategies are available to measure traffic volumes and impacts. Local government can levy heavy vehicle road users to contribute to the cost of road maintenance and repair.

6.1.10 Plastics

- The presence and management of plastics is international in scope and management of the impacts and solutions will be influenced significantly by factors and developments beyond those extracting water for bottling purposes in the Northern Rivers region.
- The NSW Government is developing a 20-year waste strategy and plastics plan in the context of broader Federal Government and inter-jurisdictional commitments to address waste and transition from linear to circular economies.
- There is a NSW Government container deposit scheme, which has resulted in a one-third reduction across the state of eligible containers, including bottles entering the litter stream.
- Research and development efforts to replace, repurpose and recycle plastics is a fast-moving and evolving space that is predicted to show significant growth within the next five to ten years.

6.2 RECOMMENDATIONS

1. Further work is undertaken to incorporate climate change into the development of recharge estimates for the Water Sharing Plan.
2. Consideration should be given to incorporate geological heterogeneity and soil and vegetation types into recharge estimates where practicable. This may be dependent in part on technological advances, including remote sensing, to characterise systems.
3. Improved monitoring of piezometric water levels is needed in locations with a perceived risk and/or lack of knowledge of groundwater responses and flow directions. This could provide baseline data, conceptual hydrogeological models and recharge estimates commensurate with potential future risk levels. Additional investments in monitoring should balance the value of expected improvements in data availability and data quality against the resources required.
4. Robust local hydrogeological assessments of aquifer connectivity with overlying shallow groundwater and surface water should be investigated via well-designed pump tests. This information should feature in hydrogeological reports.
5. Work should continue towards developing practical and comprehensive guidance on the contents of hydrogeology reports to be submitted by proponents, including specificity and standardisation of information provided and reporting requirements. Ideally, these would be able to be lodged electronically and made publically available.
6. State government agencies and local government should work to clarify roles and responsibilities to streamline assessment and approval processes, to avoid duplication of effort, and to address any gaps in the assessment and approvals process. The first step for this would be by February 2020, relevant officers from Water NSW, DPIE Water, NRAR and Tweed Council convene a workshop for Northern Rivers region bottled water to discuss and develop an approach between them.
7. Water extraction and monitoring data should be made available in standardised formats through open and accessible portals. State managed databases and portals (e.g. SEED) should be utilised where relevant.

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APPENDIX 1: TERMS OF REFERENCE (UPDATED FEB 2019)

The Chief Scientist & Engineer is requested to conduct an independent review and provide expert advice on the impacts on groundwater quantity arising from extraction by the bottled water industry in the Northern Rivers region of NSW.

1. **In undertaking the review, the Chief Scientist & Engineer will:**
    a. review existing data and information on the bottled water industry's entitlements and extractions in the context of:
        i. total water access rights (basic landholder rights and access licences), and
        ii. extraction limits established in statutory water sharing plans
    b. provide advice on the sustainability of the extraction limits in the relevant water sharing plans for groundwater sources in the Northern Rivers of NSW
    c. provide advice on whether the current or proposed groundwater monitoring bores on the Northern Rivers are sufficient.
2. **Provide advice on potential impacts:**
    a. on groundwater resources, having regard to the sustainable take of the resource and the scale of the current bottled water industry and proposed or potential expansion of the industry
    b. of the groundwater take of the bottled water industry on surface water.
3. **Provide advice on:**
    a. scientific and technical approaches to examining socio-economic factors and impacts and possible solutions using locally relevant examples
    b. localised environmental consequences related to extraction for bottled water.
4. **As needed, the Chief Scientist & Engineer may:**
    a. seek advice from relevant Government agencies and other organisations
    b. draw on additional sources of advice and expertise
    c. commission or recommend studies.
5. **The Chief Scientist & Engineer will:**
    a. consult with key local stakeholders
    b. provide an initial report by 1 February 2019
    c. provide a final report by Oct 2019.

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APPENDIX 2: SITE VISITS, CONSULTATIONS, WORKSHOP AND SUBMISSIONS

Table 19: Site visit consultations

Date	Location	Facility
9 December 2018	Urliup	Karlos Family Trust • Larry Karlos
10 December 2018	Uki	Mount Warning Spring Water • Shaun Martin • Tessa Martin
20 January 2019	Kynnumboon	Pristine Water Supply Pty Ltd • Steve Bell
20 January 2019	Nobbys Creek	Rosehill Estate 1890 Pty Ltd • Gary Appleby • Trevor Johnson
21 January 2019	Lynwood	Prime Flowers Pty Ltd • Geoffrey Bottomley • Ian Cooke
21 January 2019	Alstonville	Rous County Council Groundwater Bore • Michael McKenzie

Table 20: Consultations

Date	Location	Present
9 December 2018	Murwillumbah	Northern River Guardians • Daniele Voinot • Marian van Gestel • Gwyn Hooper • Scott Sledge • Julie Beesley Water Dragons • Greg O'Donnell • Michele Bevis
9 December 2018	Murwillumbah	Dungay Action Group • Betty Wood • Lucy Campeanu • Joy Baker • Jack Griffis • Dale Holt
9 December 2018	Murwillumbah	Tweed Water Alliance • Pat Miller • Pamela Veness • Denise White • Trevor White • Pamela Smith
9 December 2018	Murwillumbah	Bilambil Urliup Action Group • Anna Champ • Jasmin Derrington • Peter McIlveen • Barbara Downes • Louis Lambert
9 December 2018	Murwillumbah	Bunjalung community members • John Hunt • Thomas Paulson • Murray
10 December 2018	Murwillumbah	Tweed Shire Council • Michael Banks • Robyn Eisermann

		• Iain Lonsdale • Denise Galle • Danny Rose • Ray Clark • Tracey Stinson Lismore City Council • Leonie Walsh Richmond Valley Council • Mike Perkins
10 December 2018	Murwillumbah	Tweed Shire Council • Warren Polglase • James Owen • Katie Milne • Reece Byrnes • Pryce Allsop • Troy Green Hon Justine Elliot MP's Office • Jurgen Schanzenbacher
10 December 2018	Murwillumbah	Rous County Council • Phillip Rudd • Michael McKenzie
10 December 2018	Uki	• Graham Dietrich
13 December 2018	Sydney	Australian Beverages Council • Alby Taylor • Shae Courtney
20 January 2019	Murwillumbah	Combined Tweed Rural Industries Association • Colin Brooks
20 January 2019	Murwillumbah	Richmond Wilson Combined Water Users Association • Chris Magner • Catherine Richardson-Magner
20 January 2019	Ballina	• Ceridwen Quick • Clive Quick
21 January 2019	Rous Mill	• Bryan Douglas
21 January 2019	Alstonville	Nu-Pure Beverages • Brendan Moroney • Bruce Taylor Black Mount Spring Water • Tim Carey
21 January 2019	Alstonville	Save Alstonville Aquifer • Michael Hogan • Troy Outerbridge • David Huett
21 January 2019	Alstonville	Ballina Shire Council • Sharon Parry • Eoin Johnson • Ben Smith • Phillip Meehan • Sharon Cadwallader • Matthew Wood • David Wright • Andrew Smith • Simon Scott • Georgia Lee • Keith Williams (Chair of Rous County Council) Byron Shire Council • Jason Stanley • Andrew Cameron • Michael Bingham • Bryan Green

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1 August 2019	Level 48, MLC Centre 19 Martin Place, Sydney	Australian Beverages Council • Shae Courtney Blackmount Spring Water • Tim Carey • Scott Wallace
15 October 2019	Phone consultation	Kevin Graham
17 October 2019	Phone consultation	Lance Rawson

Table 21: Expert Workshop Participants – 6 September 2019

Participant Name	Affiliation
Peter Cook	Flinders University
Grant Hose	Macquarie University
Lucy Reading	Queensland University of Technology
Liliana Pagliero	University of Queensland
Neil McIntyre	University of Queensland
Louise Ryan	University of Technology Sydney
Ian Acworth	UNSW Sydney
Jason Evans	UNSW Sydney
Lucy Marshall	UNSW Sydney
Mahmood Sadat-Noori	UNSW Sydney
Martin Andersen	UNSW Sydney
Scott Sisson	UNSW Sydney
William Glamore	UNSW Sydney
Daniel Deere (independent facilitator)	Water Futures
Luk Peeters	CSIRO
Tomonori Hu	NSW Smart Sensing Network
Jenny Johnson	DPIE
Jon Stone	DPIE
Danielle Doughty	DPIE Water
Fabienne d'Hautefeuille	DPIE Water
Lynn Tamsitt	DPIE Water
Mark Simons	DPIE Water
Richard Green	DPIE Water

Table 22: Submissions

No.	Organisation
SUB 001	Ballina Shire Council
SUB 002	Bryan Douglas
SUB 003	Michael Hogan, Save Alstonville Aquifer
SUB 004	David Huett, Save Alstonville Aquifer
SUB 005	Australian Beverages Council
SUB 006	NSW Irrigators Council
SUB 007	Save Alstonville Aquifer
SUB 008	Duncan Dey
SUB 009	CONFIDENTIAL
SUB 010	Australian Beverages Council
SUB 011	CONFIDENTIAL
SUB 012	CONFIDENTIAL
SUB 013	CONFIDENTIAL
SUB 014	CONFIDENTIAL

APPENDIX 3: EXCERPTS FROM INITIAL REPORT – EXTRACTION LIMITS AND THE WATER SHARING PLAN

The following are extracts from the Initial Report providing background information about the North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan; and how extraction limits are calculated and allocated. These sections are brought forward to provide context for the analysis undertaken by the Review. Note that some reference in the following text refer to Tables and Figures in the Initial Report.

Beginning of text from the Initial Report

The first Term of Reference entails an examination of extraction levels in the WSP and seeks advice on extraction levels for the bottled water industry and future monitoring. In working to address these, the consultation process proved to be a rich source of information, data and ideas from the community and other stakeholders. The issues identified in those fora (set out in Chapter 2 of the Initial Report) that relate to the volume of water and allocation processes and issues are the focus of this section.

The quantity of water that is available for the bottled water industry in the Northern Rivers region, as with other extractors for commercial purposes is established through the *Water Management Act 2000* and the WSP instruments.

Two fundamental principles for the WSP that are important for the framing of this Review are:

1. there are established priorities of allocation with environmental and ecological first, basic rights/stock and domestic second, and industrial and commercial extraction last
2. within the category of industrial and commercial, there is no distinction made between different 'product categories' or end uses – water involved in producing food, drink, minerals, manufactured products and services are all considered on a level playing field.

The following sections discuss in more detail the relevant WSP for groundwater in the region. Further information about the regulatory framework is in Appendix 4 (of the Initial Report) and the rules applying to the four groundwater sources relevant to the Review are at Appendix 5 (of the Initial Report).

WATER SHARING PLAN FOR NORTH COAST FRACTURED AND POROUS ROCK GROUNDWATER SOURCES

Under the *Water Management Act 2000*, WSPs have been developed for many groundwater and surface water systems in NSW to control and limit usage of water resources, ensure that Basic Landholder Rights (BLR) can be met and ensure that there is sufficient water reserved as environmental water to support dependent ecosystems and maintain aquifer health. Table 23 sets out the WSPs in the Northern Rivers region.

Table 23: Northern Rivers region groundwater and surface water sharing plans

Water Sharing Plan	Plan Status	Supporting Documentation	Cease Date
Brunswick Unregulated and Alluvial	Commenced July 2016	• Brunswick water source rules • Background document	July 2026
North Coast Coastal Sands Groundwater Sources	Commenced July 2016	• North Coast Coastal Sands Groundwater source rules • Background document	July 2026
North Coast Fractured and Porous Rock Groundwater Sources	Commenced July 2016	• North Coast Fractured and Porous Rock Groundwater source rules • Background document	July 2026
Richmond River Area Unregulated, Regulated and Alluvial	Commenced Dec 2010	• Richmond River are water source rules • Background document	July 2021
Tweed River Area Unregulated and Alluvial	Commenced Dec 2010	• Tweed River area water source rules • Background document	July 2021
Alstonville Plateau Groundwater Sources	Commenced 2004 - Repealed	• Replaced by Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources	June 2016

Source: DOI (2019)

The Review is focusing on four specific groundwater sources in the Northern Rivers region where there is current, proposed or potential historical groundwater extraction for bottled water (Table 24). If the Review is made aware of additional groundwater sources in the Northern Rivers region used by the industry, these will be added to the scope as the Review progresses.

Table 24: Groundwater sources and descriptions

Groundwater Source	Description
Alstonville Basalt Plateau Groundwater Source	A fractured rock aquifer system in which Tertiary basalt extends to a depth of up to 150 metres. Groundwater is contained in fractures in the basalt. The hydrology of the area is complex and the degree of connectivity (both vertical and horizontal) is not uniform. The groundwater in this source is used for town water supply and irrigated agriculture. Discharge at the surface provides baseflow to surface waters and is important to the environment
Clarence Moreton Basin Groundwater Source	A porous rock aquifer system, overlain by the Mount Warning complex (comprised of the North Coast Volcanics and the Alstonville Plateau groundwater sources). On the eastern extent it is overlain by alluvial and coastal sand deposits. Groundwater is both contained within the system, and moves through it, due to the primary porosity of the rock as well as the fractures present due to the folding and faulting of the rock formation. Low bore yields of 1L/s, rising to up to 10L/s in highly fractured fault systems. All surface units are recharged by direct rainfall recharge with subsequent vertical leakage. Generally used for stock and domestic purposes with some sporadic irrigation/commercial supplies.
New England Fold Belt Coast Groundwater Source	A fractured rock aquifer system, overlain by the Clarence Moreton Basin and North Coast Volcanics groundwater sources. On the eastern extent it is overlain by alluvial and coastal sand deposits. Groundwater is contained within, and moves through, fractures in the rock due to the folding and faulting of the rock formations. Low bore yields of 1L/s, rising to up to 10L/s in highly fractured fault systems. Recharge is typically by direct rainfall infiltration and, combined with the degree of mineral leaching that has occurred over time, has resulted in good quality water. Generally used for small scale irrigation, stock and domestic purposes.
North Coast Volcanics Groundwater Source	A fractured rock aquifer system comprised of the Lamington Volcanics, associated with the Mount Warning Complex. It is situated on top of the New England Fold Belt Coast and Clarence Morton Basin groundwater sources. Typically composed of basalt and rhyolite, the groundwater is contained within, and moves through, fractures formed as a result of the rock cooling as well as the vesicular structures of basalt flows. Moderate bore yields of 5L/s, rising to up to 10L/s in highly fractured fault systems. Recharge is typically by direct rainfall infiltration, resulting in excellent quality water. Used for stock, domestic and irrigation water supplies. Stream and spring flow is reliant on groundwater discharge during non-rainfall periods. As a result, groundwater-dependant ecosystems are common with the groundwater source.

Source: (DPI Water, 2016c, 2016d, 2016b, 2016a)

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These sources are covered by the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources (DPI Water, 2016f) (WSP) released in September 2016.

The WSP covers 13 groundwater sources from Gosford to Tweed Heads, 10 of which had not previously been covered by a WSP. The total area covered by the WSP is approximately 76,000 km^2 (DPI Water, 2016f). The groundwater sources covered by this plan are defined either as porous or fractured rock aquifers, all with the following connectivity characteristics according to the WSP:

- low-moderate connection between surface and groundwater
- low impact on in-stream values
- years to decades travel time between groundwater and surface water (DPI Water, 2016f)

Prior to the commencement of the WSP, of the four groundwater sources in scope, only the Alstonville Plateau Groundwater Source was the subject of a WSP as noted in Table 24 above.

Prior to the finalisation of the WSP, report cards for each of the groundwater sources were issued in February 2016. For the Alstonville Basalt Plateau Groundwater Source, which had been subject to a prior plan, the proposed rule changes and technical specifications like calculation of recharge were compared against the original WSP for Alstonville.

One significant change was that the previous division of the Alstonville Plateau into six groundwater sources changed to the groundwater sources merged into one with two management zones - the Alstonville-Tuckean and the Bangalow-Wyrallah management zones. These were based on levels of extraction, particular intensity of extraction in the Alstonville-Tuckean area, and to prevent localised impacts.

Within the whole groundwater source, no water is being made available for new licences, as the source has been capped at the current entitlement. However, trading is allowed within the groundwater source, but not if the trade results in a net increase to the sum of share components in the Alstonville-Tuckean Management Zone. There are no restrictions to trades within each of the management zones or from the Alstonville-Tuckean into the Bangalow-Wyrallah zones.

The WSP is a regional water planning tool and a macro-scale instrument that considers a geographically large area to set guidelines and regulations to limit overuse or stress on an aquifer at a regional scale. The WSP does not specifically assess local scale risks, other than setting broad limits on the proximity of groundwater extractions to groundwater dependent ecosystems (GDEs), other groundwater users, aboriginal heritage sites and major water supply bores. These are summarised for the four groundwater systems in the rules in Appendix 3 (of the Initial Report). The issue of potential localised impacts from extraction will be further investigated by the Review over the coming months.

Under the WSP, priority is given to environmental water and basic landholder rights (BLR). The plan allocates an amount of water that is to be reserved for these priority uses, and prevents licensed extractions from accessing a portion of the estimated groundwater source. Licensed extractions for all other uses are secondary to BLR and environmental water. Some additional priority is given to groundwater extracted for local and major utilities that are typically licensed to extract reasonably large amounts for water security and to licensed stock and domestic bores.

Under the *Water Management Act 2000*, granting of commercial water licences (e.g. groundwater extractions that are not for BLR or utilities) is independent of their intended use. This allows ready trade and aims to promote efficient use of resources, as well as allowing new industries to develop and water to be allocated to the highest value use (DPI Water, 2016f). Under the *Water Management Act 2000* and the WSP, extraction for bottled water is treated the same as any other commercial extraction, including commercial irrigation and horticulture. Further information about the WSPs, including audit and review processes are contained in Appendix 4 (of the Initial Report).

The following sections review the purpose and methods used in the WSP that governs groundwater licenses for the areas relevant to this review.

EXTRACTION LIMITS

A major output of the WSP is the LTAAEL for each of the 13 groundwater sources. The LTAAEL determines the maximum average volume of water that can be extracted from one source in a given year. To prevent the overuse of groundwater resources, the water sharing plans generally enforce the LTAAEL to be a portion of the average recharge of the aquifer (i.e. versus water that is already stored in the aquifer). To quantify an appropriate LTAAEL, average recharge must be defined.

Groundwater sources in the WSP are described as '*less highly-connected groundwater sources*' (DPI Water, 2016f), so the estimates of aquifer recharge only consider direct rainfall. While some surface water – groundwater connectivity may exist, no surface water contribution to recharge is considered in these calculations. Under that assumption, the LTAAEL for fractured rock aquifers is determined by the following simplified procedure (DPI Water, 2015):

1. estimation of the annual average rainfall (discussed in Section 3.2.1)
2. estimation of the recharge as a fixed percentage of rainfall (discussed in Section 3.2.2)
3. determination of areas of high environmental value and non-high environmental value
4. determination of current and future water requirements (the latter increased by 10 percent to ensure a conservative estimate)
5. determination of the UEL, which is equal to the recharge in the non-high environmental value area multiplied by a sustainability index (described in Section 3.2.3)
6. determination of LTAAEL as the UEL or a lower value based on estimates of existing and future extractions.

The current total water access rights, including an estimate of BLR (which does not require a licence for extraction), was calculated for each of the groundwater sources as part of the WSP in 2016. Where the total water access rights are less than the 80 percent of the LTAAEL, water can be made available as new licence allocations by state government agencies via a controlled allocation process.

When the WSP was first released in 2016, the Alstonville Basalt Plateau Groundwater Source was the only source subject to the Review where licence allocations were at the LTAAEL, whereas (the other three sources subject of this Review were less than 60 percent allocated). There is a provision for the LTAAEL of fractured rock aquifers to be increased to a maximum of the UEL if demand for water increases beyond the predicted amount.

Within the area covered by the WSP, licences entitle their holders to a certain 'share' of the water resource. Under ordinary circumstances, one share is equal to an entitlement of 1ML/y. However, at the Minister's discretion, the allocation of water per share can be reduced to minimise environmental or socio-economic impacts, such as during a drought or in response to a growth in use of local water utility or BLR use.

The following sections review the process for water allocation determination in the WSP.

Average Annual Rainfall

Annual rainfall is variable over the relatively large area covered by the WSP. Rainfall data used by the WSP was sourced from the BOM gridded rainfall data (approximately 5 km^2 grid) from 1901 – 2011. More information on the rainfall data can be found on BOM (2015).

This rainfall model uses algorithms to estimate a weighted average rainfall in each grid based on the observations at the nearest BOM stations (see Section 1.2). This accounts for the spatial variability of rainfall throughout large catchments and is based on the best available data.

Recharge Rates

The WSP simplifies the aquifer recharge to the relationship shown in Equation 1. The systems considered in the WSP are considered to be '*less highly-connected groundwater sources*' (DPI Water, 2016f), which means there is little recharge through creek beds, and therefore, only recharge through rainfall was considered.

Calculating recharge through this relationship assumes that the aquifer is homogenous, which is a simplification of the complex geology that occurs in porous and fractured rock aquifers. It also assumes that the recharge is generated over the entire surface area of the groundwater source that is not overlain by another defined groundwater source (i.e. the outcropping area).

Average Recharge (ML/yr) = Average Rainfall (mm/yr) x Area (km^2) x Recharge Rate (%)/100

Equation 1: Average recharge

While rainfall and area are measurable (although the area over which the source is recharged is sometimes less clear, which is discussed further below, the recharge rate is more difficult to define. The transmissivity of different aquifers can vary significantly depending on the geology, and different recharge rates were applied by the WSP for each of the groundwater sources. DPI Water (2015) provides some guidance on the recharge rates applied for different groundwater source types (Table 25).

Table 25: Recharge rates recommended by DPI Water (2015)

Hydrogeological Type	Recharge Rate	Comment
Coastal Porous Rock	1 – 6%	Based on the findings of Coastal Porous Rock Rainfall Recharge Study
Inland Porous Rock	6%	
Fractured Rock (excl. North Coast Volcanics)	4%	
North Coast Volcanics	8%	Source is unclear

Table 26 shows the recharge rates adopted in the WSP for the groundwater sources relevant to this report. DPI Water (2016f) and DPI Water (2015) acknowledge that regional estimates of recharge of large aquifers is not an exact science, and they state they that due to this uncertainty have taken a precautionary approach. DPIE Water has advised that the precautionary approach was based on using zero percent recharge estimates for high value area, no allowance for recharge from anything other than direct rainfall, and sustainability indexes to ensure that use is significantly less than recharge (DOI Water, 2019).

Table 26: Rainfall recharge rates adopted in the Water Sharing Plan

Groundwater Source	Rainfall Recharge Rate adopted	Based on
Clarence Moreton Basin	6%	There is little direct data and very little demand for groundwater, therefore the NSW default 6 percent was recommended, based on the Coastal Porous Rock Rainfall Recharge Study (DPI Water, 2016f)
North Coast Volcanics	8%	DPI Water (2016f)
New England Fold Belt Coast	4%	DPI Water (2016f)
Alstonville Basalt Plateau	8%	Based on preceding WSP

Sustainability Index

The sustainability index (SI) is a qualitative risk based approach used in water sharing plans to account for the relative social, economic and environmental risks of extracting groundwater from a particular water source.

The environmental risk considers the prevalence of high priority groundwater dependent ecosystems and the risk to the groundwater source itself. It considers water quality, ecology and aquifer integrity. Environmental risk is rated as high (e.g. permanent and significant change), moderate (temporary change) or low (no change anticipated) and is a simple relative measure. If there are any mitigation actions (e.g. groundwater modelling or distance rules from sensitive areas), these may be considered to lower the environmental risk.

Socio-economic risk considers the financial and social dependence of local communities on a groundwater resource. For example, the socio-economic risk considers whether there is any readily available alternative to groundwater extraction, the contribution of groundwater dependent industry on the local economy (including employment rates) and the dependence of the local communities on groundwater resources for drinking water supplies. As per the environmental risk, the socio-economic risk is assigned a relative rating (high, moderate or low).

Following these assessments, the environmental (known as the 'aquifer risk') risk and the socio-economic risk are input into the matrix shown in Table 27 to define the final sustainability index. For example, if the aquifer risk is classified as 'High' and the socio-economic risk is 'Medium', the sustainability index would be 25 percent as illustrated in Table 27.

Table 27: Sustainability index matrix, with an example calculation of a high aquifer, medium socio-economic risk sustainability index of 25%

Aquifer Risk	High	5%	25%	50%
	Medium	25%	50%	60%
	Low	50%	60%	70%
		High	**Medium**	**Low**
		Socio-Economic Risk		

Source: (DPI Water, 2016f)

The sustainability index is used to define the upper extraction limit (UEL – the maximum allowable extraction from the groundwater source) as per Equation 2 below. The sustainability index is the portion of estimated recharge that can be assigned to the UEL.

A lower sustainability index indicates less water is to be available for extraction (i.e. more water is assigned as environmental water). All the catchments are split into two areas – high conservation areas (e.g. National Parks) and the remaining areas. For all WSP groundwater sources, the sustainability index over high conservation areas is, by default, 0 percent. This means that recharge over these areas is preserved for environmental use. The sustainability index calculated in Table 27 only relates to the remaining areas.

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UEL (ML/yr) = Recharge over non- high environmental areas (ML/yr) x SI(%)

Equation 2: UEL

Table 28 summarises the sustainability indexes for the four groundwater sources considered in this report, including the assigned socio-economic and environmental risk. Environmental risk of the North Coast Volcanics is high due to the prevalence of springs, rainforests and groundwater dependent soils. The socio-economic risk in the Clarence Moreton Basin is largely due to the predicted (at the time) reliance of the coal seam gas industry on groundwater resources, as well as the dependence of the smaller industries on groundwater. No socio-economic or environmental risk was provided for the Alstonville Basalt Plateau in the WSP, as there were limited changes to the allowable extraction from the previous Water Sharing Plan for the Alstonville Plateau Groundwater Source.

Table 28: Sustainability index for relevant groundwater sources

Groundwater Source	Socio-Economic Risk	Environmental Risk	Sustainability Index
New England Fold Belt Coast	Low	Moderate	25%
Clarence Moreton Basin	Moderate	Low	60%
North Coast Volcanics	Moderate	High	25%
Alstonville Basalt Plateau	-	-	~20%*

This is not presented in the current WSP but is based on the preceding legislation Water Sharing Plan for the Alstonville Plateau Groundwater Source

Estimates of LTAAEL

The LTAAEL is calculated differently depending on whether the groundwater source is defined as a porous or fractured rock aquifer. For fractured rock aquifers (New England Fold Belt Coast, North Coast Volcanics and the Alstonville Plateau), the UEL is calculated as per Equation 2, as a direct relationship between the recharge and sustainability index. However, in an acknowledgement of the uncertainties surrounding the recharge estimates for fractured rock, the upper extraction limit is compared to the current and estimated future requirements for water (including a 10 percent buffer on the future requirements). The future estimated requirements were calculated considering the following (DPI Water, 2015):

- growth in BLR as a result of increasing populations. BLR was assumed to grow in proportion with population. Population forecasts were based on Department of Planning estimates
- increase in requirements for dewatering, based on dewatering in the previous decade increasing proportionally with population growth
- growth in town water supply requirements, sourced from future water strategies and consultation with the relevant councils;
- growth in agricultural, which was determined by the North Coast Interagency Regional Panel based on local knowledge and present agricultural requirements
- growth in mining requirements, based on industry statistics reviewed by the North Coast Interagency Regional Panel.

Once the future estimated requirement for groundwater was calculated, the following rules are applied to determine the LTAAEL:

1. if the future estimated requirement for groundwater (+10 percent) < 10 percent of UEL, LTAAEL = 10 percent of UEL
2. if the future estimated requirement for groundwater (+10 percent) > UEL, LTAAEL = UEL
3. otherwise, LTAAEL = future requirement for groundwater (+10 percent).

In cases where the LTAAEL<UEL, the LTAAEL can be increased during the life of the WSP if the entitlement reaches 80 percent of the LTAAEL. This would require a review of the LTAAEL (of one particular groundwater source) by the North Coast Interagency Region Panel or some other similar interagency panel (DPI Water, 2016e). DPI Water (2016f) notes that the future requirement estimates were 'generous' implying that it was considered unlikely that there would be an increase in LTAAEL in the life of the plan.

For the New England Fold Belt Coast and the North Coast Volcanics, the LTAAEL is substantially smaller than (< 25 percent of) the UEL (Table 29). This provides a suitable buffer to account for the uncertainty related to the recharge rates for these areas, and results in what is likely a conservative allocation of groundwater resources. For the Alstonville Plateau, where the LTAAEL is based on the preceding WSP, the LTAAEL is relatively high compared to the average annual recharge.

Table 29: LTAAEL in fractured rock aquifers as reported in February 2019 (Initial Report)

Groundwater Source	Average Recharge over non-high environmental areas (ML/yr)	Estimate Future Requirement (+10) (ML/yr)	UEL (ML/yr)	10% of UEL (ML/yr)	LTAAEL (ML/yr)
New England Fold Belt Coast	1,500,000	60,000	375,000	37,500	60,000
North Coast Volcanics	220,000	13,000	55,000	5,500	13,000
Alstonville Plateau*	50,000	-	-	-	8,895

Source: DPI 2016
Based on the preceding legislation Water Sharing Plan for the Alstonville Plateau Groundwater Source, no future requirement or UEL was presented

For porous rock aquifers (Clarence Moreton Basin), the WSP states a higher degree of confidence in the recharge rates due to the results of the Coastal Porous Rock Rainfall Recharge Study. Further investigation is needed to determine the basis for this higher degree of confidence.

Table 30: LTAAEL for porous rock aquifers as reported in February 2019 (Initial Report)

Groundwater Source	Average Recharge over non-high environmental areas (ML/yr)	Current Requirement (ML/yr)	LTAAEL (ML/yr)
Clarence Moreton Basin	500,000	4,562	300,000

Source: DPI Water (2016f)

LTAAEL values in the porous rock aquifers were calculated as per Equation 2, where the LTAAEL is equal to the UEL. Unlike fractured rock aquifers, no reduction is made in the LTAAEL to account for cases with low current and estimated future requirements for groundwater extractions.

As a result, the LTAAEL for the Clarence Moreton Basin, shown in Table 30, is large compared to the current water extraction. While this is an indicator that the groundwater source is unlikely to be currently under stress, there is no trigger for review of the LTAAEL if there is a large growth in extraction (as would be required for the New England Fold Belt Coast or the North Coast Volcanics). However, the whole WSP is reviewed after a period of ten years, so any significant growth in these porous rock aquifers could be reviewed at this time.

Environmental Water

The WSP requires an assignment of a portion of the annual average recharge to be classed as environmental water. As mentioned previously, 100 percent of recharge over high

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conservation areas, such as National Parks, is preserved for environmental water. The total volume of water assigned as RRE is defined by the relationship in Equation 3.

$$\text{RRE (ML/yr)} = \text{Average Recharge (ML/yr)} - \text{LTAAEL}$$

Equation 3: Recharge Reserved for the Environment (RRE)

Table 31 shows the RRE for the four groundwater sources of interest. The allotment of total estimated recharge is illustrated graphically in Figure 24.

With the exception of the Clarence Moreton Basin, the RRE is in excess of 80 percent of the estimated recharge. RRE is typically higher in fractured rock aquifers due to the more conservative approach used to obtain a value of LTAAEL.

Table 31: Recharge amount reserved for the environment as reported in February 2019 (Initial Report)

Groundwater Source	Total Estimated Recharge[1] (ML/yr)	LTAAEL (ML/yr)	RRE (ML/yr)[1,2]	RRE as a percentage of estimated recharge[1]
New England Fold Belt Coast	1,980,000	60,000	1,920,000	97%
Alstonville Plateau	50,079	8,895	41,184	82%
Clarence Moreton Basin	576,000	300,000	276,000	48%
North Coast Volcanics	310,000	13,000	297,000	96%

Source: (DPI Water, 2016f)

1. All numbers presented in this table are over the whole groundwater source and include recharge and environmental water from high-conservation areas and less environmentally sensitive areas combined, which may differ from numbers expressed in the WSP
2. Table 15 in WSP Background document refers to these values as planned environmental water 'PEW'

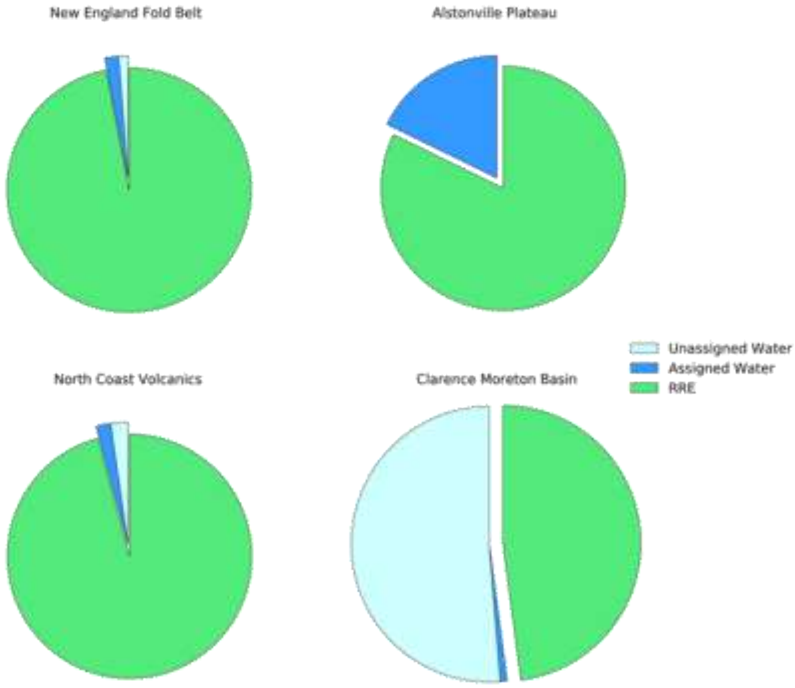

Figure 24: Allotment of estimated recharge to Recharge Amount Reserved for the Environment (total volumes differ between aquifers) as reported in February 2019 (Initial Report)

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APPENDIX 4: BASEFLOW FILTERING TECHNIQUE

Baseflow was filtered from the total daily flow time series using a recursive digital filter (Arnold et al., 1995; Arnold & Allen, 1999). It corresponds to an adaptation of digital filter methods used in signal analysis, and assumes that low frequency baseflow could be distinguish from high frequency flows. The filter equation is:

$$q_t = \beta q_{t-1} + \frac{1+\beta}{s}(Q_t - Q_{t-1}) \qquad \text{Equation 1}$$

Where, q_t is the filtered surface runoff (quick response) at day number t, Q is the original streamflow, and β is the filter parameter. The filter can be applied to the stream flow data, in both forward and reverse directions, as many times as desired. The number of times determines the degree of smoothing of the baseflow hydrograph. In general, each pass will result in less baseflow as a percentage of total flow. For this review, the filter parameter β was set to 0.925, as determined by Nathan and McMahon (1990) and Arnold et al. (1995) to provide realistic results.

Baseflow, b_t, was then calculated via:

$$b_t = Q_t - q_t \qquad \text{Equation 2}$$

Although the technique has no physical basis, it is objective and reproducible and has been successfully compared with graphical (manual) methods of baseflow separation (Arnold et al., 1995; Mau & Winter, 1997) and with measured field estimates (Arnold & Allen, 1999). For this study the filter was passed three times; forward, backwards and forward for smoothing the baseflow hydrograph based on the dataset length.

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Baseflow filtering results

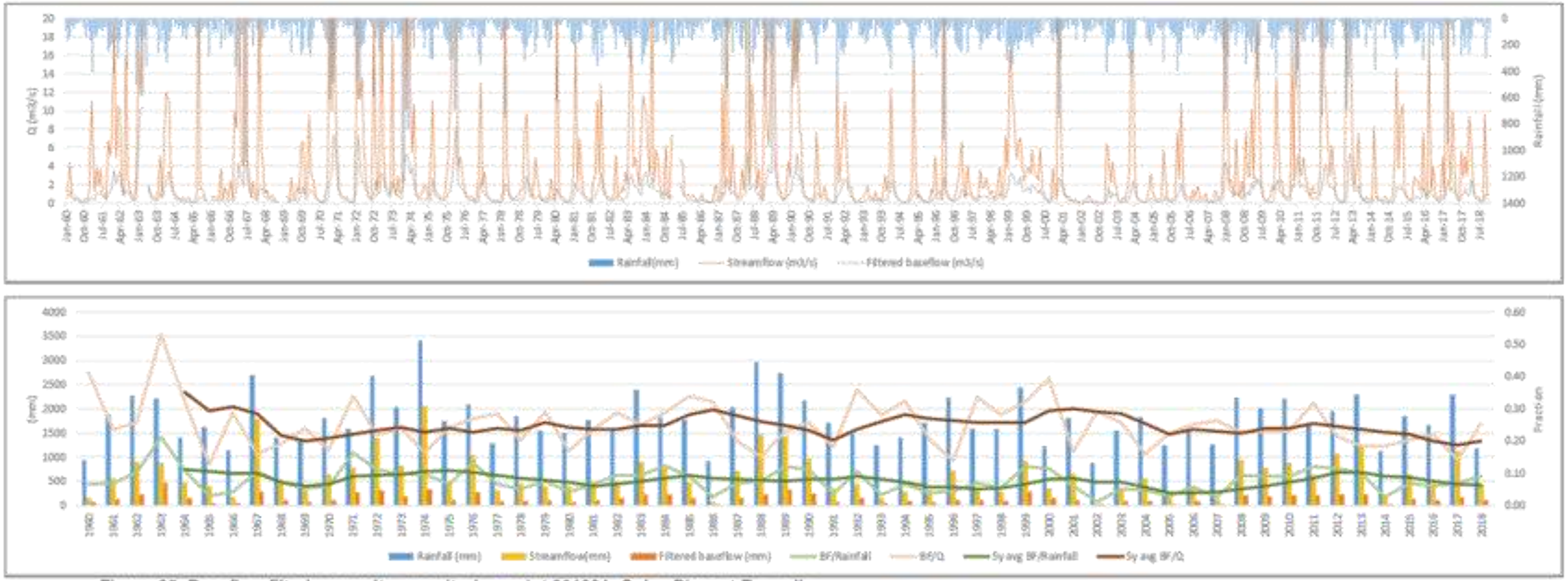

Figure 25: Baseflow filtering results - monitoring point 201001: Oxley River at Eungella

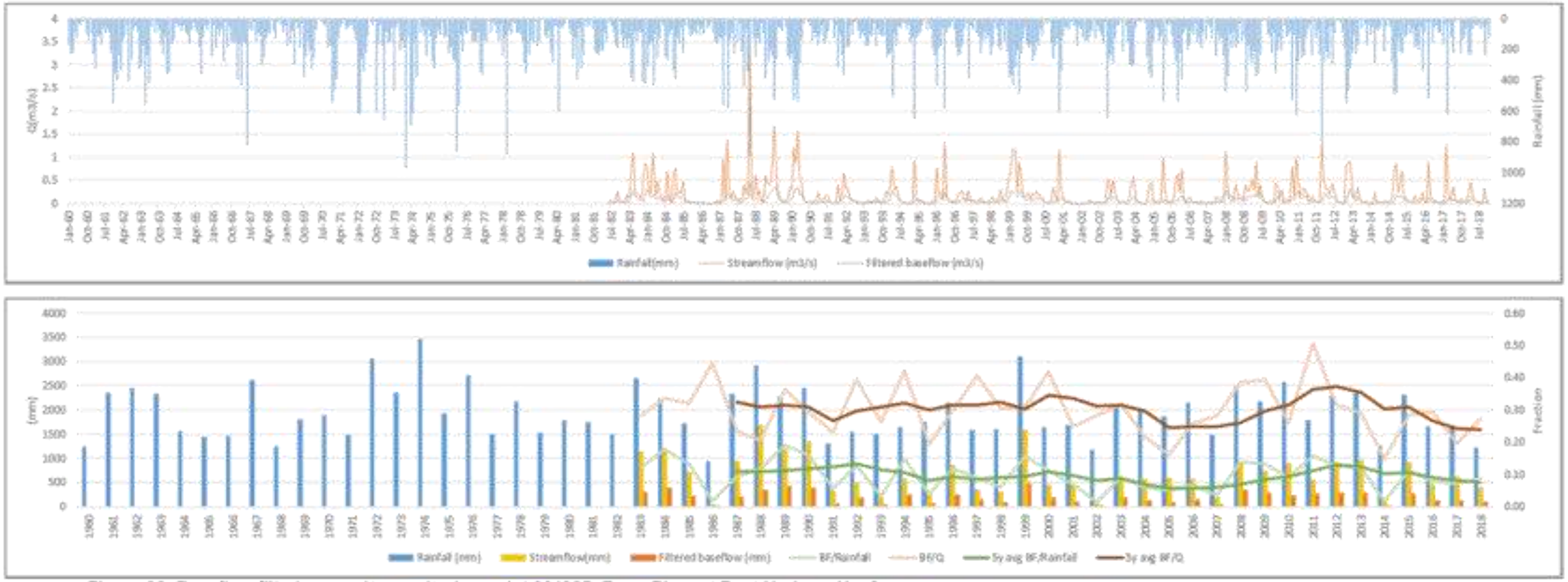

Figure 26: Baseflow filtering results monitoring point 201005: Rous River at Boat Harbour No. 3

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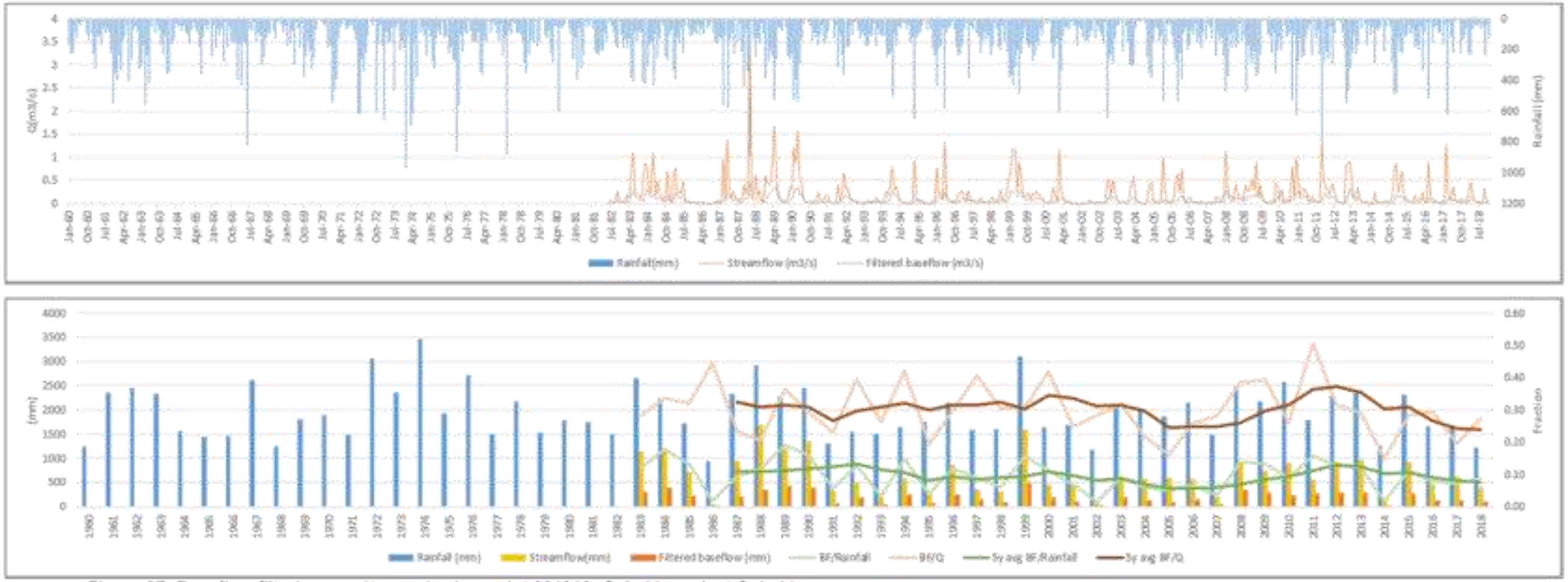

Figure 27: Baseflow filtering results monitoring point 201012: Cobaki creek at Cobaki

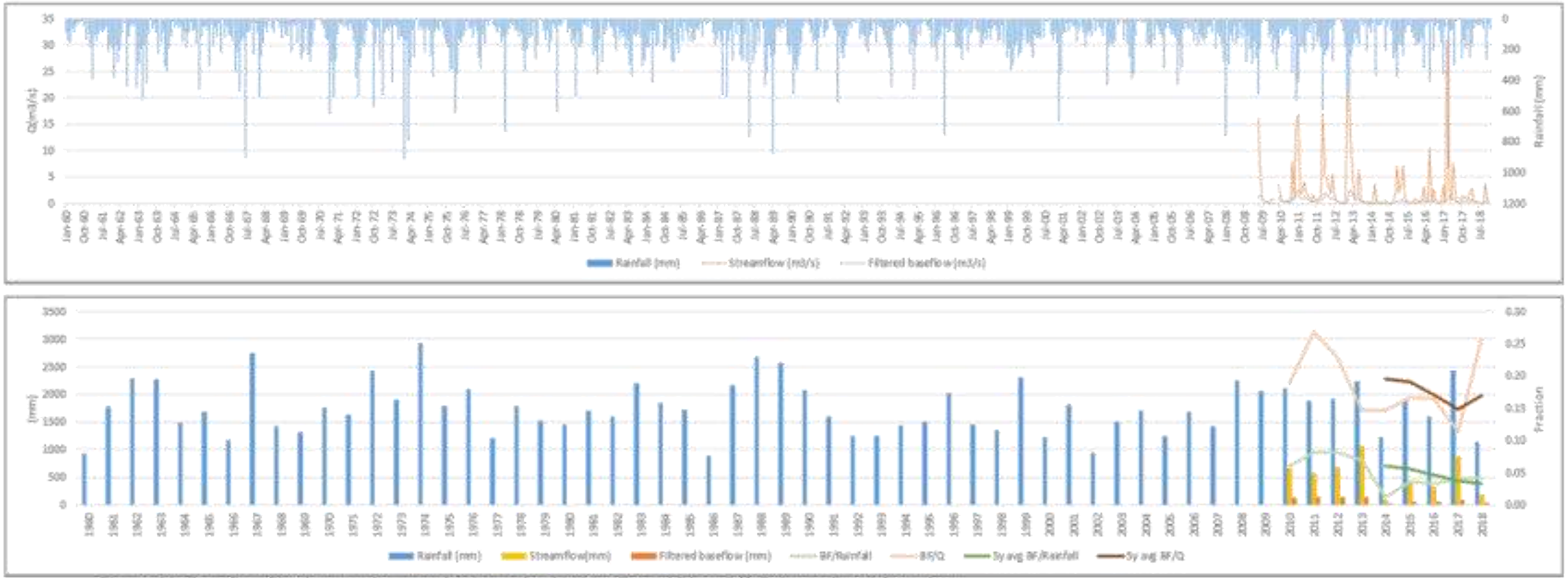

Figure 28: Baseflow filtering results - monitoring point 201015: Tweed River D/S Palmers Road Crossing

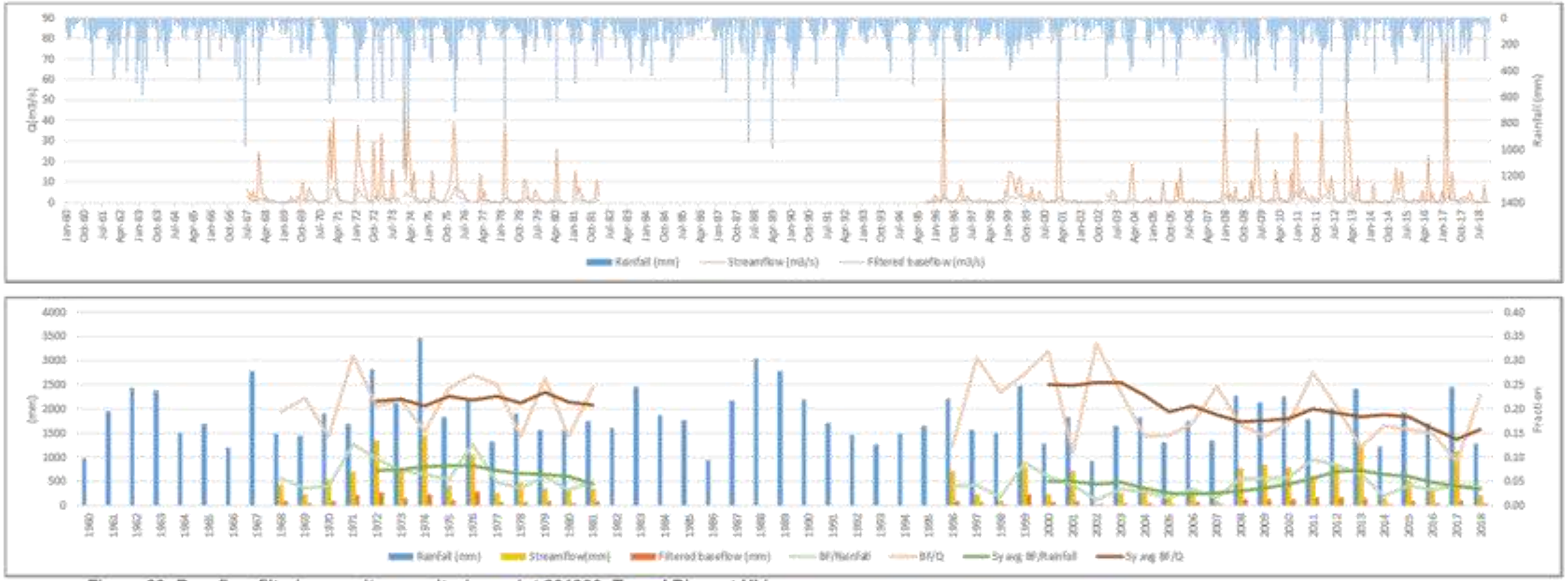

Figure 29: Baseflow filtering results - monitoring point 201900: Tweed River at Uki

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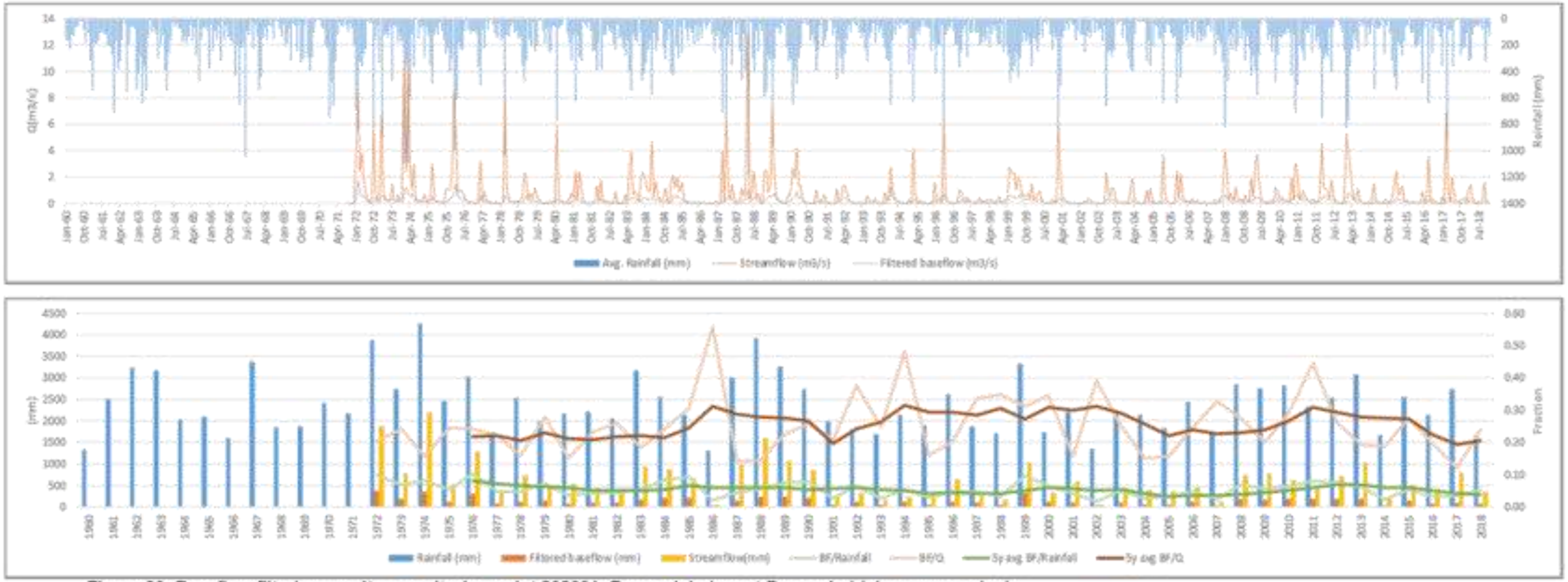

Figure 30: Baseflow filtering results - monitoring point 202001: Brunswick river at Durrumbul (sherrys crossing)

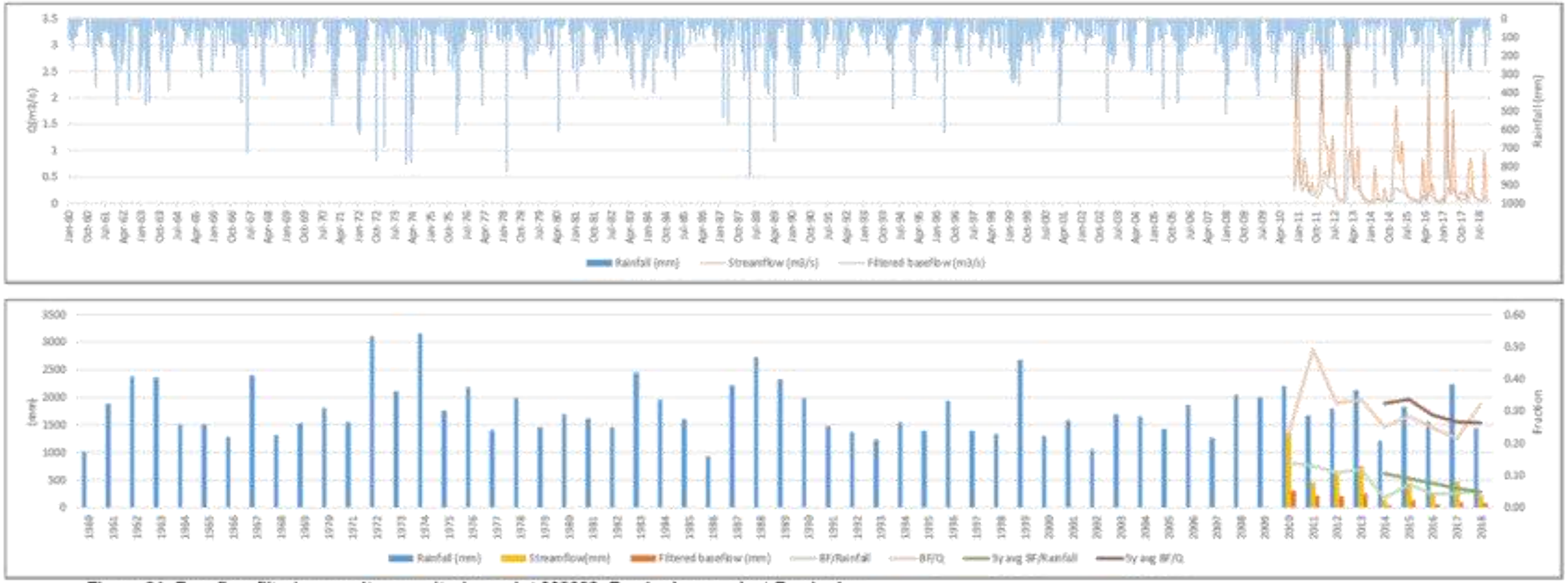

Figure 31: Baseflow filtering results - monitoring point 202002: Burringbar creek at Burringbar

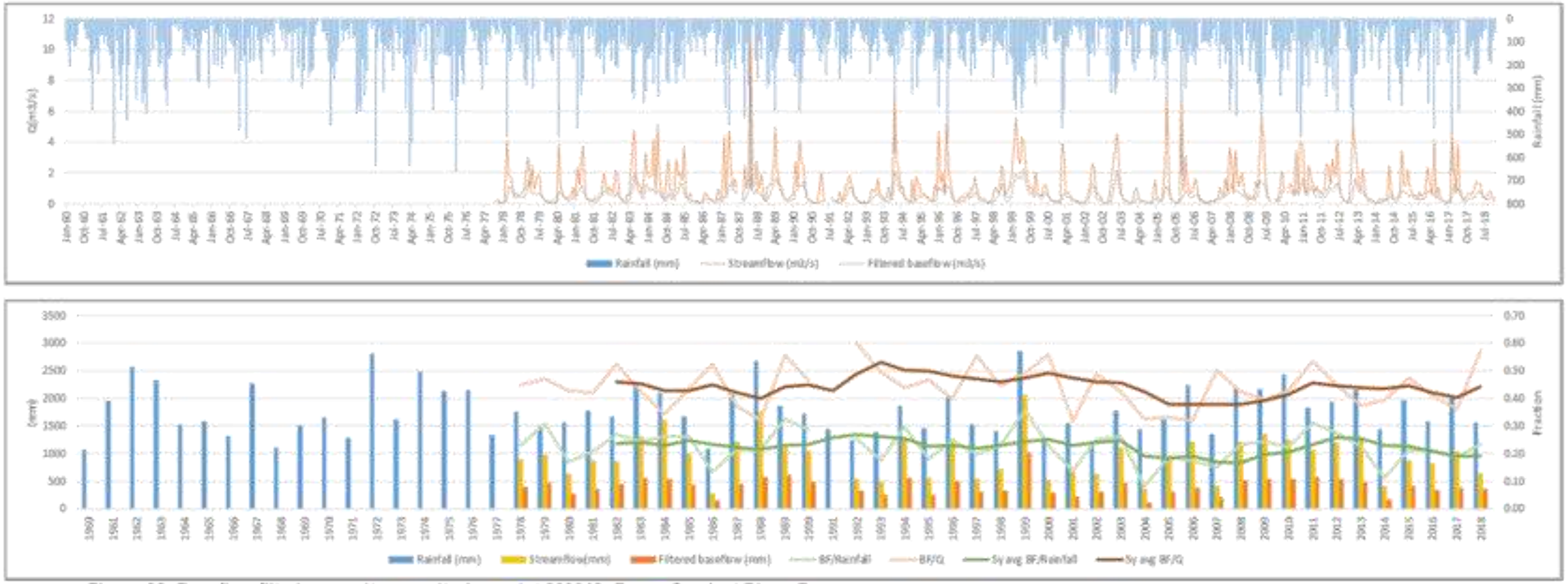

Figure 32: Baseflow filtering results - monitoring point 203012: Byron Creek at Binna Burra

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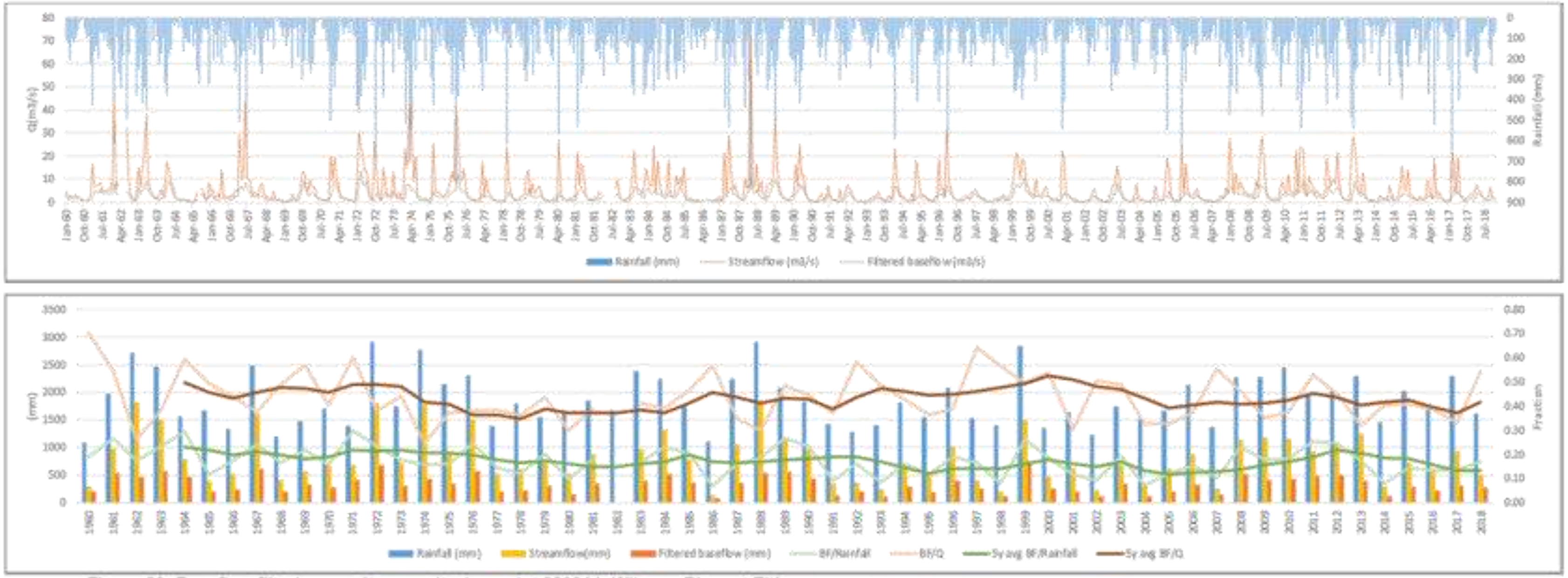

Figure 33: Baseflow filtering results - monitoring point 203014: Wilsons River at Eltham

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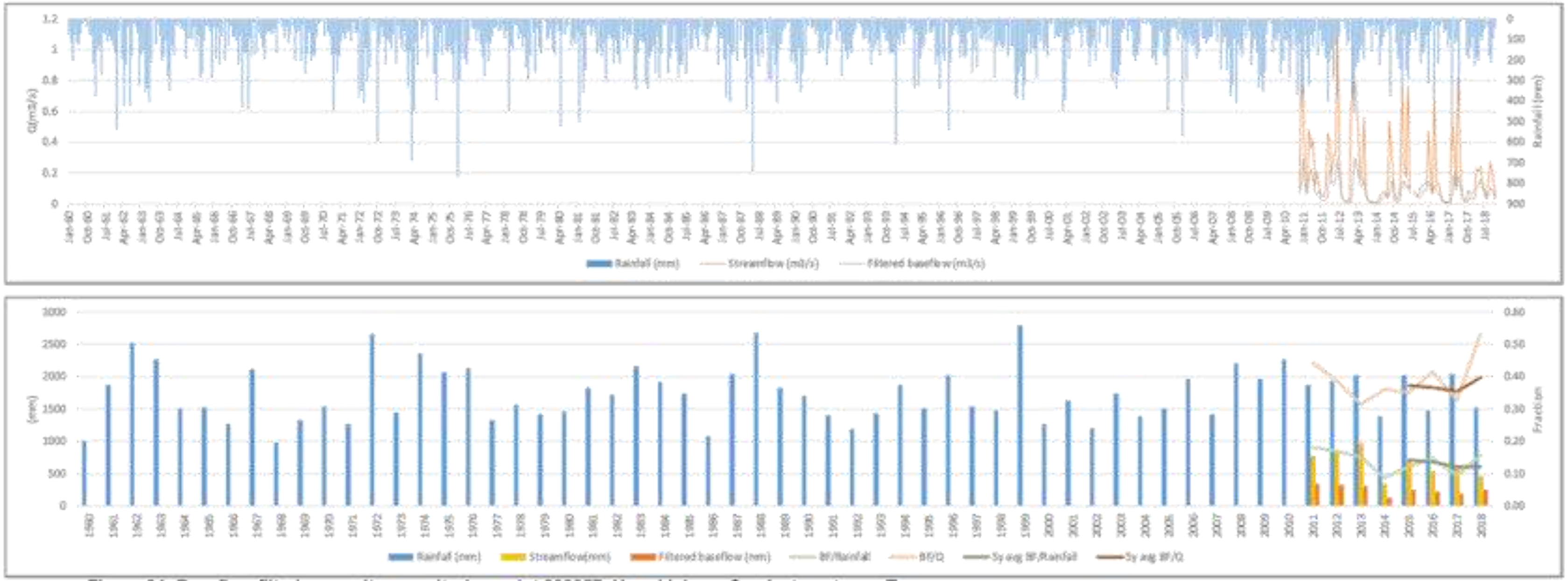

Figure 34: Baseflow filtering results - monitoring point 203057: Houghlahans Creek at upstream Teven

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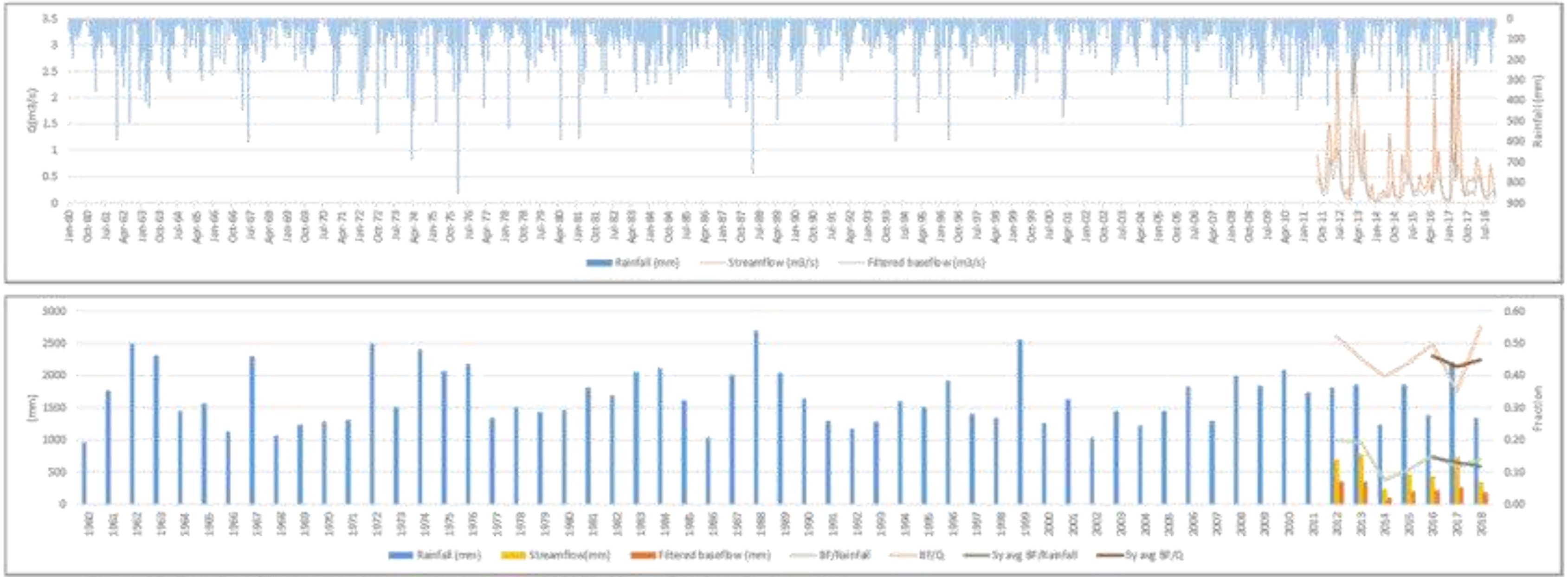

Figure 35: Baseflow filtering results - monitoring point 203059: Maron Creek at Graham road

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APPENDIX 5: MODELLING OF ALSTONVILLE PIEZOMETRIC DATA

Professor Louise Ryan

This appendix describes the GAM analysis for each of the Bore, Hole and Pipe combinations listed in Table 12. As discussed in the main report, the Review used a statistical technique called the Generalized Additive Model or GAM to explore how water levels varied over time, and also to assess the extent to which rainfall and seasonal effects could explain the observed levels.

We developed GAM models that predict piezometer level (in metres below measuring point) as a function of time, rainfall and season. The Review explored a range of options for how to best incorporate rainfall into the model. It found that 'lagged rainfall' averages, where rainfall is reported for each day as the average rainfall over the previous x days (where x was allowed to range from 10 days up to 240 days) provided a better explanation of variability in the piezometers than daily rainfall.

For each piezometer, the Review team re-ran the GAM models to identify the most appropriate lag time (x). The Review then explored the extent to which each component contributes to the variability of each piezometer. To ensure that the significant tests were appropriately adjusted for autocorrelation induced by the time-series nature of the data, a technique called the block bootstrap (Kunsch, 1989) was used, which has been implemented using the *boot* package in the statistical programming environment, R (Canty & Ripley, 2019). This analysis is an alternative to using the Seasonal Kendall Trend test which is popular in hydrogeology.

Although the primary focus in this section of the Report lies in the period from 2009 onwards, we included data from 2006 onwards in these analyses in order to boost statistical power to detect effects. These figures were computed by running models leaving out each factor and comparing the deviance explained by that model to the deviance explained by the model with all three factors in included. Statistical significance was assessed through use of a likelihood ratio test, using the block bootstrap to adjust for autocorrelation. Numbers that are statistically significantly different from 0 at $p<0.05$ are indicated by an asterix. A higher percentage indicates that the water levels in that piezometer are more highly correlated to that particular variable.

This appendix shows the results of fitting the GAM models to each of the bores. The results are summarised in the Table given in the main body of the Report. Note that no data were available after 2006 for the following bores:

- GW036701 hole 1 pipe 4
- GW036702 hole 1 pipe 4
- GW081004 hole 1 pipe 1

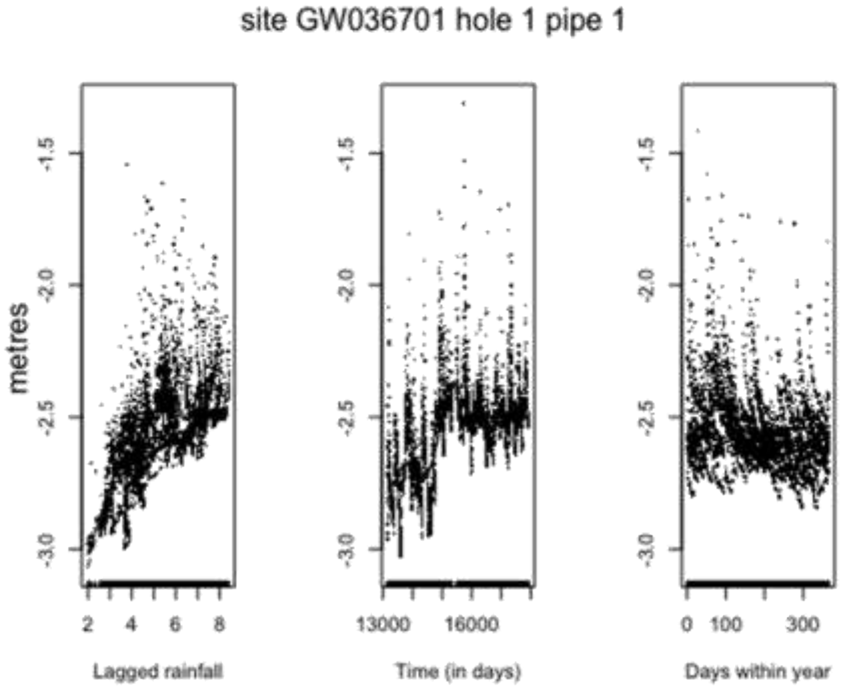
Analysis for site GW036701 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 240 days. Adding rain into the model explained an additional 32.61 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 11.11 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.128).

Adding time into the model explained an additional 41.26 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There were statistically significant non-linearities in the time effect (p= 0.018).



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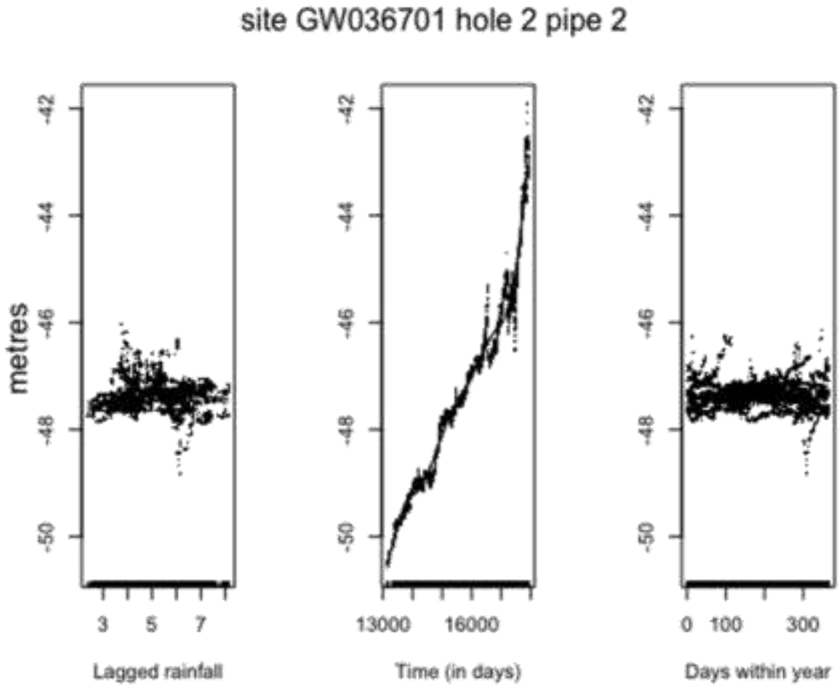
Analysis for site GW036701 hole 2 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 7.6 percent of variability compared with a model that included just time and season. But this increase was not statistically significant (p= 0.217).

Adding season into the model explained an additional 3.26 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.462).

Adding time into the model explained an additional 97.91 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There was no statistically significant non-linearity in the time effect (p= 0.106).



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Analysis for site GW036702 hole 3 pipe 1 data from 2006 only

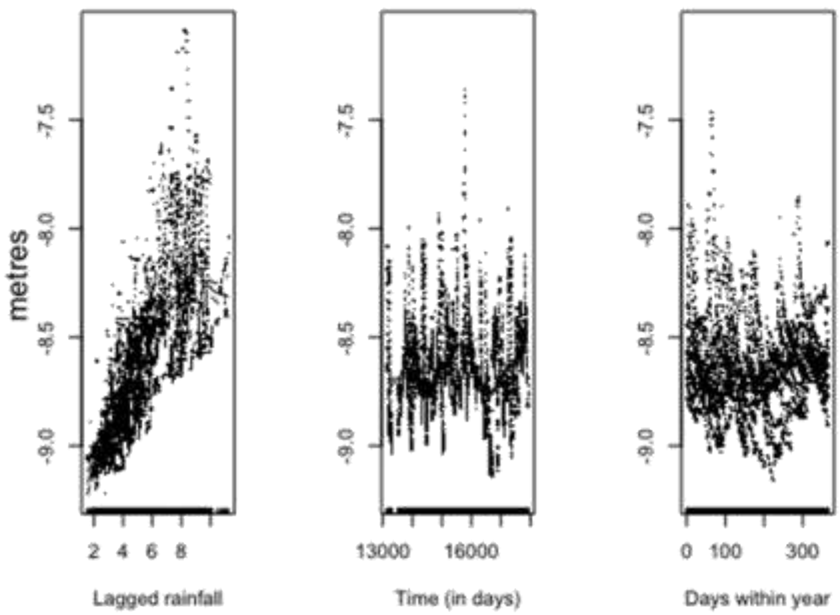
The highest percent variation explained was given by lagging rain over 150 days. Adding rain into the model explained an additional 49.42 percent of variability compared with a model that included just time and season. This effect was statistically significant ($p<.001$).

Adding season into the model explained an additional 4.27 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant ($p= 0.296$).

Adding time into the model explained an additional 8.01 percent of variability compared to a model with just rain and season, but this effect was not statistically significant ($p= 0.052$).

There was no statistically significant non-linearity in the time effect ($p= 0.058$).

site GW036702 hole 3 pipe 1



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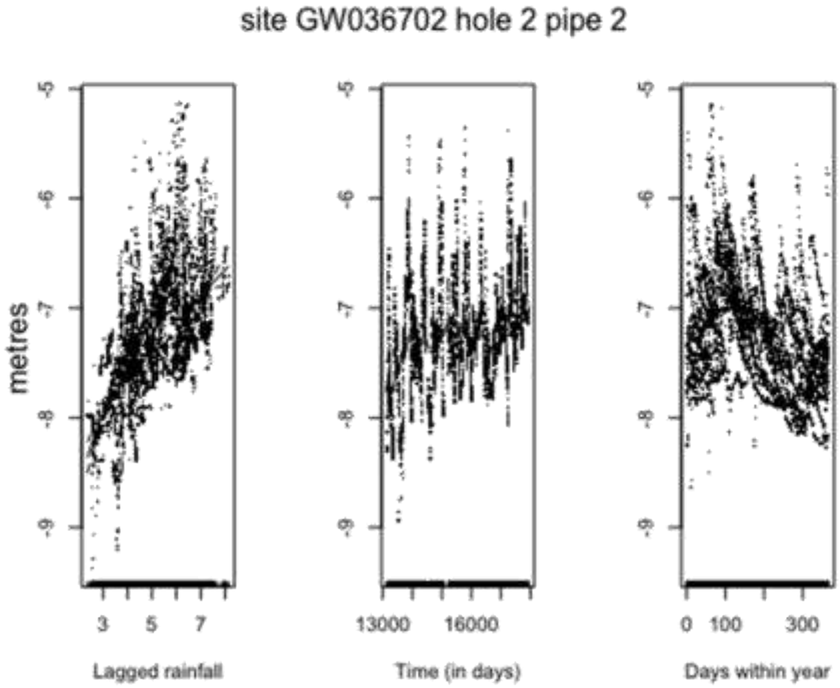
Analysis for site GW036702 hole 2 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 28.9 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 21.11 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.066).

Adding time into the model explained an additional 17.83 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.01).

There was no statistically significant non-linearity in the time effect (p= 0.193).



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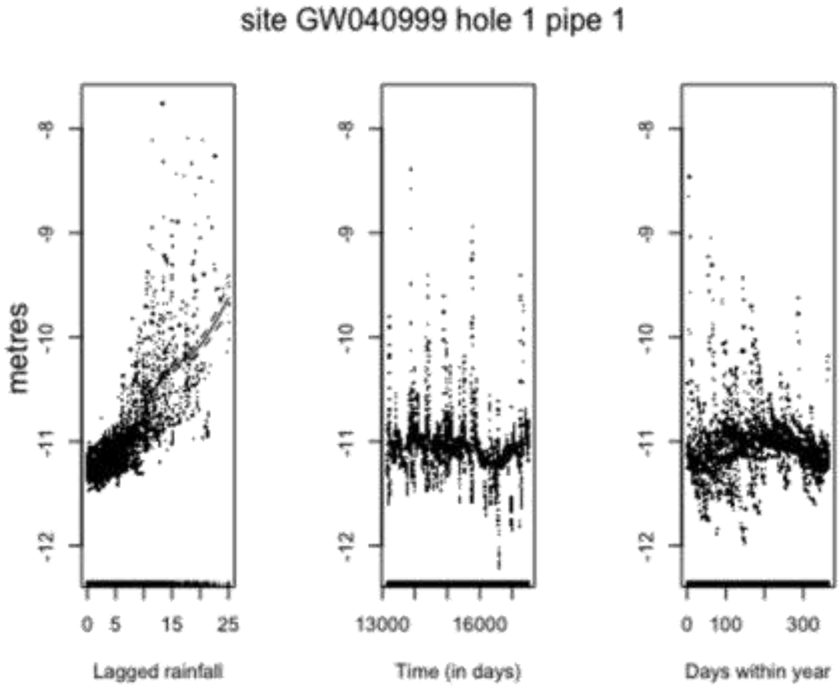
Analysis for site GW040999 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 30 days. Adding rain into the model explained an additional 57.37 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 8.34 percent of variability compared to a model with just rain and time. This effect was statistically significant (p= 0.009).

Adding time into the model explained an additional 10.62 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.002). There were statistically significant non-linearities in the time effect (p= 0.007).



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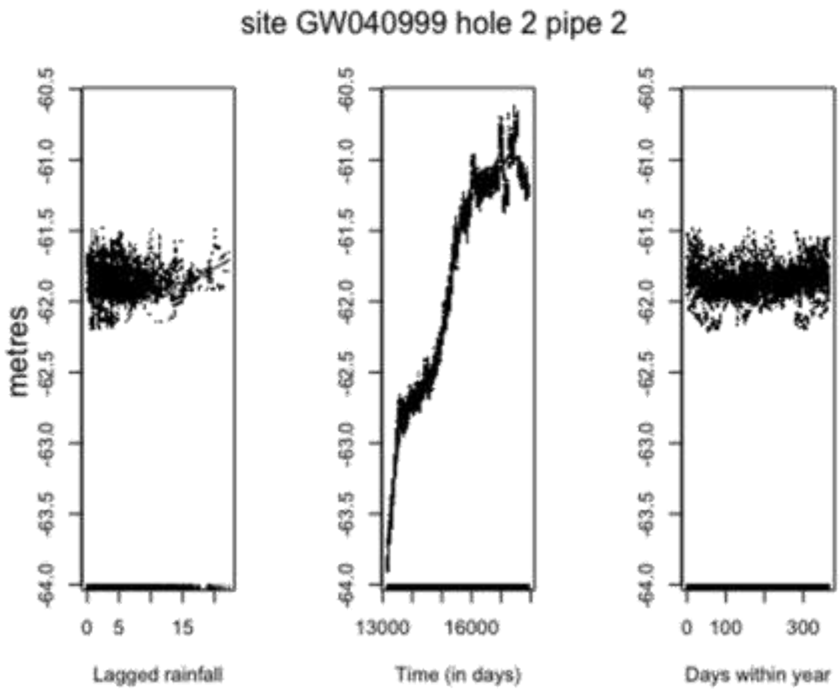
Analysis for site GW040999 hole 2 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 40 days. Adding rain into the model explained an additional 1.46 percent of variability compared with a model that included just time and season. but this increase was not statistically significant (p= 0.734).

Adding season into the model explained an additional 7.27 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.267).

Adding time into the model explained an additional 98.24 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001). There were statistically significant non-linearities in the time effect (p= 0.016).



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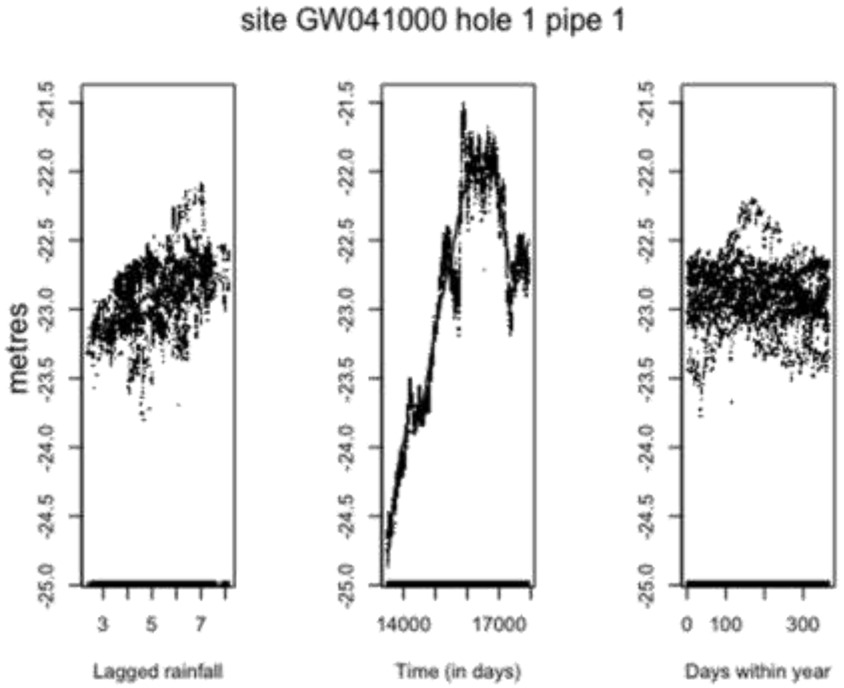
Analysis for site GW041000 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 16.59 percent of variability but this increase was not statistically significant (p= 0.14).

Adding season into the model explained an additional 2.3 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.743).

Adding time into the model explained an additional 93.79 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There were statistically significant non-linearities in the time effect (p<.001).



Analysis for site GW041000 hole 1 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 20.68 percent of variability but this increase was not statistically significant (p= 0.061).

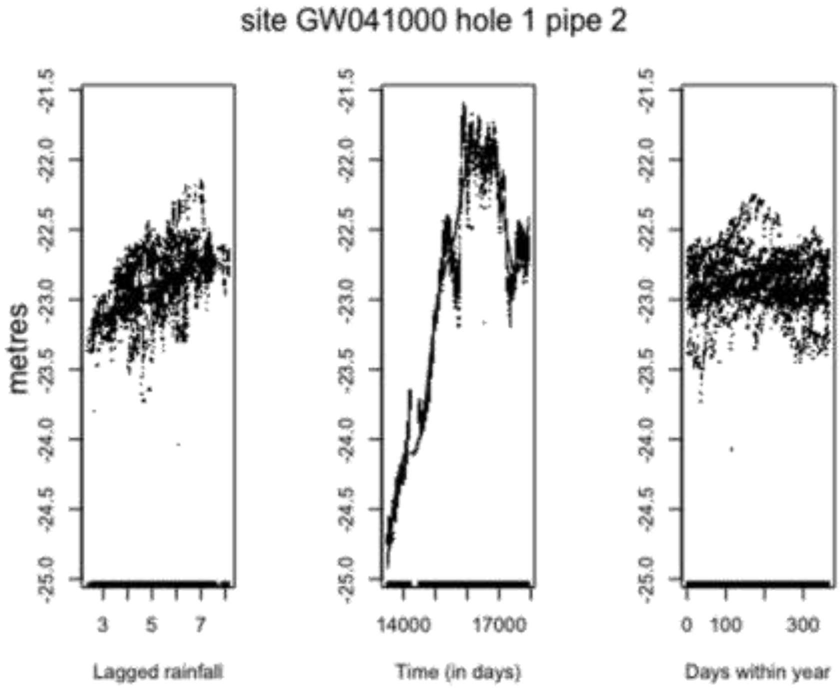
Adding season into the model explained an additional 3.03 percent of variability compared to a model with just rain and time.

However, this effect was not statistically significant (p= 0.576).

Adding time into the model explained an additional 95.01 percent of variability compared to a model with just rain and season.

This effect was statistically significant (p= 0.001).

There were statistically significant non-linearities in the time effect (p<.001).



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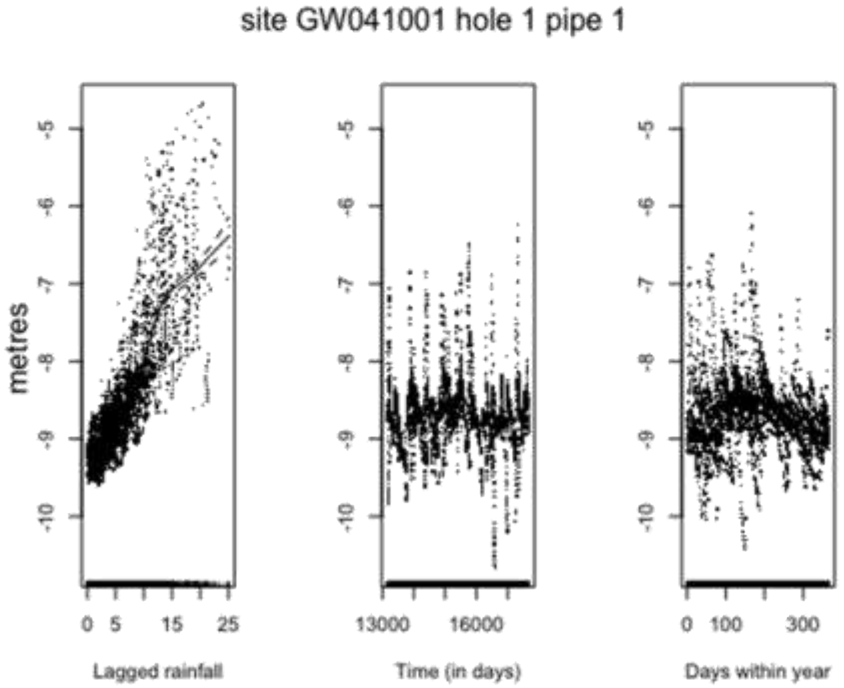
Analysis for site GW041001 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 30 days. Adding rain into the model explained an additional 68.44 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 8.47 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.126).

Adding time into the model explained an additional 8.18 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.031).

There were statistically significant non-linearities in the time effect (p= 0.018).



Analysis for site GW041001 hole 2 pipe 2 data from 2006 only

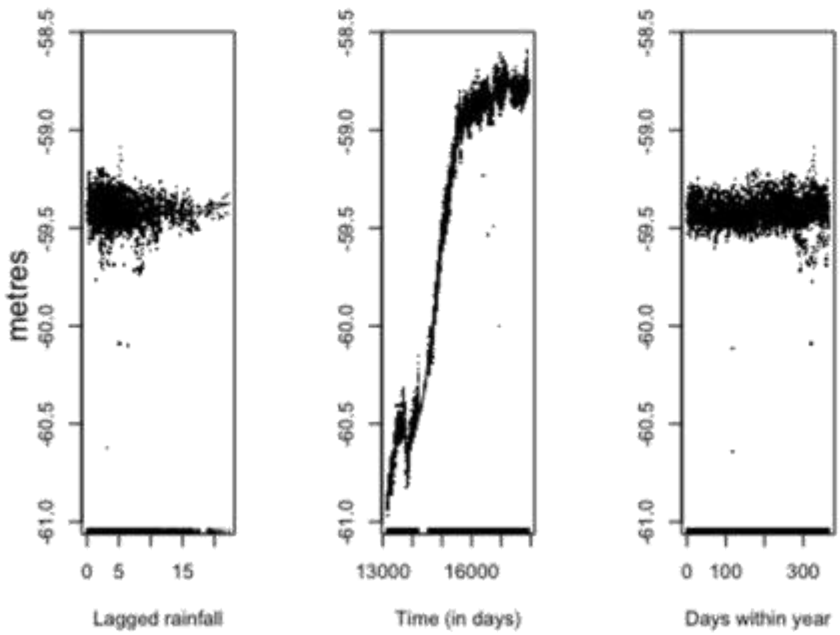
The highest percent variation explained was given by lagging rain over 40 days. Adding rain into the model explained an additional 2.7 percent of variability but this increase was not statistically significant (p= 0.406).

Adding season into the model explained an additional 1.71 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.568).

Adding time into the model explained an additional 99.02 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There were statistically significant non-linearities in the time effect (p<.001).

site GW041001 hole 2 pipe 2



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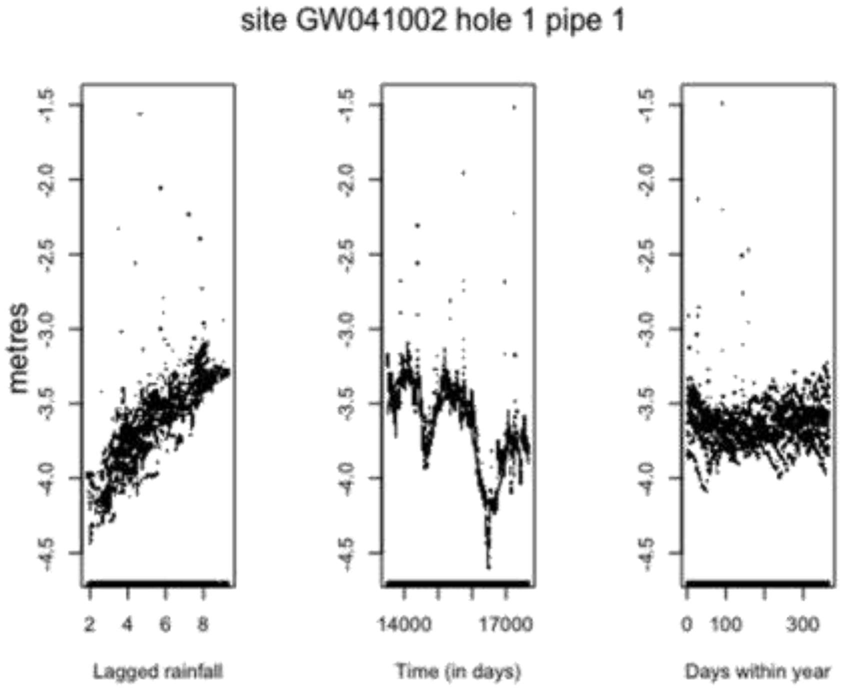
Analysis for site GW041002 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 200 days. Adding rain into the model explained an additional 61.02 percent of variability compared with a model that included just time and season. This effect was statistically significant (p= 0.001).

Adding season into the model explained an additional 4.54 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.151).

Adding time into the model explained an additional 75.22 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.005).

There were statistically significant non-linearities in the time effect (p= 0.016).



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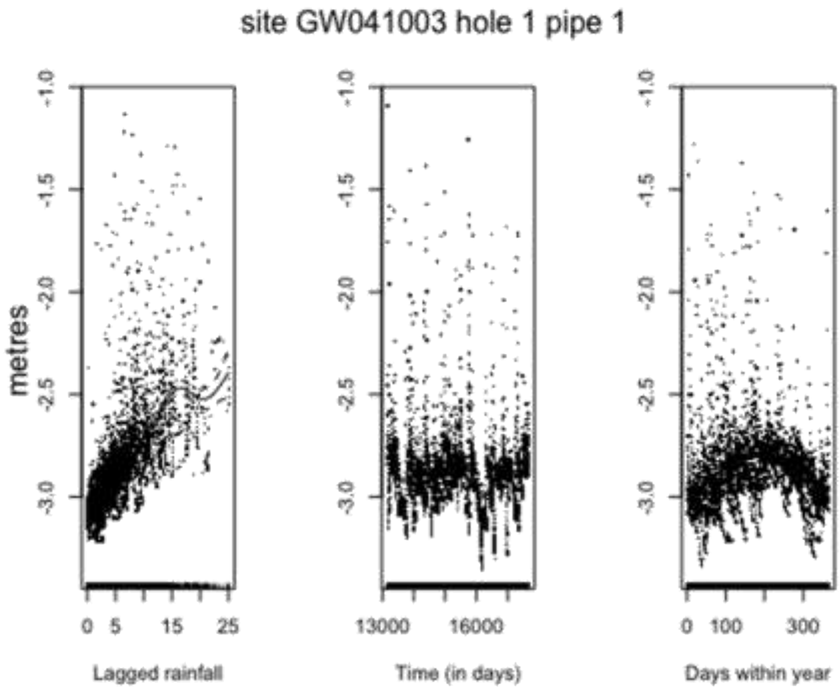
Analysis for site GW041003 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 30 days. Adding rain into the model explained an additional 38.81 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 10.76 percent of variability compared to a model with just rain and time. This effect was statistically significant (p= 0.001).

Adding time into the model explained an additional 7.78 percent of variability compared to a model with just rain and season, but this effect was not statistically significant (p= 0.259).

There was no statistically significant non-linearity in the time effect (p= 0.228).



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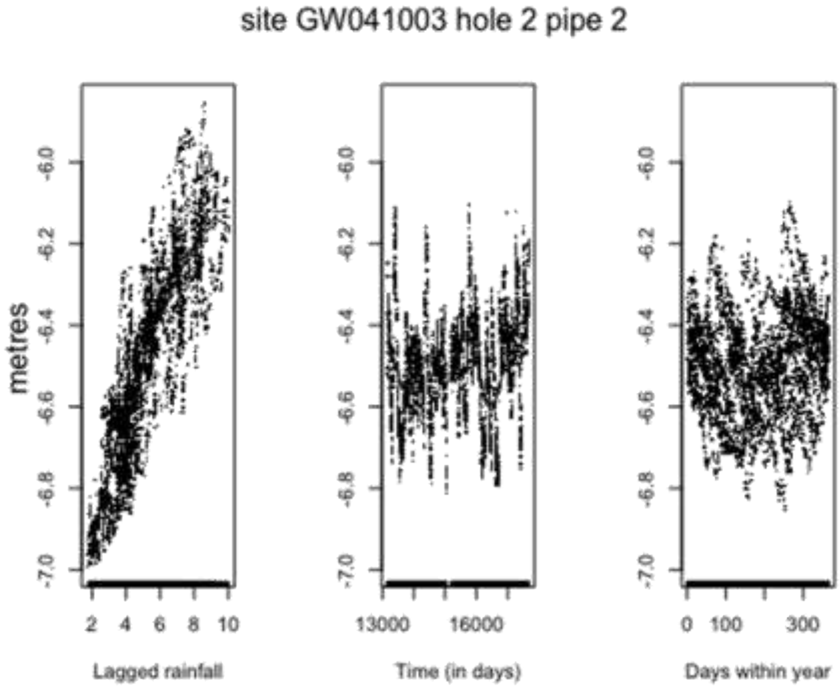
Analysis for site GW041003 hole 2 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 180 days. Adding rain into the model explained an additional 63.43 percent of variability compared with a model that included just time and season. This effect was statistically significant (p= 0.001).

Adding season into the model explained an additional 5.04 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.383).

Adding time into the model explained an additional 18.75 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.014).

There were statistically significant non-linearities in the time effect (p= 0.023).



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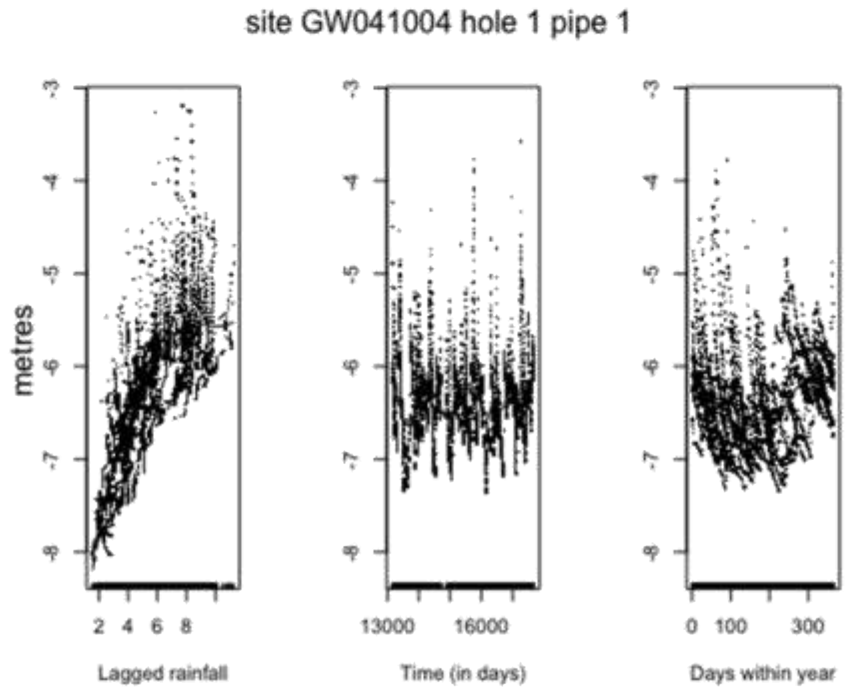
Analysis for site GW041004 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 150 days. Adding rain into the model explained an additional 50.21 percent of variability compared with a model that included just time and season. This effect was statistically significant (p= 0.001).

Adding season into the model explained an additional 11.22 percent of variability compared to a model with just rain and time. This effect was statistically significant (p= 0.049).

Adding time into the model explained an additional 7.78 percent of variability compared to a model with just rain and season, but this effect was not statistically significant (p= 0.093).

There was no statistically significant non-linearity in the time effect (p= 0.07).



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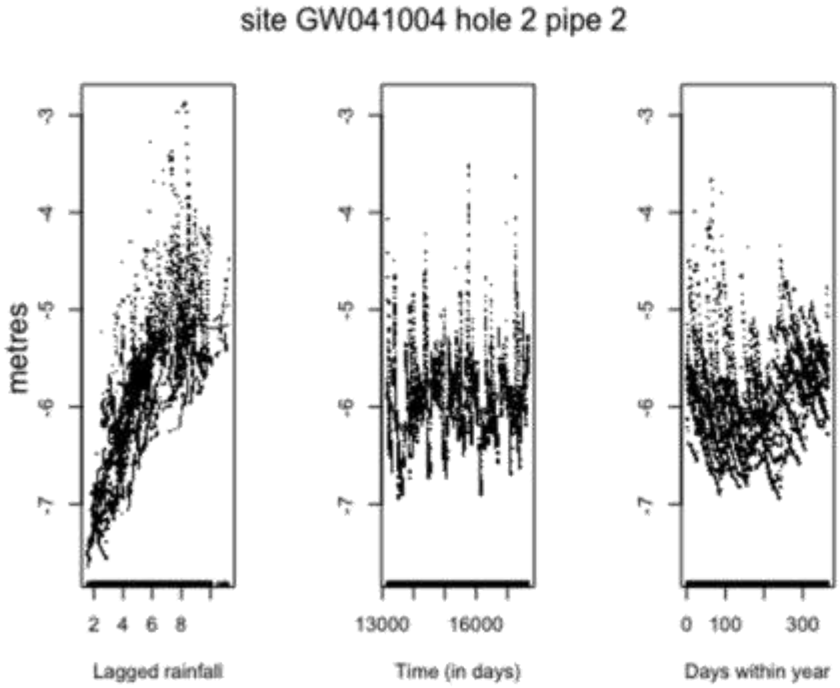
Analysis for site GW041004 hole 2 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 150 days. Adding rain into the model explained an additional 50.63 percent of variability compared with a model that included just time and season. This effect was statistically significant ($p<.001$).

Adding season into the model explained an additional 11.08 percent of variability compared to a model with just rain and time. This effect was statistically significant ($p= 0.039$).

Adding time into the model explained an additional 8.17 percent of variability compared to a model with just rain and season but this effect was not statistically significant ($p= 0.191$).

There was no statistically significant non-linearity in the time effect ($p= 0.178$).



168

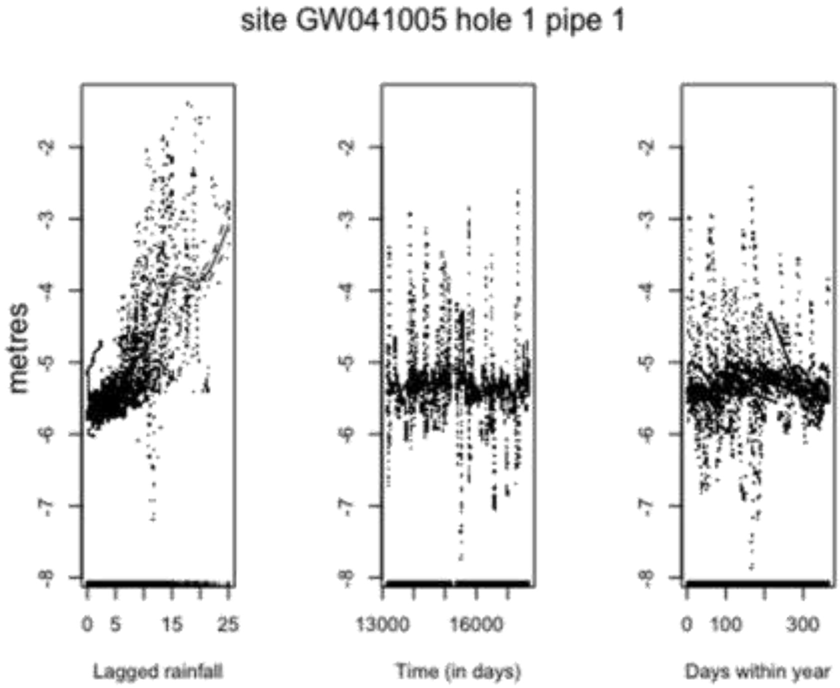
Analysis for site GW041005 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 30 days. Adding rain into the model explained an additional 53.08 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 2.76 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.169).

Adding time into the model explained an additional 5.17 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.044).

There were statistically significant non-linearities in the time effect (p= 0.028).



169

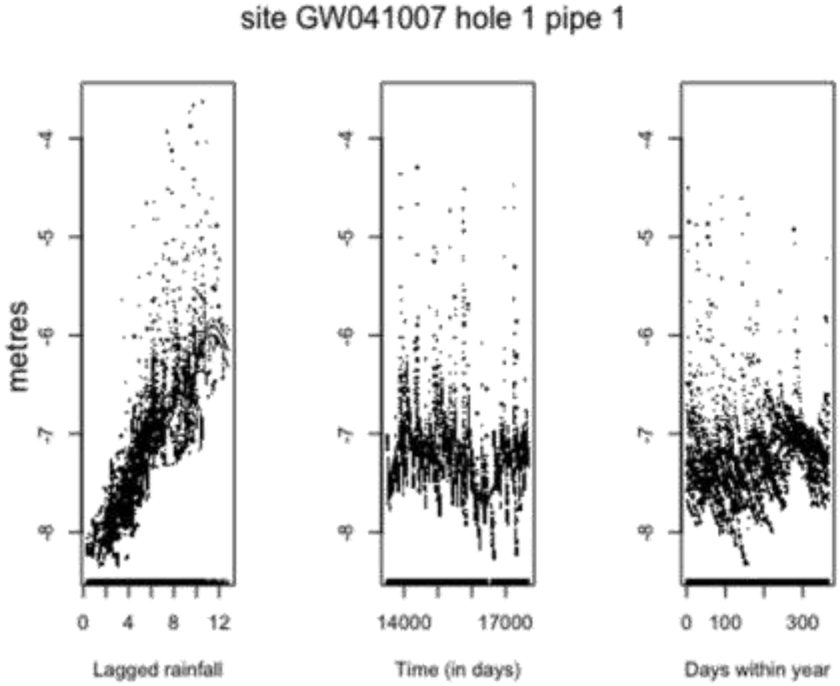
Analysis for site GW041007 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 100 days. Adding rain into the model explained an additional 54.98 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 7.11 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.078).

Adding time into the model explained an additional 18.85 percent of variability compared to a model with just rain and season but this effect was not statistically significant (p= 0.056).

There were statistically significant non-linearities in the time effect (p= 0.008).



170

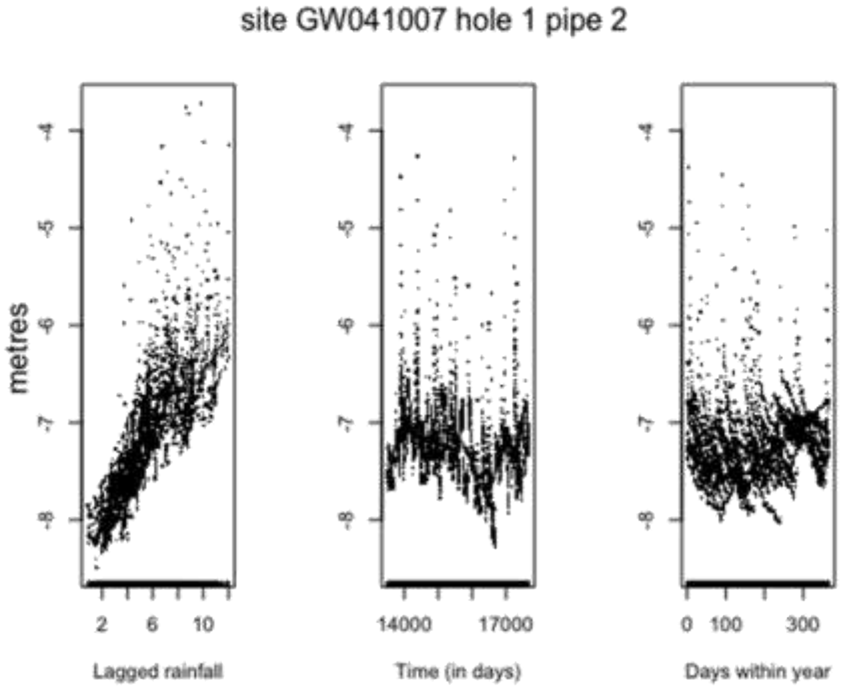
Analysis for site GW041007 hole 1 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 120 days. Adding rain into the model explained an additional 50.81 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 6.99 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.062).

Adding time into the model explained an additional 22.23 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.007).

There were statistically significant non-linearities in the time effect (p= 0.003).



171

Analysis for site GW041008 hole 1 pipe 1 data from 2006 only

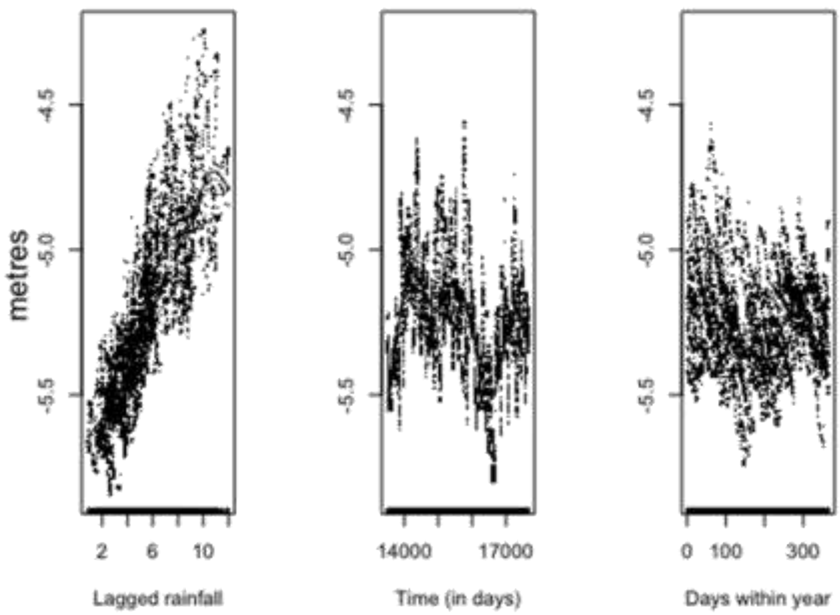
The highest percent variation explained was given by lagging rain over 120 days. Adding rain into the model explained an additional 56.38 percent of variability compared with a model that included just time and season. This effect was statistically significant ($p<.001$).

Adding season into the model explained an additional 10.49 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant ($p= 0.087$).

Adding time into the model explained an additional 36.79 percent of variability compared to a model with just rain and season. This effect was statistically significant ($p= 0.007$).

There were statistically significant non-linearities in the time effect ($p= 0.01$).

site GW041008 hole 1 pipe 1



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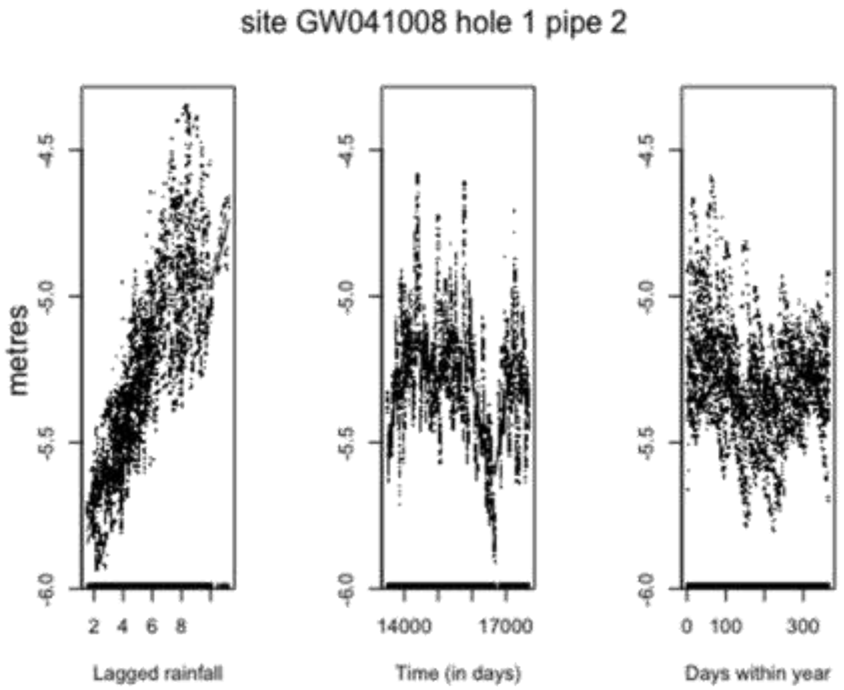
Analysis for site GW041008 hole 1 pipe 2 data from 2006 only

The highest percent variation explained was given by lagging rain over 150 days. Adding rain into the model explained an additional 57.62 percent of variability compared with a model that included just time and season. This effect was statistically significant ($p<.001$).

Adding season into the model explained an additional 15.87 percent of variability compared to a model with just rain and time. This effect was statistically significant ($p= 0.004$).

Adding time into the model explained an additional 36.41 percent of variability compared to a model with just rain and season. This effect was statistically significant ($p= 0.017$).

There were statistically significant non-linearities in the time effect ($p= 0.006$).



173

Analysis for site GW081000 hole 1 pipe 1 data from 2006 only

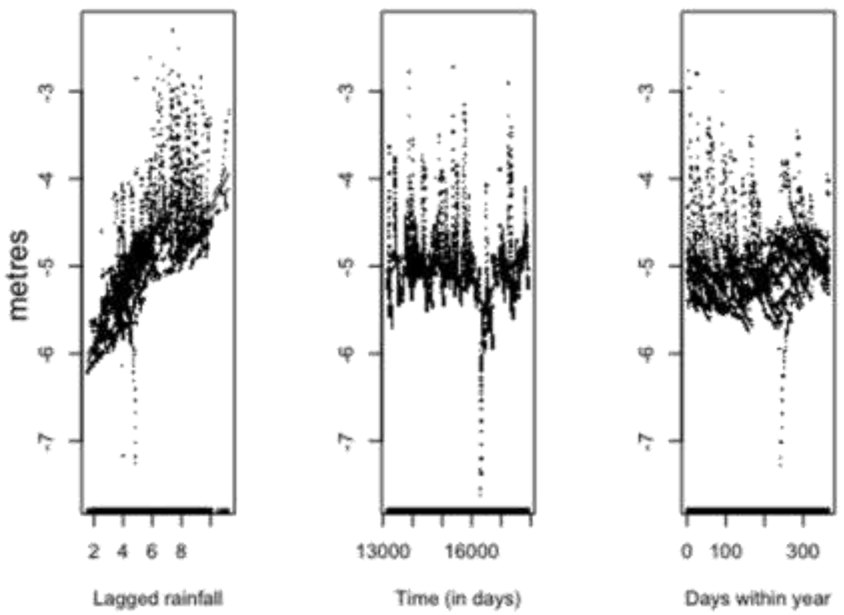
The highest percent variation explained was given by lagging rain over 150 days. Adding rain into the model explained an additional 46.88 percent of variability compared with a model that included just time and season. This effect was statistically significant ($p<.001$).

Adding season into the model explained an additional 3.58 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant ($p= 0.202$).

Adding time into the model explained an additional 15.33 percent of variability compared to a model with just rain and season but this effect was not statistically significant ($p= 0.072$).

There was no statistically significant non-linearity in the time effect ($p= 0.07$).

site GW081000 hole 1 pipe 1



174

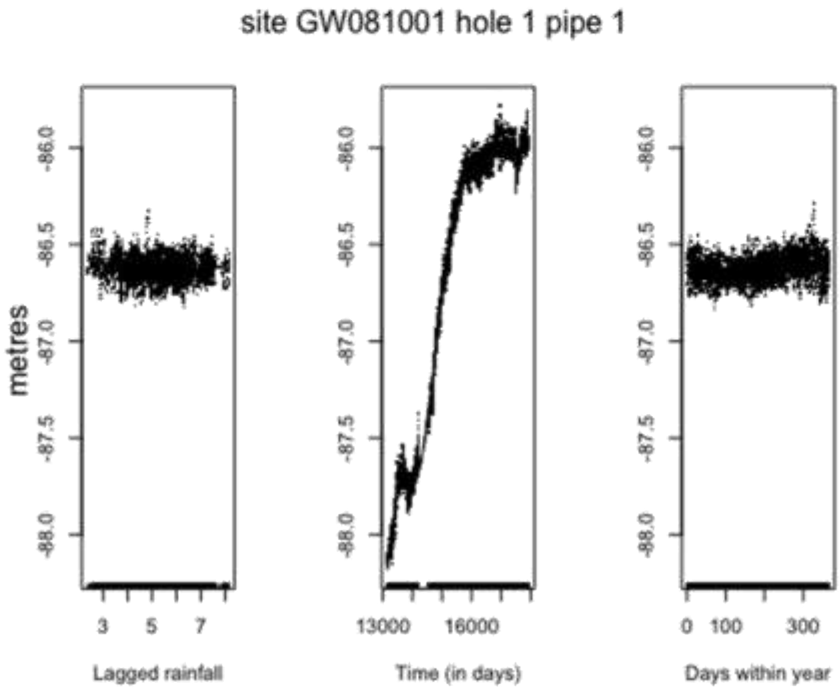
Analysis for site GW081001 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 2.46 percent of variability but this increase was not statistically significant (p= 0.421).

Adding season into the model explained an additional 10.95 percent of variability compared to a model with just rain and time. This effect was statistically significant (p= 0.044).

Adding time into the model explained an additional 99.35 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There were statistically significant non-linearities in the time effect (p<.001).



175

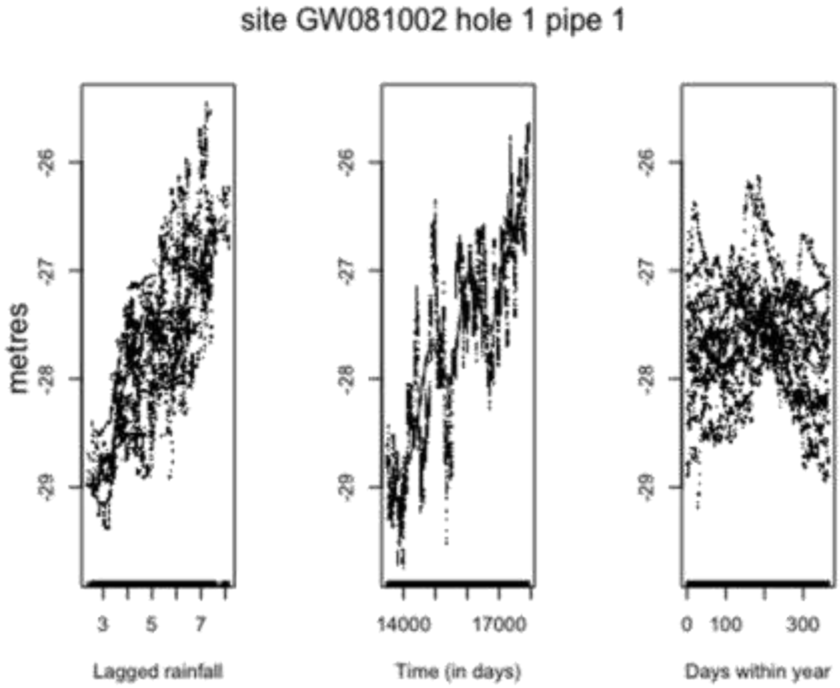
Analysis for site GW081002 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 44.91 percent of variability compared with a model that included just time and season. This effect was statistically significant (p= 0.001).

Adding season into the model explained an additional 7.05 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.462).

Adding time into the model explained an additional 71.2 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There was no statistically significant non-linearity in the time effect (p= 0.277).



176

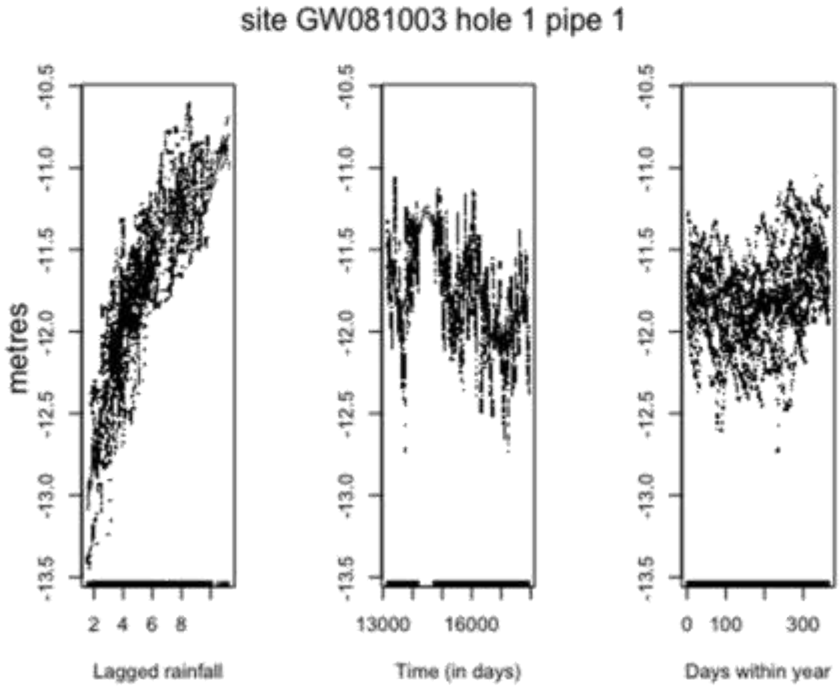
Analysis for site GW081003 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 150 days. Adding rain into the model explained an additional 66.13 percent of variability compared with a model that included just time and season. This effect was statistically significant (p<.001).

Adding season into the model explained an additional 13.57 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.129).

Adding time into the model explained an additional 35.11 percent of variability compared to a model with just rain and season. This effect was statistically significant (p= 0.004).

There were statistically significant non-linearities in the time effect (p= 0.009).



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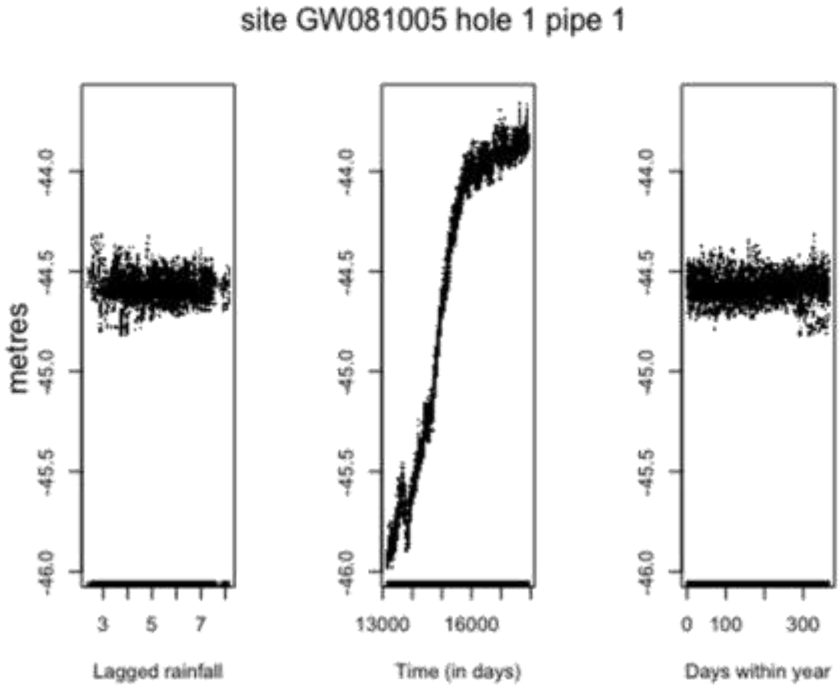
Analysis for site GW081005 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 280 days. Adding rain into the model explained an additional 1.77 percent of variability but this increase was not statistically significant (p= 0.48).

Adding season into the model explained an additional 0.83 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant (p= 0.585).

Adding time into the model explained an additional 99.23 percent of variability compared to a model with just rain and season. This effect was statistically significant (p<.001).

There were statistically significant non-linearities in the time effect (p<.001).



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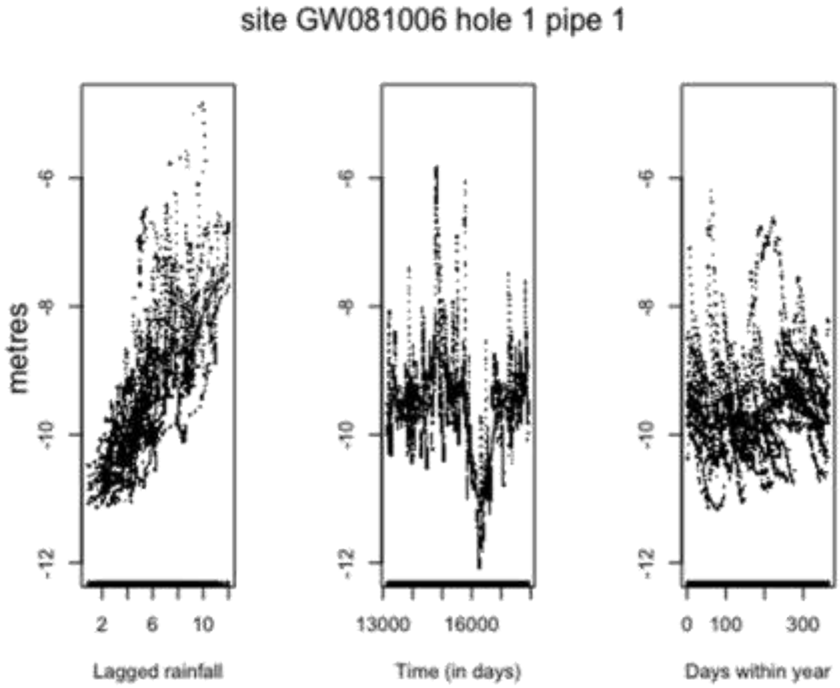
Analysis for site GW081006 hole 1 pipe 1 data from 2006 only

The highest percent variation explained was given by lagging rain over 120 days. Adding rain into the model explained an additional 43.52 percent of variability compared with a model that included just time and season. This effect was statistically significant ($p<.001$).

Adding season into the model explained an additional 5.02 percent of variability compared to a model with just rain and time. However, this effect was not statistically significant ($p= 0.264$).

Adding time into the model explained an additional 42.1 percent of variability compared to a model with just rain and season. This effect was statistically significant ($p= 0.023$).

There were statistically significant non-linearities in the time effect ($p= 0.019$).



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APPENDIX 6: CASE STUDY - LUMLEY PARK AND CONVERY'S LANE, ALSTONVILLE

This case study provides one of the few examples for the region and illustrates the complexities of evaluating and ascertaining potential connections between the deeper groundwater system, the shallower aquifers and impacts on local assets. However, it is not provided to specifically examine connectivity and drawdown effects.

Rous County Council has TWS bores at Lumley Park and Convery's Lane that draw from the deeper aquifer in the Alstonville Basalt Plateau Groundwater system (Table 32). These bores have allocations that provide town water supply at around ten times or higher than most licences for bottled water extraction. These bores are also in close proximity to the DPIE Water monitoring bores.

Table 32: Details for TWS bores, the allocation, depth of the bore, and nearby DPIE groundwater monitoring piezometers

TWS Bore Name	TWS bore allocation (ML/y)	TWS depth (m below measuring point)	DPIE monitoring bore	Depth of monitoring piezometer (screen interval)	Monitoring bore year installed
Convery's Lane	253	111	GW036702	17-21m	1987
			GW036702	150-168m	1987
Lumley Park	530 (max historical extraction 192)	82	GW081005	60-71 m	1999
			GW081006	7.5-12 m	1999
			GW41001 -1	Shallow*	2005-06
			GW41001 -2	Deep*	2005-06

*the exact depth was not available

In 2006 a comparison was made of the Convery's Lane TWS bore pumping data with the deeper groundwater levels at the nearby DPIE Water monitoring bore GW036702 around one km away. At the time, investigations found that the pressure heads in the deeper groundwater system dropped significantly when the Convery's Lane TWS bore was pumping, indicating that pumping was not sustainable. Once these pumps ceased it took several years for pressure heads to recover (Green, 2006) (Figure 36). In 2003, Rous County Council ceased using the Convery's Lane bore due to its effect on the deeper groundwater levels (Rous Water, 2014). Further investigation would be required to ascertain the hydrogeologic relationship between the deep level pumping, the shallow water levels and rainfall.

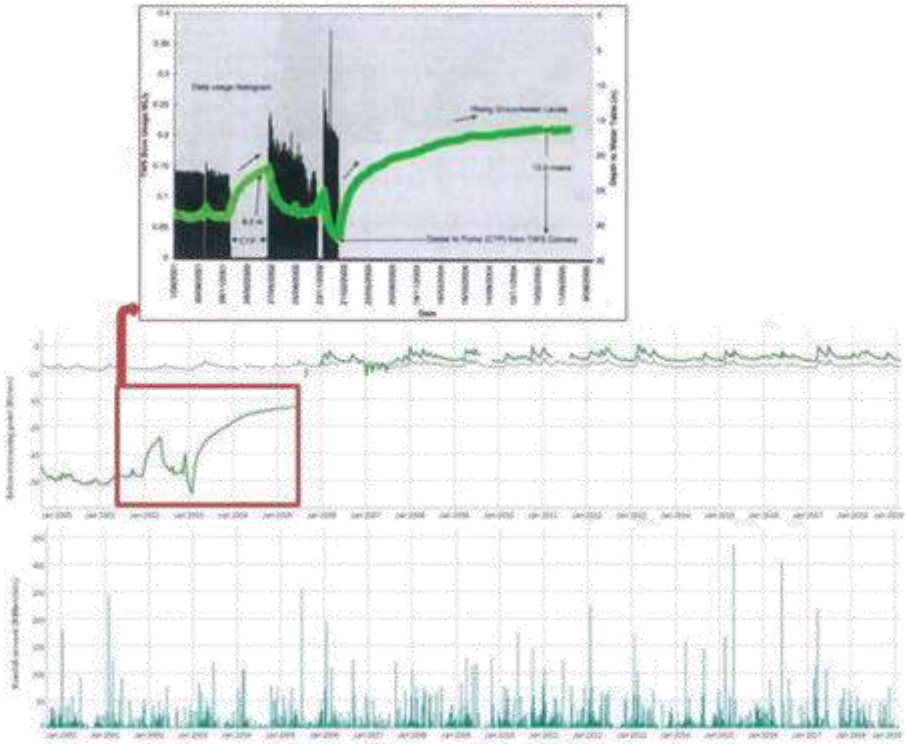

Figure 36: Convery's Lane TWS bore usage (ML/y) with GW036702 (deeper and shallow) levels and rainfall data.

The Convery's Lane usage shows gaps in extraction in 2001-2002 and from 2003. The bore usage is shown in subset graph in black columns. Figure modified from (Parsons Brinckerhoff, 2011).The nearby bores shows a response from the deeper monitoring bore (depth to groundwater shown as below measuring point in green), while the monitoring bore GW036702.3.1 (shallow) may be associated with rainfall (nearby Bureau of Meteorology rainfall stations, shown in blue columns). Data source: WaterNSW and BoM

In the case of the TWS bore at Lumley Park, in contrast to that at Convery's Lane, investigations of the groundwater pressure heads at the nearest DPIE Water monitoring bore around one km away (GW081005 (deeper) and GW081006 (shallow)) in 2006 indicated that drawdown during pumping at this site had limited influence on groundwater levels (Parsons Brinckerhoff, 2011). This may indicate a confined or partially confined aquifer and help to ensure that a remnant subtropical rainforest (Scientific Committee, 2019) is not impacted by the TWS. This rainforest is likely a GDE that contains highly diverse vegetation, invertebrates and fauna including a small melaleuca swamp community with platypus (Moore, 2014). However, it has been estimated that this rainforest most likely relies on the shallow groundwater zone during dry periods and contains at least one spring feeding into Maguires Creek (Green, 2006; Parsons Brinckerhoff, 2011).

Previous analysis indicated that groundwater pressure heads within the TWS bore at Lumley Park, or in close proximity to it, were likely to be temporarily lowered during the period it was operational (2002-2006) (Parsons Brinckerhoff, 2011). However, the deeper groundwater levels at the monitoring bore in proximity remained around 45 m below ground level (Parsons Brinckerhoff, 2011) (Figure 37). The TWS bore was used again for a period in

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between late August and late December 2007, but has not been operational since (Rous County Council, 2019a, 2019b).

Additional monitoring piezometers were installed in 2005-2006 (GW041001_1 and _2) near the TWS bore at Lumley Park (~10-20 m away) and Lumley Cutting (~50-100 m away). The deeper levels during this period were generally stable, with the four dips potentially attributed to measurement error, periods when the data from the logger was being downloaded or the logger was down (Figure 37 and Figure 38). Small rises in the shallow levels seem to follow the significant rainfall events. It was previously reported that groundwater levels in the shallow aquifer are rapidly recharged with rainfall events (Green, 2006), which can be seen in Figure 38.

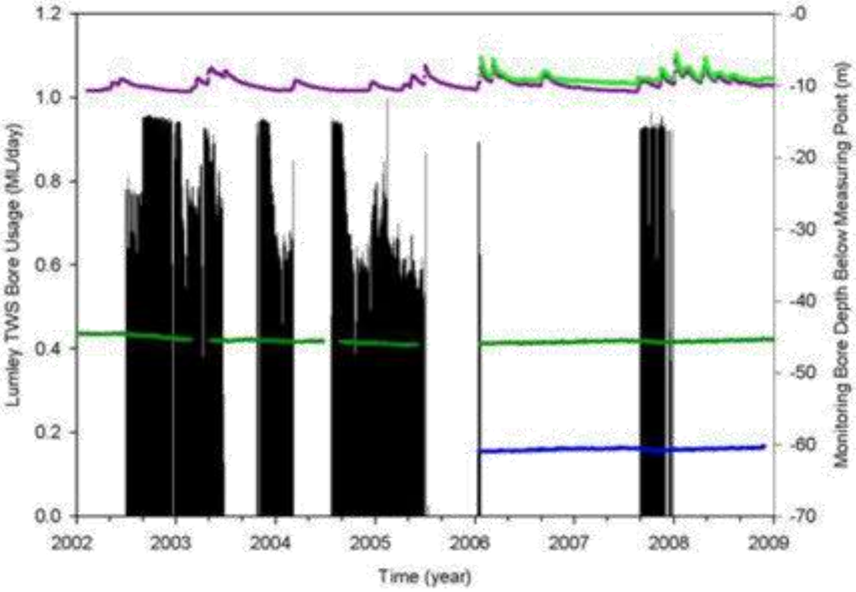

Figure 37: Lumley Park TWS bore usage (black columns) and water level and/or pressure observed at DPIE monitoring bores GW081006 (shallow) and GW081005 (deeper) from 2002 to 2009.

Source: Rous County Council (2019a) and WaterNSW data register (WaterNSW, 2019)

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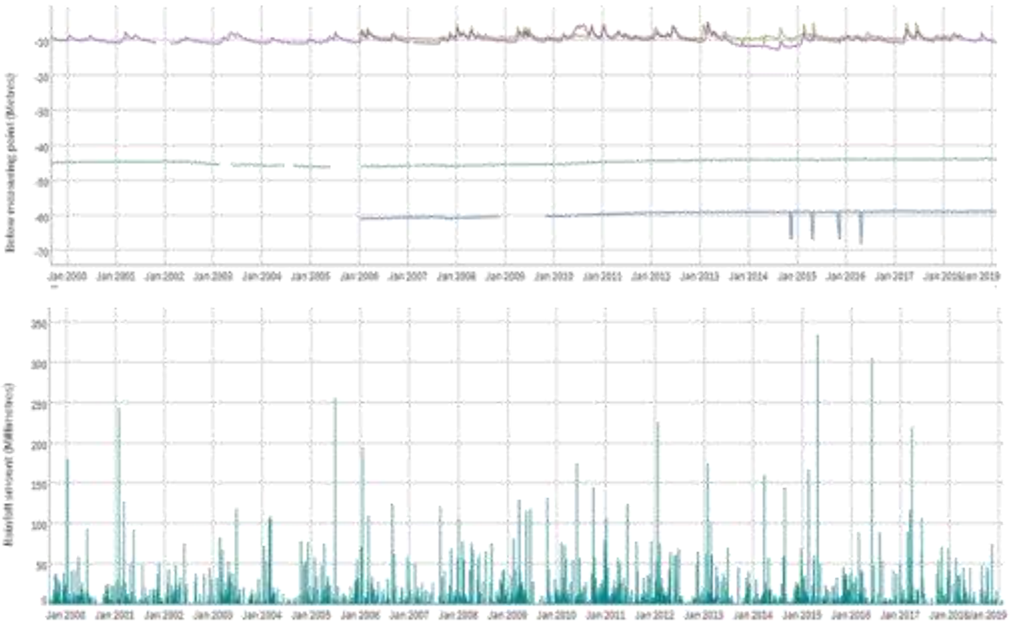

Figure 38: Groundwater levels from DPIE monitoring bores near Lumley Park plotted with rainfall
Groundwater levels from DPIE monitoring bores near Lumley Park: GW081006 (shallow, purple line) and GW081005 (deeper, green line) and two more recent monitoring bores GW041001.1.1 (shallow, light green line) and GW041001.2.2 (deeper, light blue line, note the four dips are most likely associated with logger servicing); and the rainfall amount (nearby Bureau of Meteorology rainfall stations, shown in blue columns). Data source: WaterNSW and BoM

At Lumley Park, the monitored levels did not appear to support an immediate link between extraction and the deeper and shallow levels nearby; whereas at Convery's Lane there appeared to be a link between extraction and drawdown from the deeper aquifer. This example highlights the complexity of the spatial and temporal variation across the fractured rock aquifers despite monitoring of the deeper and shallow aquifers over extended periods. However, these investigations also highlight the value of properly conducted investigations, which include field investigations, conceptual model development, and bore testing.

As these cases do not include monitoring of the local GDEs, it is difficult to draw conclusions about environmental impacts. Further monitoring at Lumley Park (Parsons Brinckerhoff, 2011) and an assessment of the interaction with the GDE could determine if the pumping rate may cause unacceptable drawdown (Moore, 2014). Monitoring suggestions, highlighted in reports prepared for Rous, included monthly data collection of groundwater levels and parameters including: EC, pH, temperature and redox potential, as well as annual monitoring for major ions, metals, and nutrients to detect any potential changes in groundwater quality (Parsons Brinckerhoff, 2011).

APPENDIX 7: SETBACK RULES FROM THE WSP

Table 33: Minimum distance rules to minimise interference between bores in fractured rock groundwater sources (Alstonville Basalt Plateau, New England Fold Belt Coast, and North Coast Volcanics)

Other bore/asset type	Minimum distances
An existing bore that is not used for basic rights	200m (bores < 20ML/yr) 400m (bores > 20ML/yr)
An existing bore that is used for basic rights	200m
The boundary of the property (unless consent gained from neighbour)	100m
A local or major water utility bore	500m
A bore used by the Department for monitoring purposes	400m

Exceptions – the above restrictions do not apply if either:

- The bore is used solely for basic rights;
- The bore is a replacement bore;
- The bore is used for monitoring, environmental management or remedial works; or
- The location of the bore would result in no more than minimal impact on existing extractions within the water source.

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 cl 40

Table 34: Minimum distance rules to minimise interference between bores in porous rock groundwater sources (Clarence Morton Basin)

Other bore/asset type	Minimum distances
An existing bore that is not used for basic rights	400m
An existing bore that is used for basic rights	100m
The boundary of the property (unless consent gained from neighbour)	50m
A local or major water utility bore	1000m
A bore used by the Department for monitoring purposes	200m

Exceptions – the above restrictions do not apply if either:

- The bore is used solely for basic rights;
- The bore is a replacement bore;
- The bore is used for monitoring, environmental management or remedial works; or
- The location of the bore would result in no more than minimal impact on existing extractions within the water source.

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 cl 40

Table 35: Minimum distance rules to minimise contamination

Contamination source	Minimum distances
The plume associated with a contamination source	Any distance from the plume that is insufficient to protect the groundwater source; or 250-500m if no drawdown will not occur within 250 m of plume; or or 250m

Exceptions – the above restrictions do not apply if either:

- The distance is adequate to protect the groundwater source, its dependent ecosystems and public health and safety; or
- The bore is used for monitoring, environmental management or remedial works.

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 cl 41

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Table 36: Minimum distance rules to minimise impacts on GDEs and environmentally sensitive areas

GDE or environmentally sensitive area	Minimum distances
A high-priority GDE	100m (for bores used for basic rights)
A high-priority GDE or the outside perimeter of a National Park estate	200m (for bores not used for basic rights)
A high-priority karst environment GDE	500m (for bores not used for basic rights)
A river or stream (1st, 2nd or 3rd order)	40m (for bores not used for basic rights)
An escarpment	100m (for bores not used for basic rights)

Exceptions – the above restrictions do not apply if either:

- The water supply works (bores) are used for monitoring, environmental management purposes or remedial work;
- A hydrogeological study demonstrates no drawdown of the groundwater at the outside edge of the GDE; or
- No more than minimal impact will occur to any groundwater dependent vegetation in the nearby National Park estate.

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 cl 42

Table 37: Minimum distance rules to minimise impacts on groundwater-dependent culturally significant sites

Site	Minimum distances
A groundwater-dependent culturally significant site	100m (for bores used for basic rights)
A groundwater-dependent culturally significant site	200m (for bores not used for basic rights)

Exceptions – the above restrictions do not apply if either:

- The bore is used for monitoring, environmental management or remedial works; or
- The location of the bore at a lesser distance would result in no greater impact on the groundwater source and its groundwater dependent culturally significant sites.

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 cl 43

APPENDIX 8: DECISION MAKING AND UNCERTAINTY

As part of Term of Reference 1, the Review was requested to provide advice on the sustainability of the extraction limits in the relevant Water Sharing Plan (WSP) for groundwater sources in the Northern Rivers.

While in common use, the term 'sustainability' is complex and underpinned by principles that require interpretation and consideration of multiple, changing and sometimes competing factors. The *Protection of the Environment Administration Act 1991* considers the sustainability to be informed by integration of social, economic and environmental considerations in decision-making processes. For the purposes of this report, 'groundwater sustainability' relates to managing the current (environmental and anthropogenic) use of the resource to provide for ensure long-term water security.

Regulatory instruments provide a framework and strategies to help achieve this long-term security, including adaptive management, risk assessment of proposed developments and approval conditions for licences and development applications. However, within these frameworks, judgements still need to be made. Salient questions in exercising judgement include for example, how much risk is acceptable, to whom, under what circumstances, with what information and what consequences and the degree of confidence in the assumptions made, what tools can be drawn on to reduce uncertainty in a way that is cost effective and proportional to the level of risk.

The Review recognises the community concern about water allocations and use, and the desire for greater certainty and more definitive information about sustainability to inform decision making at a regional, local and individual scale. Yet all decisions entail some degree of uncertainty, and all decisions are made in the context of imperfect knowledge.

At an individual- and community-level we are faced on a daily basis with the challenge of making decisions that balance risks and potential benefits of actions. These range from the routine to significant, may be implicit or explicit and are dynamic in light of changing knowledge – with advances and evolutions in science often shifting the balance. All are influenced by the actions and/or opinions of others, communal decisions made more complex by diverse stakeholder priorities and values.

In undertaking its work, the Review considered risk and uncertainty and how these have been managed by decision-makers and proponents from a scientific perspective based on currently available knowledge. This Section sets out how these concepts were approached by the Review and informed consideration of sustainability and impacts under the Terms of Reference.

TYPES OF UNCERTAINTY

Much has been written, both for academic and popular science audiences, on the topic of decision making under uncertainty. Some issues are well recognised – for example the need to account for sample variability, computational uncertainty or establishing appropriate margins of error. However, increasing recognition is being given to the importance and best means of communicating uncertainty to diverse audiences and recognition of the emotional side of decision making under uncertainty. Some offer practical guidance for individuals.

The prestigious US National Academy of Sciences (NAS) convened an expert panel several years ago to develop guidelines around environmental decision making under uncertainty (Institute of Medicine, 2013). The report had a strong focus around human health risks associated with environmental exposures. Notwithstanding this focus, the report offers many useful principles that can help in contexts where a regulatory body is faced with the challenge of making a complex decision.

One of the first steps in any uncertainty analysis should be a clear articulation of the various sources of, and nature of, the uncertainties involved and it is useful to distinguish between the different types of uncertainty.

Statistical variability, sometimes referred to as aleatory uncertainty, refers to natural variation in the physical environment and in human behaviour and biology. In the context of this Review, there will be statistical variability associated with daily rainfall levels or with how much water is actually extracted by an individual licensee within the maximum amount allowed.

This kind of variability is inherent to the system and cannot be reduced by collecting further data, though the latter may be extremely useful in helping decision makers to understand further this kind of uncertainty. This first type of uncertainty is, at least in broad principle, easy to accommodate through statistical modelling.

Model uncertainty refers to the fact that in virtually every area of enquiry, there will be uncertainties associated with the conceptual understanding of the relevant science that describes the context of interest. A useful definition of scientific modelling that recognises both its values and limitations is

"The generation of a physical, conceptual, or mathematical representation of a real phenomenon that is difficult to observe directly. Scientific models are used to explain and predict the behaviour of real objects or systems and are used in a variety of scientific disciplines, ranging from physics and chemistry to ecology and the Earth sciences. Although a central component of modern science, scientific models at best are approximations of the objects and systems that they represent—they are not exact replicas. Thus, scientists constantly are working to improve and refine models" (Rogers, 2011).

It is useful to subdivide model uncertainty into uncertainty associated with the broad nature of the model itself as well as uncertainty associated with particular parameters or inputs needed to characterise a particular model.

In some contexts, there can be substantial scientific debate about the appropriate conceptual model for a situation at hand. In the Review, an example of this uncertainty is in the appropriate method to calculate the recharge rate of groundwater. As will be seen later in Section 4.3.1, there are two approaches that can be used to model the recharge rate of groundwater, being Chloride Mass Balance and the baseflow filtering approach. The choice of which model to use may be based on a conceptual understanding of the mode of recharge (local or widespread, rainfall to groundwater versus rainfall to surface water to groundwater), previous experience, availability of data and tools.

Even in settings where scientists agree in broad terms over the appropriate conceptual modelling framework, there will often be uncertainty over the particular inputs needed to precisely define that model. This is referred to as parameter uncertainty.

Parameter uncertainty can generally be reduced through additional data collection, though this may involve time consuming and costly effort. In the context of this Review, it is likely that hydrogeologists would agree in broad terms about how one should go about constructing a model to characterise the aquifers in the Northern Rivers region. However, there might be variations in opinions regarding precise approaches.

The greatest source of uncertainty in this context arises from limitations in the availability of data to inform the right inputs to these models and to help define the needed model parameters. This would include data from geological surveys designed to help characterise the nature and structure of the aquifers and to elucidate their recharge behaviours.

There is a fourth kind of uncertainty referring to settings where there may be fundamental disagreements about the nature of the processes driving the situation of interest or where it is impossible to collect all the data needed to properly inform the system due to cost and time considerations. The term deep uncertainty is sometimes used to describe this kind of uncertainty. This kind of uncertainty classically arises in settings where decisions may have long-term consequences, but where it is not possible to accurately predict the future with full accuracy.

The process of decision making under uncertainty naturally follows several phases. The first phase involves problem formulation and scoping, creating an inventory or even a taxonomy of the uncertainties associated with a particular decision making context. This would involve listing out the various sources of statistical variation and heterogeneity. As part of the process in identifying and listing these sources, it is important to assess whether a particular source of heterogeneity might have impact on the decision and hence need to be incorporated specifically, or whether it is simply a source of heterogeneity that can be noted and then set aside and not considered further. In the hydrogeological context for example, it is typical to recognise that while there will always be a lot of small-scale fluctuations in the structure of a porous aquifer, it is not necessary to capture these precisely and only a general, larger-scale description of the aquifer characteristics may be needed.

As part of the first scoping phase of a decision, it is very important to assess whether some of the sources of uncertainty could be reduced relatively easily and in an acceptable timeframe through additional data collection or even research. It will also be critical to identify any sources of deep uncertainty and also to decide on the broader strategies that will be used to incorporate the identified uncertainties into the decision making process and ongoing risk management. Applying appropriate strategies to account for and manage those uncertainties correspond to the second and third phases of decision making under uncertainty, the focus of the following section.

APPROACHES TO INCORPORATING AND MANAGING UNCERTAINTY

A variety of modern-day tools are available to help with the incorporation of uncertainty considerations into decision making. Indeed, the science of Decision Theory goes back to the work of probability theorists such as Pascal and Bernoulli in the 17th and 18th centuries who discovered identified that people do not always react completely rationally and predictably when it comes to making decisions under uncertainty. These early developments were largely done in the context of gambling games where the choices and associated losses or gains were fairly simple.

The concept of Utility was developed to measure the value that people place on certain outcomes happening and then the decision making could be framed in terms of choosing the action with the highest expected utility. Alternatively, strategies such as minimax (choosing the option that minimizes the worst outcome) can be used in settings where it is difficult to assign probabilities to the relevant scenarios. Polasky et al. (2011) discuss these ideas in the context of environmental impact assessment. However, they make the point that these fairly simple classical decision theory tools work well only in settings where existing information is extensive and where the probabilities, risks and benefits associated with various decisions are well delineated. In most complex real world settings, more sophisticated tools are needed.

Modern decision science has evolved considerably in order to have relevance in and applicability in complex real-world settings. For example, there have been extensions to so-called multi-attribute utility analysis for settings involving multiple different outcomes. Cost-benefit analysis is an example. Extensions to the setting of multiple decision makers led to the field of game theory which has found wide application and interest from economists.

Tools such as probabilistic risk assessment were proposed in the late 80s and 90s as a means of incorporating uncertainty into the modelling process.

While probabilistic risk assessment cannot remove uncertainty, it provides a means of enabling decision makers to gain a clearer understanding of the impact of various sources of uncertainty on the outcomes of interest. Probabilistic risk assessment typically uses Monte

Carlo simulation and Bayesian methods to add extra layers to the modelling process. It works very well in terms of addressing the second type of uncertainty, model and parameter uncertainty. An example would be in areas of water quality and risk assessment, some stakeholders may have concerns that variation in the amount of water drunk by individuals each day might affect the estimated dose-response of contaminants and hence impact on the decision making process. By extending classic dose-response modelling to incorporate this variability, it is possible to explicitly assess the impact of this variability. Probabilistic Risk Assessment has also been adopted by the US Nuclear Regulatory Commission.

In very complex settings, the number of scenarios needing to be considered can easily balloon out to an unmanageable level. Some new computational tools have been recently developed to handle this. For example, MIT researchers utilise Bayesian networks to efficiently evaluate and compare thousands of decision options in the context of robotics and autonomous vehicle management (Kochenderfer et al., 2015; Hodgett & Siraj, 2019) describe a computational tool that builds uncertainty into a complex decision framework via a series of triangular distributions.

Bayesian modelling approaches can also be used in settings where there are uncertainties about the model to be used. In data-rich settings, statistical methods can be used to guide the choice between different models or even to build a "meta-model" that includes multiple models as special cases. In complex settings such as groundwater modelling, model specification requires the input of experts with deep knowledge of the subject. Once a model has been specified, there will still be a need to use a combination of data and informed by expert knowledge to estimate model parameters. (Peterson & Western, 2014) used this kind of approach in the context of groundwater modelling.

Rojas (2010) refer to this as a multi-model approach and discuss how this kind of approach can be used to consider the impact of various future scenarios. However, this kind of approach can be difficult to apply in practice. While it naturally allows for a wide range of opinions about the right conceptual model, it still requires that there be enough data available to help quantify the different sources of uncertainty. These approaches can also be computationally very complex when the individual models in the multi-model all require the running of a time consuming hydrogeological model. This can also make such models very expensive to develop. Asher et al. (2015) discuss a more computationally feasible approach based on surrogate models that approximate a complex hydrogeological model with an empirical model that captures the relationship between various model inputs and expected outcomes.

However, the greatest challenge in complex real-world settings is not so much running the models, but delineating all the different elements involved in the decision making and characterising the probabilities and uncertainties associated with these events. In settings that are data-poor or subject to deep uncertainties, the more mathematical tools described above become less relevant since it becomes almost impossible to attach realistic probabilities to the various settings being considered. While the ideal is of course to reduce uncertainty in order to create more reliable predictive models of environmental systems, this step can be time consuming, expensive and potentially unfeasible in the timeframe needed for decision making. Polasky et al. (2011) In such cases other more pragmatic solutions may be taken such as adaptive management, with monitoring and feedback steps to maintain an up-to-date view on the trajectory of an issue so that changes can be made, including potentially decisions to cease activity, informed by new information.

Adaptive management is a precautionary measure in certain cases where there is uncertainty, defined as a "procedure for implementing management while learning about which management actions are most effective at achieving specified objectives." (OEH, 2018). It is an "iterative based approach involving explicit testing of the achievement of defined goals" (Preston, 2017).

The *Water Management Act 2000* provides that "the principles of adaptive management should be applied, which should be responsive to monitoring and improvements in understanding of ecological water requirements." The NSW Land and Environment Court of NSW has held that an adaptive management approach might involve monitoring management impacts, research, periodic evaluation of outcomes and learning reviewing and adjusting in light of these and establishing effective compliance systems.

Scenario planning provides an appealing method to facilitate thinking and planning about potentially complex future events and outcomes. Scenario planning is less quantitative than traditional decision theory approaches, relying instead on a set of detailed stories that reflect possible changing conditions over time. An advantage of the scenario approach is that it allows the incorporation of complex interplays between social, economic and physical factors such as climate. However, this flexibility and capacity also leads to the main weakness of the approach, namely the difficulty in quantifying the relative likelihoods of the various scenarios. Also important is to prepare responses to potential scenarios with action 'trigger' points, thereby avoiding both the risk of automatically defaulting to a 'middle' option or over-investing to manage theoretical extremes unless required.

A threshold approach to decision making involves identifying critical boundaries that might have major implications if crossed. Setting emissions caps in the context of planning related to climate change is an example of a threshold approach to environmental management.

Resilience thinking refers to the idea of organizing decisions so that they can adapt or transform to a new mode of operation should the old mode become unworkable. Adaptive monitoring in those settings, emphasizing the importance of having access to good quality data that can be used to monitor the context of interest and potentially being used to trigger alerts should problems arise. In the context of aquifer management, having access to reliable data from monitoring bores can play a critical role in terms of assessing the long-term viability of the system and activities.

Polasky et al. (2011) also argue that most situations can benefit from the use of multiple tools and stress the importance of thinking of decision-making as a dynamic process that can responsively adapt in the face of change and of new information. Fletcher, Lickley, and Strzepak (2019) discuss similar ideas in the context of water resource planning. This is consistent with statutory and policy approaches described earlier. In the context of the Review, this kind of adaptive planning and decision making would require that reliable data be available to inform on the state of the various aquifers. Section 3.4 discusses how the data from the network of 29 functional monitoring bores in the Alstonville Plateau region can potentially be monitored in a real-time manner and how such analyses can either provide reassurance that the system is in good health or perhaps trigger a warning that some change might be needed.

Communicating uncertainty

Once the various sources of uncertainty have been identified and a strategy developed for decision making in that context, the next step involves ensuring that issues of uncertainty are communicated to various stakeholders and other audiences. There has been significant research undertaken into the effectiveness of visual and descriptive versus numerical representations of the uncertainty in risk. Professor David (Spiegelhalter, 2017) has written for both the scientific community and the general public about the importance of using clear language and graphical displays to help audiences understand the nature and sources of uncertainty and magnitude of consequences. An overriding principle is that information needs to be presented in a clear and digestible way. Greater attention is also needed to evidence about how visual representations including infographics are processed and understood by different reading audiences (Spiegelhalter, Pearson, & Short, 2011).

APPLICATION OF PRINCIPLES AND CONCEPTS BY THE REVIEW

The Review has examined the potential impacts and consequences of groundwater extraction for bottling purposes having regard to the statutory context in which water resources are allocated and managed and approaches of decision makers at regional and local levels to understand and manage risk and uncertainty.

In so doing, the Review has analysed the assumptions underpinning the relevant WSP, including the strategies deployed and level of conservatism applied to assumptions to manage uncertainty. The Review undertook further analyses and gave consideration to comparable and alternate approaches to managing uncertainty.

The Review was cognoscente of the complexity of the groundwater system, including potential groundwater and surface water interactions in confined and unconfined aquifers and implications this has for any extraction. The Review accepted the assumption that drawing groundwater from a bore will have some impact on the water balance, both spatially and temporally, and may have potential consequences for other water assets in the vicinity, including the environment and other groundwater users. These consequences can be related to changes in both water quantity and quality that may not emerge in the short term. At the same time, an effect on a system may be a measurable effect but may not have significant consequences or be of lesser significance relative to other factors at play.

Insofar as possible the Review has sought to provide pragmatic and feasible suggestions to improving knowledge and understanding. While not directly in its Terms of Reference, it has also made observations about communication and data arrangements as they relate to the management of water resources and transparency and confidence in decisions made.

ACRONYMS

Table 38: Acronyms

Acronym	Complete Term
ACT	Australian Capital Territory
ADR	Australian Design Rules
AIP	Aquifer Interference Policy
APCO	Australian Packaging Covenant Organisation
ATC	Automatic Tube Counts
AWD	Available water determination
AWRA-L	Australian Water Resource Assessment Landscape model
BLRs	Basic Landholder Rights
BOM	Bureau of Meteorology
CCA	Coca-Cola Amatil
DPE	Department of Planning and Environment (now DPIE)
DPI Water	Department of Primary Industries Water
DPIE	Department of Planning, Industry and Environment
EGS	Environmental goods and services
EPA	Environmental Protection Authority
ESD	Ecologically sustainable development
GAM	Generalized Additive Model
GDE's	Groundwater dependent ecosystems
GMP	Good Manufacturing Practice
HDPE	High density polyethylene
HVNL	Heavy Vehicle National Law
HVSS	Heavy Vehicle Safety Stations
KM	Kilometres
LEP	Local Environment Plan
LGA	Local Government Area
LTAAEL	Long Term Average Annual Extraction Limit
ML	Mega Litres
ML/y	Mega Litres per year
mm/yr	millimetres per year
MRFs	Materials Recycling Facilities
NAS	National Academy of Science
NRAR	Natural Resources Access Regulator (NRAR)
NRC	Natural Resources Commission
NSW	New South Wales
NTC	National Transport Commission
NWI	National Water Initiative

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OCSE	Office of the Chief Scientist & Engineer
PCT	Plant Community Type
PET	Polyethylene terephthalate
PEW	Planned Environmental Water
RCP	Road Contribution Plan
REA	Representative Elementary Area
REV	Representative Elementary Volume
RMS	Roads and Maritime Services
RRE	Recharge amount reserved for the environment
SEED	Sharing and Enabling Environmental Data
SI	Sustainability Index
SILO	Scientific Information for Land Owners
SSDs	State significant Developments
SSIs	State Significant Infrastructure
TAD	Total Available Drawdown
TOR	Terms of Reference
UEL	Upper Extraction Limit
UNSW	University of New South Wales
WAL	Water Access Licences
WSP	Water Sharing Plans

Report No. 4.3 **Condition 9. Additional Load at Byron STP**
Directorate: Infrastructure Services
Report Author: Dean Baulch, Principal Engineer, Systems Planning
File No: I2019/2155

Summary:

This report is for Council information and reviews compliance with the Byron Bay Sewerage Augmentation Scheme - Conditions of Approval (2002). Condition 9(iii) requires that sufficient reuse (recycled water) capacity be available before the acceptance of any additional load at the treatment plant.

In the years since the approval was granted (2002 to date), 2,408 Equivalent Tenements (ET) have been approved, resulting in an additional load of 1.42ML/day at the treatment plant. The current day operating capacity of the reuse system equates to 2.02ML/day or 3,427ET. Therefore the reuse system provides sufficient capacity to accommodate the additional load as defined in the Conditions of Approval

This report is a response to resolution 540 point 5, 6 and 19-598 point 2 and 3.

RECOMMENDATION:

That Council:-

1. **Note that compliance with Condition 9 of the Approval is satisfactory.**

2. **That staff investigate and recommend a modern day industry method for calculating Average Dry Weather Flow that can be applied consistently across all of Council's Sewage Treatment Plants.**

Attachments:

1 Byron Bay Sewerage Augmentation Scheme - Conditions of Approval, DM387682 , page 753⇩
2 ASSESSING THE DEMANDS & SUPPLY CAPACITY OF THE BYRON BAY URBAN RECYCLED WATER SCHEME - Planit Consulting 2018, E2019/93964 , page 763⇩

REPORT

19 - 540 **Resolved** that Council adopt the following Committee Recommendation(s):

Report No. 4.2 Byron Bay Integrated Management Reserve Update
File No: I2019/1588

Committee Recommendation

1. (…)

5. That listing for Byron Bay STP Catchment of sewage load resulting from Development Consents after 9 December 2002 (or similar) be brought to the next WWSAC.

6. That Council note that Byron Bay STP capacity was reassessed in recent years.

7. That Council note that when ADWF reaches 80% of plant capacity (assessed in 2002 as 6.95 ML/day) Condition 6 requires action by Council.

19 - 598 **Resolved** that Council adopt the following Committee and Management Recommendation(s):

Report No. 4.1 Byron Bay Integrated Management Reserve - Byron Bay STP Catchment
File No: I2019/1847

Committee Recommendation 4.1.1

1. That the Council note the report.

2. That a report on Byron Bay STP Catchment sewerage load resulting from Development consents after 9 December 2002 (or similar) be brought to the next meeting of WWSAC.

3. That the Conditions of Consent for the Byron Bay STP be included with the Report.

In 2002 the Byron Sewage Augmentation Scheme was approved. This scheme comprised of the upgrading of West Byron Sewage Treatment Plant (STP), decommissioning of South Byron STP, construction of a sewerage transfer pipeline between South Byron STP and West Byron STP, and upgrading of associated pumping stations.

Byron Sewerage Augmentation Scheme was put to a special meeting of Council, held at Council's chambers on 9 December 2002. The resolution (02–1329) of Byron Shire Council adopted the Conditions of Approval (see Attachment 1) for the Scheme.

The Waste and Water Sewage Advisory Committee recently requested information regarding Council's compliance with the consent conditions of the report. The Committee's request was specifically related to Condition 9 of the resolution. This report also expands into other related parts of the "Conditions of Consent".

The section from Condition 9 of the Approval that has raised the query is Condition 9(iii), which states, "Additional load at West Byron STP will not be accepted until: availability of sufficient reuse capacity to accommodate 100% of the volume of treated effluent generated by the additional load".

“Additional Load” is defined in the report as “any sewage load resulting from development consents after the date of this approval”. Date of Approval is 9 December 2002.

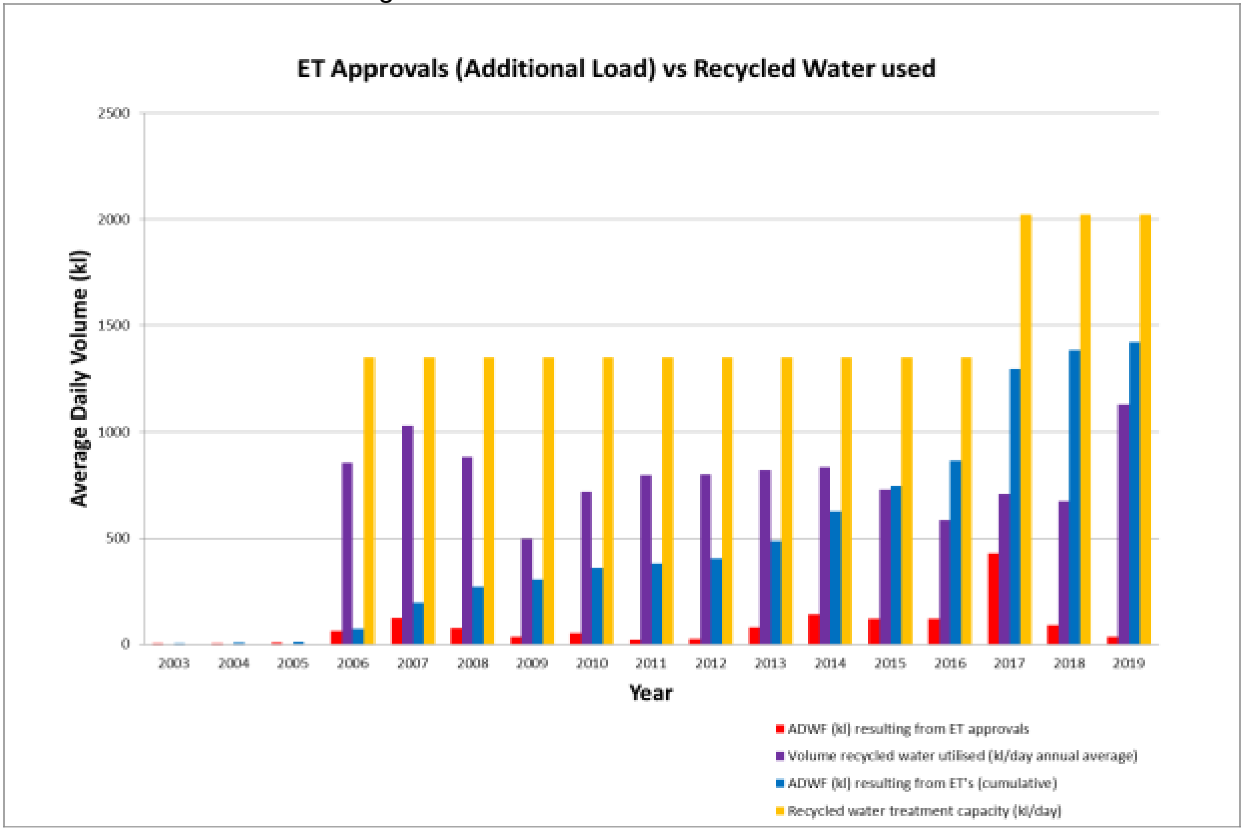
From December 2002 to the end of November 2019, 2,408 additional sewer Equivalent Tenements (ET) have been approved by Council through development consents.

The theoretical capacity of the effluent reuse system is 1.77 ML/d (3,000ET). This was modelled by Planit Consulting in 2018 (see Attachment 2). The current day operating capacity of the reuse system to produce treated effluent is 26 Litres per second or 2.25ML/day less 10% of water for filter backwash purposes equates to 2.02ML/day or 3,427ET. Therefore the reuse system provides sufficient capacity to accommodate the additional load as defined above.

As stated the current operational capacity of the effluent reuse system is 2.02ML/day (January 2020). This is planned to be increased to 2.77ML/day (4,695ET) in the current financial year by carrying out pipework modifications and upgrades at the plant.

Summary	**Current ET**	**Available Capacity (ET)**
Condition 9(iii) Additional Load Calculation	2,408	-
Theoretical effluent reuse system capacity 2018	3,000	592
Current effluent reuse system capacity 2020	3,427	1,019
Future effluent reuse system capacity >2021	4,695	2,287

It is important to note the difference between actual use of the reuse system and the capacity of the system. Actual use is dependent on environmental conditions – factoring in rainfall and drought. The number of users is the other large factor in taking up the reuse effluent volume - more customers obviously increases demand and consumption. The following graph shows the actual reused volume used against the additional load.

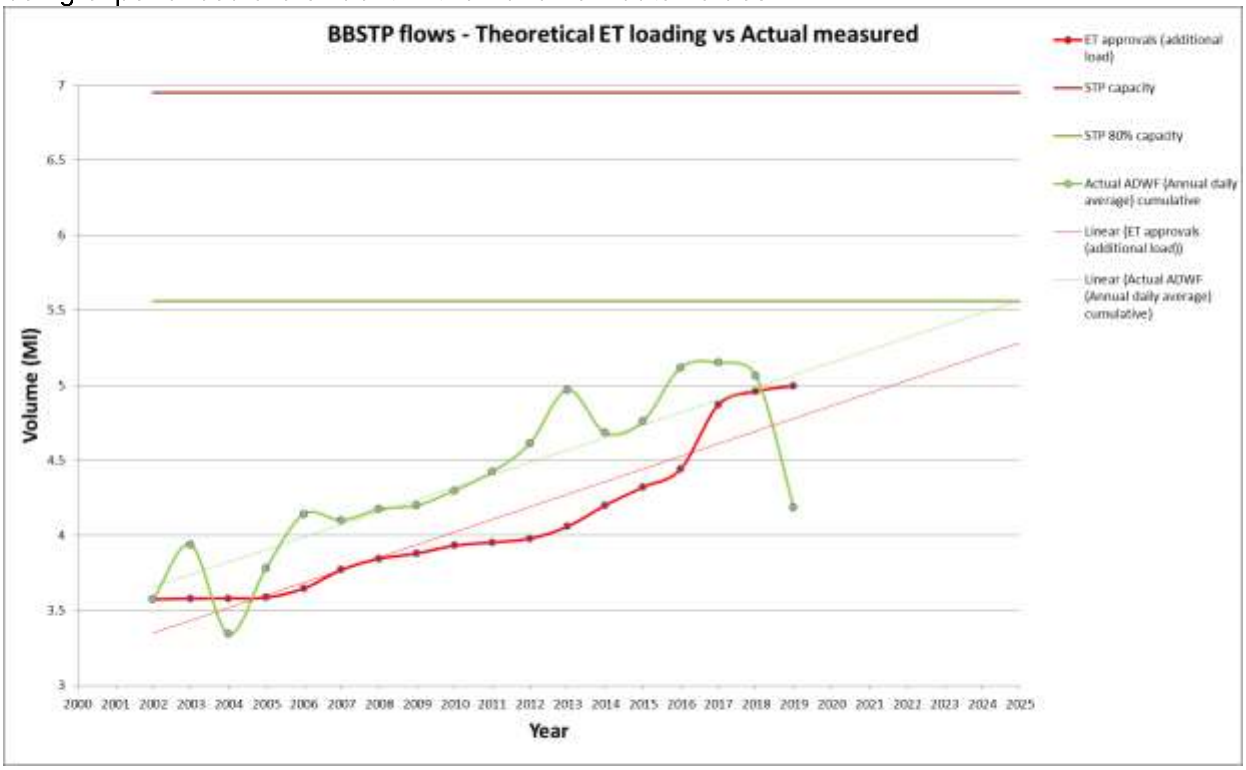


The current Byron Shire Recycled Water Management Strategy 2017 – 2027, adopted by Council, sets out the strategic direction for recycled water management in the Byron Shire. In order to meet the key direction targets of the Strategy as well as Condition 9(iii), various infrastructure projects are required to be constructed. Included in the Strategy is development of the rural and environmental scheme along the Western Corridor. Council is currently investigating the supply options to the Western and Southern Corridors. Potential customers identified to the west include “The Farm”, “Sea Peace”, Cape Nursery and several macadamia farmers. Along the Southern Corridor there are a number of macadamia farmers who have requested connection to the scheme. The supply to each customer will be assessed on its merits (cost/benefit analysis).

The first customer identified for connection to the scheme along the Western Corridor is “The Farm” due to the close proximity to existing infrastructure. This customer is expected to be connected early in the 2020/2021 financial year. The supply to the Western and Southern Corridors will meet the Strategy’s planned focus to be of beneficial use in rural and environmental applications.

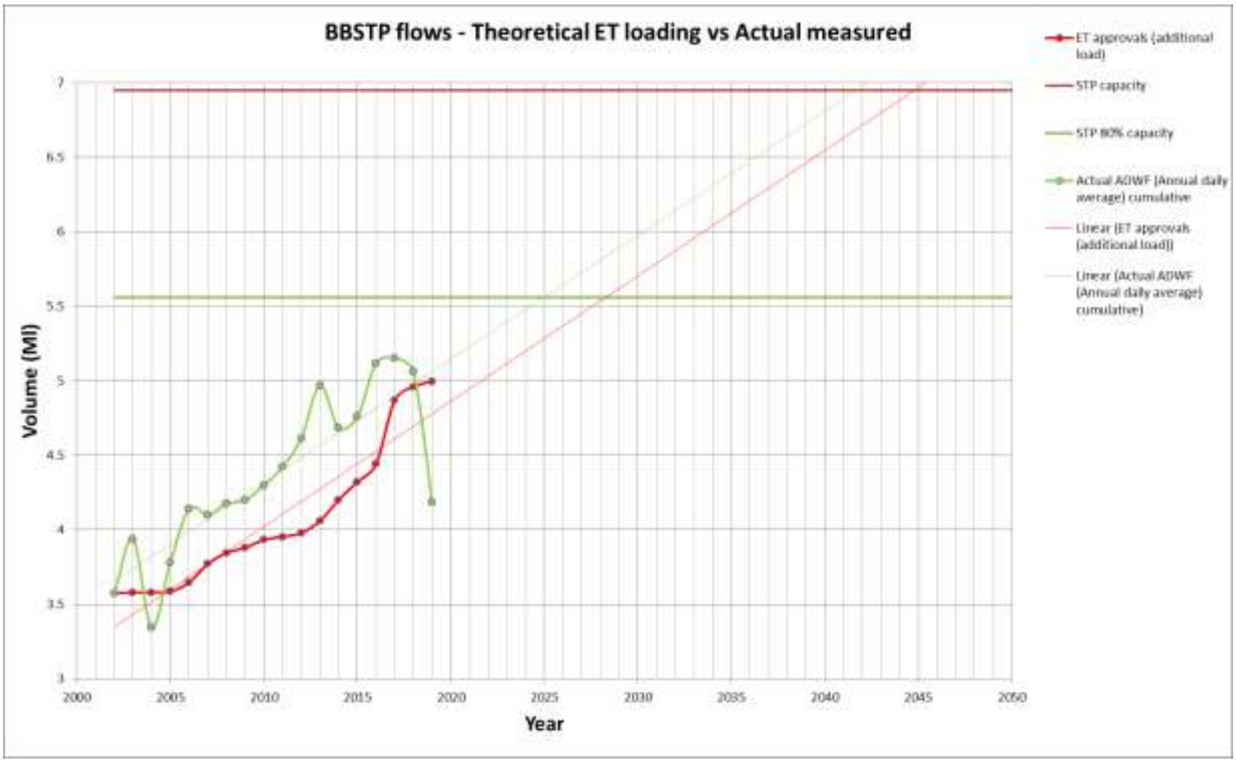
Condition 6 of the “Conditions of Approval” also states that when the ADWF reaches 80% of treatment capacity, investigations must commence to identify feasible strategies for the management of sewage flows above the capacity of the plant. Following the flow trends from 2002 to current (27 November 2019), the plants 80% capacity is expected to be reached in 2025. Council staff will continue to monitor the inflows into the plant and once 80% capacity is reached, will commence investigation of strategies for management of sewage flows.

The following graph shows the flow trend for the Byron STP. The data points above and below the linear trend are an indication of wetter or dryer than average years. The current drought conditions being experienced are evident in the 2019 flow data values.



The actual ADWF figures are an average of the full years flow totalised daily at the Byron STP. The top 20% and bottom 10% of data was removed from the calculations to exclude rainfall effect and recording anomalies from the figures used. The result is the annual ADWF. Within Byron Bay the ADWF varies according to the season. There is a summer peak in Dec/Jan and over Easter; a winter low and the "shoulder period" during the remaining time. This creates a range that is not reflected in the graph or data. The actual flow reflected is an average of the year’s data.

The data shows that the actual and derived (through ET calculations) ADWF trends over the past 15 years are tracking parallel to each other, indicating a level of certainty with the figures used. Based on the last 15 years of actual flow data, the Byron STP is expected to reach capacity in 2042.



The method stipulated in the “Conditions of Approval” states the definition for ADWF as “the average flow over a period of not less than five (5) consecutive days with no rainfall, with no more than 5mm of rain in the preceding ten (10) days”. Using this method, there is the potential to obtain skewed results due to the large flow variations over the three flow periods. ADWF in the winter can be as low as 60% of the summer peak. In order to ensure the actual annual average was calculated, the entire year’s data has been used.

On 22 March 2018 Council Resolution 18-193 adopted the Policy - Water and Sewer Equivalent Tenements 2018 that includes the Dry Weather Flow definition:

The average daily flow to the treatment works during seven consecutive days without rain (excluding a period which includes public holidays) following seven days during which the rainfall did not exceed 0.25 millimetres on any one day.

The above highlights that we have varying definitions for calculating ADWF and we now have an opportunity to update this calculation/condition in line with modern day industry methods that can also be applied consistently across all of Council’s treatment plants.

Byron Bay Sewerage Augmentation Scheme – Conditions of Approval

General

1. The proposal shall be carried out in accordance with:
   (i) the proposal contained in the EIS and SIS *Byron Bay Sewerage Augmentation Scheme* dated 30 August 2001 prepared for Byron Shire Council by Environmental Resources Management Australia Pty Ltd, subject to modifications to the proposal as described in the document *Byron Bay Sewerage Augmentation Representations Report* (the Representations Report) prepared for Byron Shire Council by Environmental Resources Management Australia Pty Ltd dated September 2002;
   (ii) all identified procedures, safeguards and mitigation measures identified in the EIS, SIS, and Representations Report;
   (iii) the conditions of concurrence imposed by the Director–General of the NPWS in the document *Concurrence Report for the Proposed Establishment of a 24 ha Melaleuca Regeneration Area, West Byron Sewage Treatment Plant* dated June 2002 prepared by NPWS Conservation Programs and Planning Division–Northern Directorate; and
   (iv) the conditions of approval imposed by Byron Shire Council.

In the event of any inconsistency between the conditions imposed by Council (these conditions) and recommendations contained in the EIS, SIS or Representations Report, these conditions shall prevail.

Notwithstanding the above, in the event of any inconsistency between the concurrence conditions imposed by the Director–General of the NPWS and these conditions, the recommendations in the EIS, SIS, or Representations Report, the concurrence conditions imposed by the Director–General of the NPWS shall prevail.

These conditions do not relieve Council of the obligation to obtain all other necessary approvals, licences or permits required under any other Act. Without affecting the generality of the foregoing, Council shall comply with the terms and conditions of such approvals, licences and permits.

Finalisation of draft Byron Bay Effluent Management Strategy

2. Council shall, as soon as practicable but no later than six (6) months from the date of this approval, finalise the draft *Byron Bay Effluent Management Strategy*. As part of finalisation of the draft strategy, Council shall:

- consult with the EPA, and take into account any comments it may have with regard to the implementation of the strategy; and
- include provision for the periodic review of the strategy, this period to be no greater than five (5) years.

Definitions

3. For the purposes of implementation of these approval conditions, the following definition of 'Average Dry Weather Flow' (ADWF) shall apply:

   'The average flow over a period of not less than five (5) consecutive days with no rainfall, with no more than 5 mm of rain in the preceding ten (10) days.'

   The efficacy of this definition shall be reviewed no later than 12 months from the date of commissioning of the West Byron STP augmentation and at 12 month intervals thereafter. The review shall include consultation with relevant stakeholders, including, but not limited to: DLWC, the Byron Bay Wastewater Steering Committee. If deemed appropriate, this definition may be amended, subject to a process including consultation with relevant stakeholders.

4. For the purposes of implementation of these approval conditions, the following definition of 'additional load' shall apply:

   'Additional load is any sewage load resulting from development consents after the date of this approval.

5. For the purposes of implementation of these approval conditions, the following definition of 'reuse project' shall apply:

   'An enterprise utilising treated effluent under a valid Environment Protection Licence where required, holding a valid contract with Council, and with all required infrastructure in place and operational.

West Byron STP Capacity

6. West Byron STP shall not accept flows for treatment in excess of 6.95 ML/day (ADWF). This is the plant's treatment capacity. Council shall continuously monitor the Average Dry Weather Flow entering the upgraded West Byron STP to assess the load on the plant in relation to the plant's treatment capacity. When 80% treatment capacity is reached, Council shall investigate feasible strategies for management of sewage flows above the capacity of the plant. In the event that load exceeds 100% treatment capacity, Council shall meet to discuss appropriate courses of action to prevent further exceedances.

7. The load which shall be received at West Byron STP at the time of commissioning of the upgraded plant shall be limited to the load from the West Byron catchment at that time.

8. The transfer of sewage flows from South Byron STP to West Byron STP catchment shall be conditional upon:

   (i) West Byron STP satisfactorily meeting all applicable performance requirements as per construction contract requirements and as specified in the plant's Environment Protection Licence and in this approval; and

   (ii) the availability of a reuse project(s) capable of accepting a minimum of 326 ML/yr of treated effluent as determined in the Effluent Management Strategy.

9. Additional load at West Byron STP will not be accepted until:

   (i) the transfer of 100% of the sewage flows from South Byron catchment;

   (ii) West Byron STP satisfactorily meeting all applicable performance requirements as specified in the plant's Environment Protection Licence and in this approval;

   (i) availability of sufficient reuse capacity to accommodate 100% of the volume of treated effluent generated by the additional load; and

   (iv) availability of treatment capacity as defined in Approval Condition 6 above.

Effluent Quality Standard for West Byron STP

10. Unless otherwise determined by the EPA, treated effluent produced by West Byron STP, as measured at the licensed STP outlet (unless otherwise indicated), shall meet the following quality standards:

Parameter	Abbrevi	Units	Standard

	ation		**(90^{th} percentile)**
Biochemical Oxygen Demand	BOD_5	mg/L	10
Suspended solids	SS	mg/L	15
Total Nitrogen	TN	mg/L	3 (50^{th} %ile)
Total Phosphorus	TP	mg/L	0.5 / 0.3[1]
Faecal Coliforms	FC	cfu/100 mL	200

[1] At the licensed STP outlet and wetland outlet respectively

The quality of treated effluent delivered to reuse sites shall be subject to separate determination.

Nutrient Load Limit for West Byron STP

11. Nutrient loads discharged to Belongil Creek, as measured at the outlet of the constructed wetland, shall not exceed 1,502 kg per year for Total Nitrogen and 300 kg per year for Total Phosphorus.

. Council shall continuously monitor nutrient loads discharged to the Belongil Creek. Determination of nutrient loads shall be based on a minimum of weekly sampling continuously averaged over a two month period, converted to an equivalent annual load.

In the event that the equivalent annual nutrient load for either Total Nitrogen or Total Phosphorus exceeds 80% of the applicable limits specified in this Approval Condition, Council shall investigate feasible management strategies to reduce loads below 80%.

In the event that the equivalent annual nutrient load for either Total Nitrogen or Total Phosphorus exceeds 100% of the applicable limits specified in this Approval Condition, Council shall meet to discuss appropriate courses of action to prevent further exceedances.

Byron Bay Wastewater Steering Committee

12. The Byron Bay Wastewater Steering Committee shall be consulted with respect to all matters relating to wastewater management (including reuse) for Byron Bay. Council shall review the need for the Byron Bay Wastewater Steering Committee upon commissioning of the West Byron STP and adoption of the Byron Bay Effluent Management Strategy.

Construction Environmental Management Plan

13. Prior to the commencement of construction works, Council shall prepare a Construction Environmental Management Plan (CEMP). The plan shall be prepared in consultation with the EPA, NPWS, DLWC, the Byron Bay Wastewater Steering Committee, and any other relevant party. The plan shall also be prepared in accordance with these conditions of approval, all relevant Acts and Regulations, and accepted environmental management best practice.

14. The CEMP shall address, but not be limited to, the following:

(i) specific environmental management objectives and strategies for the main environmental management elements and include, but not be limited to: water quality; noise and vibration; air quality/odours; erosion and sedimentation; access and traffic; property acquisition and/or adjustments; heritage and archaeology; groundwater; contamination; waste/resource management; flora and fauna; weed control; acid sulphate soils, hydrology and flooding; geotechnical issues; visual screening, landscaping and rehabilitation; hazards and risks; energy use, resource use and recycling; and utilities;

(ii) identification of the statutory and other obligations which Council is required to fulfil during project construction including all approvals and consultations/agreements required from authorities and other stakeholders, and key legislation and policies which control the Proponent's construction of the project;

(iii) definition of the role, responsibility, authority, accountability and reporting of personnel relevant to the EMP;

(iv) measures to avoid and/or control the occurrence of environmental impacts;

(v) measures (where practicable and cost effective) to provide positive environmental offsets to unavoidable environmental impacts;

(vi) environmental management procedures for all construction processes which are important for the quality of the environment in respect of permanent and/or temporary works;

(vii) monitoring, inspection, and test plans for activities and environmental qualities which are important to the environmental management of the project including performance criteria, specific tests, protocols (eg frequency and location) and procedures to follow;

(viii) steps Council intends to take to ensure that all plans and procedures are being complied with; and

(ix) consultation requirements with relevant government agencies.

15. The CEMP shall be made publicly available.

Community Notification

16. Throughout the construction phase, Council shall keep the local community informed of the progress of the project including any traffic disruptions and controls, construction of temporary detours, changes to local access and any work required outside normal construction hours.

17. At least one week prior to commencement of construction of the transfer pipeline, Council shall provide written information to affected residents of properties adjoining the pipeline route regarding the timing and duration of the works.

Contact Telephone Number and Complaints Register

18. Prior to the commencement of construction works, Council shall establish and publicly advertise a contact telephone number to operate for the duration of the construction period, to allow any member of the public to make a complaint or comment about the construction works. The contact telephone number shall be staffed during normal business hours. An initial response to any complaints received shall be provided within 2 (two) working days and, where required, a more detailed response within 10 (ten) working days.

19. Council shall establish a complaints register to record details of any complaints received.

Construction Contractor's Environmental Management Responsibilities

20. Construction tenders must include suitable documentation of accreditation in accordance with the Construction Policy Steering Committee's *Environmental Management Systems Guidelines*.

21. In the assessment of tenders for construction of the proposal, Council shall include as a key evaluation criterion, the tenderer's demonstrated commitment to environmental management and track record in this regard.

22. Council shall require that the successful contractor includes as part of its project team, an environmental adviser with appropriate qualifications in environmental management and/or environmental auditing. Council shall define the role of the environmental adviser in the contract documentation for the project and the role shall include undertaking regular environmental compliance audits, providing training in environmental issues for the contractor's personnel and overseeing implementation of contractor's environmental management responsibilities.

Construction Stage Environmental Audit

23. On at least one occasion, at a time approximately midway through the construction period, Council shall engage an appropriately qualified and experienced environmental auditor to conduct an audit of the construction activities with respect to compliance with these conditions of approval, the measures contained in the EIS and the requirements of any other licences or approvals. Where required, the audit shall include recommendations to address any identified non–compliances.

Construction Hours

24. All construction activities shall be undertaken between 7.00 am to 6.00 pm Monday to Friday, 8.00 am to 1.00 pm Saturdays with no work on Sundays or Public Holidays except for construction work which fulfils the following:
    (i) any works which do not cause noise emissions to be audible at any nearby residential property;
    (ii) the delivery of materials which is required outside these hours requested by the police or other authorities for safety reasons; or
    (iii) emergency work to avoid the loss of lives and/or property, and/or to prevent environmental harm.

Construction Noise

25. Council shall prepare a Noise Management Plan for inclusion in the CEMP which will identify practical and cost–effective noise abatement measures to be implemented with the objective of meeting the following construction noise level criteria:
    (i) for construction periods of four weeks or less, the L_{10} noise level, when measured over a period of not less than 15 minutes when the construction site is in operation, must not exceed the background level by more than 20 dB(A);
    (ii) for construction periods of greater than four weeks and not exceeding 26 weeks, the L_{10} level, measured over a period of not less than 15 minutes when the construction site is in operation, must not exceed the background level by more than 10 dB(A); and
    (iii) for construction periods greater than 26 weeks, the L_{10} level, measured over a period of not less than 15 minutes when the construction site is in operation, must not exceed the existing background noise level by more than 5 dB(A).

A value of 5 dB(A) shall be added to the sound pressure levels recorded from the construction activities if the noise is substantially tonal or impulsive in character.

Erosion and Sedimentation Control

26. As part of the CEMP, Council shall prepare a detailed Erosion and Sedimentation Control Plan which details principles and measures to be implemented during construction including the following:

    (i) installation of erosion and sediment control structures around stockpiles and downslope of excavation areas;

    (ii) minimisation of cleared areas; and

    (iii) ongoing revegetation of disturbed areas.

    The Plan shall be prepared in consultation with the EPA and DLWC

27. As part of the CEMP, Council shall develop, in consultation with the EPA, a water quality monitoring program and incident response procedure to detect and manage any incidences of pollution of waterways by effluent during construction.

Air Quality

28. During construction, Council shall implement dust suppression measures on unsealed roads and on spoil stockpiles to minimise dust generation.

Landscape and Rehabilitation

29. As part of the CEMP, Council shall prepare a landscape plan detailing landscaping and revegetation works to be undertaken at the West Byron STP site, the South Byron STP site and along the transfer pipeline route.

Traffic Management

30. As part of the CEMP, Council shall prepare a Traffic Management Plan detailing measures to be implemented to minimise disruption to traffic during the construction of the transfer pipeline. The Procedure shall include a protocol for notifying properties adjoining the pipeline route of the construction works. The Plan shall include, but not be limited to, consideration of the following management measures:

    (i) need for road closures and detours;

    (ii) temporary reduction of lane widths on Ewingsdale Road;

    (iii) reduced construction speed zone limit; and

    (iv) locations for safe parking of construction vehicles.

Indigenous Heritage

31. Council shall ensure that a qualified archaeologist is present during ground–disturbing construction works in Survey Units 2 and 4 and during initial planting works in Survey Unit 5. If any potential sites or artefacts of indigenous heritage significance are identified, work in the immediate area shall cease and the NPWS, Arakwal Aboriginal Corporation, and Byron Shire Council Aboriginal Consultative Committee consulted to determine the most appropriate course of action.

32. The Arakwal Aboriginal Corporation shall be invited to undertake monitoring during construction activities in areas of potential cultural heritage sensitivity.

33. As part of the induction and training program for personnel involved in the project construction, the requirements of the *National Parks and Wildlife Act 1974* in relation to indigenous heritage shall be addressed.

34. If any construction work is undertaken on land subject to a Native Title Claim, a process of consultation must be undertaken with the relevant claimant group.

Non-indigenous Heritage

35. During construction works, an exclusion zone of at least 10 m radius is to be established around the Byron Bay Railway Station and Stationmaster's Residence, and the Railway Water Tower. No construction work shall be undertaken within this exclusion zone.

36. Council shall consult with the NSW Heritage Office to develop a suitable research design to undertake an archaeological assessment of the pipeline route through the identified area. The assessment shall be undertaken prior to the commencement of construction and an excavation permit under the provisions of the *Heritage Act 1977* obtained if required.

Waste Management

37. As part of the CEMP, Council shall prepare a Waste Management Plan to address the management of wastes during construction works. The Plan shall identify requirements for waste avoidance, reduction, reuse and recycling. It shall also detail requirements for handling, stockpiling and disposal of wastes specifically spoil, contaminated soil or water, demolition material, cleared vegetation, oils, greases, lubricants, sanitary wastes, timber, glass, metal, etc. It shall also identify any site for final disposal of any material. Any waste material that is unable to be reused, reprocessed or recycled shall be disposed of to a landfill licensed by the EPA to receive that type of waste.

Commissioning of Upgraded West Byron STP

38. The construction EMP shall include specific risk management measures to minimise the likelihood of disruption to operation of West Byron STP during connection of new infrastructure.

39. The construction EMP shall also identify appropriate contingency measures for implementation in the event that problems are encountered with connection of the new infrastructure.

40. The EPA shall be consulted with respect to the development of the above mentioned risk management and contingency measures.

Operational Environmental Management Plan

41. Council shall formally adopt an Operational Environmental Management Plan (OEMP) for the upgraded West Byron STP no later than one month prior to the commissioning of the plant. The plan shall be prepared in consultation with the EPA, NPWS, DLWC, BBWSC, the Belongil Swamp Private Drainage Board and any other relevant stakeholder. The plan shall be prepared in accordance with these conditions of approval, all relevant Acts and Regulations and accepted environmental management best practice.

42. The OEMP shall address, but not be limited to, the following:

    (i) identification of the statutory and other obligations which Council is required to fulfil including all licences/approvals and consultations/agreements required from authorities and other stakeholders, and key legislation and policies which control Council's operation of West Byron STP;

(ii) ongoing consultation with all relevant stakeholders;

(iii) details of a monitoring program to be implemented including sampling strategies and protocols to ensure the quality of the monitoring program;

(iv) steps Council intends to take to ensure that all plans and procedures are being complied with;

(v) relevant provisions of the Belongil Estuary Management Plan; and

(vi) management strategies employed for: effluent reuse options; effluent management including monitoring at discharge points in terms of quality and quantity, groundwater levels; groundwater quality monitoring; biosolids disposal; noise; water quality; air quality (including dust and odours); health and public safety; landscaping and maintenance and issues relating to flora and fauna; security; waste/resource minimisation, management, removal and disposal; hydrology and flooding; hazards and risks, and emergency response plans; energy use and measures for minimisation.

43. The OEMP shall be made publicly available.

44. A suitably qualified and experienced consultant shall be engaged to provide advice on the inherent uncertainties associated with the results generated by the computer simulation model(s) used in the environmental assessment. Relevant information regarding this uncertainty shall be addressed in preparation of the operational EMP. The findings of the investigation shall be made publicly available.

Monitoring

45. As part of the OEMP, Council shall, in consultation with relevant stakeholders, prepare and implement a Monitoring and Impact Verification Plan (MIVP). The MIVP shall be prepared within three (3) months of commissioning of the augmented West Byron STP and shall address all applicable matters as identified in the EIS, SIS, NPWS Concurrence Report, Representations Report and any other relevant documents.

Monitoring activities which do not fall under a specific licence, permit or other form of approval shall be reviewed annually and amended as appropriate. The review process shall also include consultation with appropriate State government agencies and other relevant stakeholders.

The results of all monitoring and assessments of impact prediction accuracy shall be incorporated into the annual report detailing the performance of the sewerage system.

Decommissioning of South Byron STP

46. Subject to the satisfactory performance of the augmented West Byron STP in accordance with all applicable licence and approval conditions, the decommissioning of the South Byron STP site, as described in the EIS, shall be completed within twelve (12) months of the permanent transfer of South Byron STP sewage catchment flows to West Byron STP.

47. Council shall ensure the Environment Protection Licence for South Byron STP is retained until such time it has been adequately demonstrated that West Byron STP is operating in accordance with applicable performance requirements as specified in the West Byron STP Environment Protection Licence and in this approval.

Operation Stage Environmental Audit

48. Twelve (12) months following handover of the upgraded plant by the construction contractor, Council shall engage an appropriately qualified and experienced environmental auditor to conduct an audit of the plant's operation with respect to compliance with these conditions of approval, the measures contained in the EIS and the requirements of any other licences or approvals. Where required, the audit shall include recommendations to address any identified non–compliances. The findings of the audit shall be made publicly available.

Sewerage System Performance Reporting

49. Council shall prepare an annual report detailing the performance of the sewerage system with respect to all performance objectives specified in all applicable licences and approvals. For the second and subsequent years of operation of West Byron STP, the report shall include comparisons with preceding years. The report shall be made publicly available at no cost to interested parties.

Constructed Wetland Performance

50. Commissioning of the augmented West Byron STP shall be conditional upon completion of all required works associated with establishment of the constructed wetland at least 12 months prior to commissioning.

51. Prior to commissioning of the upgraded wetland, suitable criteria shall be developed to provide an objective measure of the success or otherwise of the upgraded wetland and its readiness for incorporation into the STP process train.

Water Quality

52. Prior to the commissioning of the project and as part of the OEMP, Council shall prepare, to the satisfaction of the EPA, a detailed operation stage Water Quality Monitoring Program which shall address, but not be limited to, the following:
    (i) water quality monitoring locations, including locations upstream and downstream of the wetland system;
    (ii) frequency of sampling;
    (iii) testing and verification protocols;
    (iv) reporting mechanisms; and
    (v) actions to be undertaken if non–compliance with specified water quality parameters is identified.

53. Notwithstanding item (v) in Approval Condition 52, in the event that the performance of the augmented West Byron STP does not meet the limits of the EPA Environment Protection Licence for three (3) consecutive months, Council shall suspend acceptance of any additional load until satisfactory resolution of the issues contributing to the non–compliances. Additional loads shall only be accepted following satisfactory compliance with the specified water quality parameters for a period of three (3) consecutive months from the date of resolution.

54. As part of the OEMP, Council shall, in consultation with the EPA, develop a monitoring and verification protocol to verify the predicted benefits to water quality in Tallow Creek as a result of the project.

Acid Sulphate Soils

55. As part of the OEMP, Council shall prepare an Acid Sulphate Soils (ASS) Management

Plan outlining measures to identify areas of ASS and management measures to be implemented. The Plan shall be prepared in accordance with the *Acid Sulfate Soils Manual* (ASSMAC, 1998) and any subsequent revisions.

Groundwater

56. As part of the OEMP, Council shall consult with the DLWC with regard to the most suitable locations for regional bores for the timely detection of off–site waterlogging. Council shall also consult with the DLWC regarding technical details for the configuration of additional groundwater monitoring bores.

Drainage Management Plan

57. As part of the OEMP, Council shall, in consultation with the Belongil Swamp Private Drainage Board, develop and implement a Drainage Management Plan which shall address, but not be limited to:
    (i) drainage charges;
    (ii) flow and water quality monitoring;
    (iii) access and drain maintenance; and
    (iv) erosion control.

58. Council shall enter into negotiations with the Belongil Swamp Private Drainage Board regarding contributing (financially and/or as otherwise agreed) toward the maintenance of the Board's drains used by Council for the conveyance of treated effluent to Belongil Creek. As far as practicable, negotiations shall be finalised prior to the commissioning of the augmented West Byron STP.

Flora and Fauna

59. Council shall investigate the specific habitat requirements of the Comb–crested Jacana (*Irediparra gallinacea*) with respect to the species' minimum water depth requirements and incorporate this into the operating strategy for Cell H. This investigation shall be completed prior to commissioning of the upgraded West Byron STP.

Odour Management

60. As part of the OEMP, Council shall prepare an Odour Complaint Response Procedure which outlines the actions to be undertaken, including monitoring, if a complaint is received in relation to odour levels in the vicinity of West Byron STP or the transfer pipeline.

Review/Reporting Periods

61. Unless otherwise stated, the timing of all annual reviews and reporting shall coincide with any similar review/reporting required under the plant's Environment Protection Licence.

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PLANIT

6 February 2018

Bryan Green
Byron Shire Council
PO Box 219
Mullumbimby NSW 248

Dear Bryan,

ASSESSING THE DEMANDS & SUPPLY CAPACITY OF THE BYRON BAY URBAN RECYCLED WATER SCHEME

At the request of Byron Shire Council (Council), Planit Engineering Pty Ltd (Planit) has assessed the demands and supply of the Byron Bay Urban Recycled Water Scheme (BBURWS). This report includes high-level baselines of the existing supply capacities for the recycled water treatment and the recycled distribution systems, respectively, as well as forecasted future demands and the resulting estimated future capacity requirements.

Planit has evaluated options to increase capacity of the recycled water treatment unit operations at the Byron Sewage Treatment Plant. This report also prioritises improvements with consideration for maximum plant throughput in-line with demands, and with due consideration to estimated capital cost and minimising potential disruptions to STP operations.

Please do not hesitate to contact the undersigned on (02) 6687 4666 or, alternatively, via email at johnh@planitengineering.com.au if you have further questions or require additional information.

Yours sincerely,

John Hart
Project Manager

QUEENSLAND | NEW SOUTH WALES | VICTORIA | NORTHERN TERRITORY

PROJECT MANAGEMENT | TOWN + ENVIRONMENTAL PLANNING | LANDSCAPE ARCHITECTURE | ENGINEERING

Table of Contents

1. INTRODUCTION AND BACKGROUND

The high rate of development in Byron Shire will place increased demand on Council infrastructure and, as this growth is expected to continue, considerations of future populations need be made when considering potential upgrades to that infrastructure. Along with residential and commercial growth in the region, an increase in the public's acceptance of recycled water applications is expected to increase demands on the treatment and supply infrastructure for this service.

Currently, Council processes an average of 890 kL/d of treated effluent from the Byron Sewage Treatment Plant (BSTP) for further treatment through chlorine disinfection and tertiary filtration, to produce Class A recycled water. The water is distributed to customers through the Byron Bay Urban Recycled Water Scheme (BBURWS). The current theoretical capacity of the recycled water treatment works is 1.77 ML/d. Given the forecast growth in the region, Council wishes to know:

- The present respective capacities of the various BBURWS treatment and distribution components.
- In order to maintain capacity for future recycled water demands, whether increases may be required in the respective capacities of the treatment works at the STP and distribution network.
- What these capacity increases may entail.

The ability to supply recycled water to the BBURWS is reliant on the capacity of the BSTP treatment, conveyance, disinfection, and tertiary treatment operations, the recycled water buffer tank, and the capacity of the distribution pipework and infrastructure. The capacity of the overall system is also affected by the variability in the peak instantaneous, peak daily and seasonal demands for recycled water, as well as the diurnal variation in the BSTP effluent that is available in the first place for tertiary treatment to supply the recycled water. Thus, one must consider the capacities of each system when evaluating the actual baseline and the future forecasts for recycled water supply and demand.

Below are details and the results from the investigation into the capacities of the BBURWS distribution system, the BSTP recycled water treatment operations, and options for potential upgrades to meet future demand forecasts.

2. HYDRAULIC MODELLING OF DEMAND AND DISTRIBUTION

2.1 HYDRAULIC MODEL

In order to understand the current and future recycled water demands in Byron Shire, and the ability of the current infrastructure to manage these demands into the future, it is necessary to consider the predicted growth of recycled water customers. For the purpose of this investigation, Byron Shire recycled water customers will be categorized as those receiving water from the following pipelines:

- DN250 PVC pipe from the STP into the Byron Bay town site and the Byron Bay Golf Course (BBGC).
- DN280 HDPE pipe connecting the hospital in the west of the STP.
- DN90 loop to Clarkes Beach (referred to as the "90 mm loop").

Refer to Appendix A for a plan showing the extent of the model, and to Appendix B for a table of the existing and future modelled demands.

Each of these distribution pipelines was modelled using EPANET software to determine its suitability for its respective forecast levels of recycled water demand, or whether infrastructure upgrades are required. EPANET is a hydraulic analysis package that simulates behaviour and performance of an urban recycled water network.

Modelling assumed that the four-plex recycled water supply pumps at the BSTP deliver a constant supply pressure of 50 m head that is maintained across the full demand range.

2.2 PEAK DAILY USE FIGURES

For the purpose of gauging the capacity of pipe delivery infrastructure, the figures used in modelling represent the peak daily consumption (on an annual basis) expected for each type of user and each property. The figures used are based on actual Council 2011 to 2017 BBURWS flow records.

To determine the capacity of the existing pipes, the hydraulic model is based on the forecast BBURWS peak flows; however, peak flows overestimate the existing and forecast maximum daily flows since peak flows may not necessarily occur simultaneously for all users. As such, the average daily rate may not always equate to the sum of all daily peaks. Planit made conservative estimates of the flow patterns for each user; this conservative approach is considered appropriate given that specific demand patterns can change and that current daily usage totals do not significantly affect the model output (except for the Golf Course flow that does significantly affect the model output).

2.3 TYPES OF END USERS

For the purpose of modelling the network, Planit has assigned the categories of "On Demand" and "Constant Flow" to each recycled water end user. The categories reflect the demand pattern for each user and are summarised as follows:

End User Classification	Demand Profile
Residential	On Demand
Golf Club	Constant Rate
Commercial Nursery	On Demand
Schools/Sporting Fields	On Demand
Toilet Blocks	On Demand

Table 1 - Customer Classifications and Demand Profiles

2.3.1 Residential Demands

The analysis of the recycled water demand for the West Byron Harvest Estate is based on:

- The Water Supply Code of Australia WSA03-2011, Water Services Association of Australia (WSA03-2011);
- The South East Queensland Residential End Use Study: Baseline Results -Winter 2010 - Cara Beal, Rodney Stewart, Tsu-Te (Andrew) Huang November 2010; and,
- Standards New South Wales Development Design Specification D11 Water Supply Version 3.0 based on AUS-SPEC-1 NSW-D11 as Amended May 2009 (NR D11).

NR D11 specifies total usage demand figures for a single supply network, but makes no allowance for a dual supply network, the relative contribution from the potable and non-potable supplies, or for diurnal demand curves. As such, Planit has sourced relevant data from the Water Supply Code Australia and the South East Queensland Residential End Use Study. A factor was then applied to this data to make it compatible with the NR D11 document.

The South East Queensland Residential End Use Study provides a 24-hourly Diurnal Pattern Analysis for the Gold Coast based on the average day and hour flow rates (on a per capita basis) for the residential detached households in the area. The proposed Harvest Estate is located in the region close to the NSW QLD border and was assumed to have similar climatic and social conditions to the Gold Coast. On this basis, the use of South East Queensland Residential End Use Study is considered appropriate.

NR D11 demand figures for a single supply drinking water network are contained in Clause D11.05 and apply to the total usage from a single supply network. These figures are shown below:

Design Criteria	Value
Peak Instantaneous Demand	0.15 L/s/ET
Minimum Pressure at the meter	20 m; 197 kPa
Maximum Pressure in the Network	79 m; 780 kPa
Demand per EP	850 L/day
EP per ET	3.2

Table 2 – NR D11 Design Criteria

2.3.2 Percentage of Recycled Water

The South East Queensland Residential End Use Study Diurnal Pattern includes Usage figures for irrigation, showers, clothes washers, toilets, taps, bathtubs, dishwashers and leaks.

Planit has assumed that recycled water will be used for irrigation, toilets and 50% of taps and leaks and that potable water will be used for the remainder. On this basis, the total water usage on an average day will be 35% recycled and 65% potable.

2.3.3 Diurnal Curves - Average Day

Planit has applied a factor to the South East Queensland Residential End Use Study Diurnal Pattern to match the requirements of NR D11.

2.3.4 Peak Instantaneous Flow

Planit has applied a peaking factor to the peak flow from the South East Queensland Residential End Use Study for the Gold Coast area to match the NR D11 Peak Instantaneous Demand of 0.15 L/s/ET.

The diurnal usage patterns used in the model are included in Appendix C

2.3.5 Byron Bay Golf Course

The Flow to the BBGC has been modelled as a constant rate of 8 L/s, per what Planit understands is the present BSC supply settings to that user.

2.3.6 Harvest Estate

Prospective development planned in the area known as the West Byron Urban Land Release Area includes the Harvest Estate, a potential ~300-lot residential development in its first phase, located approximately 2.5 km west of the Byron Bay town site.

Recycled water will be distributed throughout the development vial a dedicated recycled water network with service connections to each lot for external use. The lots in the Harvest Estate are intended to be developed over nine phases with a commencement date of 2018.

2.3.7 Commercial Nursery

We have assumed the commercial nurseries will use water at a constant rate over a four-hour period between the hours of 6:00 a.m. and 10:00 a.m. At the expected flow rates of 0.25 and 0.31 L/s, we consider this as an appropriately conservative method to calculate the peak demand.

2.3.8 Schools Sporting Grounds

We have assumed that irrigation will occur between 12:00 a.m. and 4:00 a.m. which is in line with recycled water use practices.

2.3.9 Toilet Blocks

We have based the estimated flow per cubicle on AS3500 Table 3.3 - Probable Simultaneous Demands per Loading Unit (LU). These values have been applied to Loading Units to calculate a flow rate per-water closet cistern, which will apply to both a WC cubicle and a urinal. Small flows, with unpredictable behaviour, are expected and we consider this as an appropriately conservative method to calculate the flow.

To include items such as cleaning, we have allowed 0.25 hoses for each WC as follows:

Per Cubicle - Typical Installation	No.	Loading unit (LU)	LU Total	Flow Rate (l/s)
Water closet cistern	1	2	2	0.10
Hose	0.25	8	2	0.04
Total			**4**	**0.14**

Table 3 - WC Demand Allocation

The Probable Simultaneous Demands for 4 LUs is 0.14 L/s. To allow for some uncertainty, we have allowed for a demand of 0.2 L/s to each cubicle/urinal (a safety factor of ~1.5). For Peak flow analysis, we have applied this calculation to the 5 units at each toilet block installation and assumed operation between 4:00 a.m. and 11:00 p.m. at outside Toilet Blocks, and between 6:00 a.m. to 11:00 p.m. for inside toilets. We have also included a base demand of 0.05 L/s for outside toilets outside of these hours.

For the purpose of modelling demands toilet blocks have been included at the following locations; refer to Appendix B:

Existing:

- Railway Park Exeloo
- Fish Heads Public Toilets

- Pool Toilets
- APEX park Exeloo
- Surf Club Urinals
- Clarks Beach Public Toilets
- Recreation Grounds
- Cavanbah Centre
- Byron Bay Bowling Club

Future:

- The Beach Hotel
- The Railway Hotel
- The Northern Hotel
- Toilets at Red Devils Park

We understand that there may be additional future demands from, for example, The Farm at Byron Bay, local farmers to the west of the STP, the hospital, other caravan parks and nurseries. However, it is premature to model these demands at this time given the lack of information regarding their demand flows and time-of-use profiles.

2.4 MODELLING DEMAND PATTERNS

2.4.1 Hydraulic Assumptions

The hydraulic model in this investigation utilised 2010 to 2017 recycled water demand figures supplied by Council, and applied these for predicting recycled water demands for a range of end-users during each year from 2017 until 2037, at which time the forecast full demand is assumed to be reached.

It was necessary for Planit to make reasonable assumptions for demand figures where BSC data sets were incomplete.

2.4.2 Users Modelled

Details of the names and types of end users and usage rates are shown in Appendix B.

2.4.3 Demand Types

As previously mentioned, Planit has based its analysis on customers either requiring their recycled water to be supplied "on-demand" at the required pressure and flow, or receiving it as a "constant flow" throughout the day. The demand pattern applied to each type of customer depends on how the customer is likely to use recycled water.

On Demand

End-users that do not have the capacity to provide their own storage will be supplied with recycled water on demand. These include the residents in the West Byron Harvest Estate, Byron Bay High School and the sporting fields and nurseries.

These customers will expect a constant flow rate and pressure at all times so the BURWS must be sized to suit all conditions from 'average days' to 'peak summer days,'. This is similar in manner to the way a potable water supply is designed to operate.

Although the BBHS, sporting fields and nurseries will require on-demand supply, depending on each user's circumstances, there may be scope to limit the time they receive supply in order to mitigate peak flow.

Constant Flow

Major irrigators with the ability to provide their own storage, such as the Golf Club, can be supplied at a constant flow rate. These customers provide their own storage sized to balance peak and seasonal demands. Typically, these users will enter into an agreement with BSC to receive water throughout the year at a constant rate.

2.5 BBURWS SUPPLY PUMPS

As per design information supplied by BSC, the BBURWS supply pumps at the BSTP are modelled as 50 m head constant flow.

2.6 HYDRAULIC MODELLING RESULTS AND COMMENTS

2.6.1 Results

Planit's modelling shows that the existing pipework of both systems has enough capacity to deliver the current and predicted future peak flows without suffering an unacceptable pressure loss in the system.

Under current and known future conditions, the modelled pressures at these limiting system nodes are shown in Table 4.

Parameter	Value	Comment
Total Forecast BBURWS Peak Flow	39 L/s	Peak flow with current users and Harvest Estate
Minimum Pressure sustained at the Byron Bay Golf Club	> 38 m at 20:00 hrs	Modelled pressure is OK
Minimum Pressure at Clarkes Beach	> 29 m at 20:00hrs	Modelled pressure is OK

Table 4 - Pressure at the Limiting Nodes - Peak Flow

2.6.2 Discussion

The largest peak demand occurs at the Harvest Estate. This is a site where users will expect constant pressure and flow so there is little opportunity to modify usage patterns to improve (decrease) the peak.

The connection to the Harvest Estate is at CH1850 on the DN250 pipe connected to the BBGC. The BBGC is located at the furthest end of the DN250 and, with the current arrangement, it receives water at a constant rate over 24 hours. Currently, the constant flow to the BBGC is modelled to persist during the Harvest Estate peak.

Despite demand at the toilet blocks occurring during peak demand time, the amount of water used is minimal in comparison to the BBGC and Harvest Estate, leading to a minimal impact forecasted on the system's modelled performance.

Demand at the commercial nurseries, schools and sorting grounds were modelled to occur outside the peak flow times and do not contribute to peak flow rates.

The DN280 pipe to the Hospital has no current demand.

2.6.3 Future Predicted Pressure at Peak Flow

Future BBURWS users that Council is contemplating for the near-term will not present a significant risk of a lack of instantaneous daily supply capacity.

Planit's modelling found that the following sections of the system are presently close to maximum capacity:

1. DN250 supplying Byron Bay CBD and the BBGC; and,
2. The 90 mm loop, at the Clarkes Beach demands.

Despite this, Planit's modelling shows that the existing pipework of both systems have enough capacity to deliver the current and predicted future flows without suffering an unacceptable pressure loss in the system. An additional 3.5 L/s could be delivered at peak times to the Clarkes Beach node through the 90 mm loop. With the current pipe, increasing the flow above 3.5 L/s could lead to an unacceptably low delivery pressure in the 90 mm loop to customers at the furthers reach of the loop, but the model suggests that the other customers on the 90 mm loop will not be affected.

These are indicative peak flow capacities for the most disadvantaged user in each section of the system. Generally, the most disadvantaged user is at the far end of the pipe, therefore, more capacity may be available to users located closer to the STP. The location and demand requirement of future potential users will need to be considered when assessing their impact on overall system performance.

In order to consider adding additional future customers, it will be necessary to first determine their annual and peak demands, diurnal usage patterns, location in the system and their expected timing to connect to the BBURWS.

2.7 HYDRAULIC MODELLING SUMMARY

Hourly peak flow modelling suggests a future user peak daily demand of 1.92 ML/d; refer to Appendix D.

The peak daily demand will be distributed through three main sections of the distribution network; therefore, Planit modelled the estimated instantaneous peak flow capacity (i.e., supply to users) for each of these sections; refer to Table 5, below.

Pipe	Current Peak Flow Capacity
DN280 HDPE – Connection to the Hospital in the west	40 L/s
DN250 PVC – Connection from BSTP through town site to the Byron Bay Golf Course	40 L/s
90 mm HDPE Byron Bay Loop (also forming a portion of the DN250 capacity)	10 L/s

Table 5 –Estimated Current Pipe Capacities

Table 6 below contains details of current and future demands in relation to each system capacity.

Process	Current Peak Flow Capacity	Current Estimated Peak Demand Flows	Restriction	Estimated Future Peak Demand Flows
DN280 HDPE to the west	40 L/s	0	Pipework flow capacity	TBD
DN250 PVC to Byron Bay and to the BBGC	40 L/s	22 L/s	Pipework flow capacity	39 L/s
DN90 HDPE Byron Bay Loop (forms a portion of the DN250 flow)	10 L/s	6.5 L/s	Pipework flow capacity	10 L/s
Recycled supply pumps at STP	50 L/s	N/A	Pump capacity (3 duty, 1 standby)	N/A

Table 6 - Present and Forecast Future Demands

With the full build-out of future users identified at this stage of work, the modelling of present and forecast future demands suggests that the forecast future peak instantaneous flows throughout the BBURWS could approach 49 L/s and 1.92 ML/L; this essentially equals the maximum supply capacity of the system of 50 L/s. Above this, the supply pressure may drop below an acceptable level for the reticulation system requirements.

Of importance, note the future peak flows in the DN280 have not been estimated at this time. If this line is to be tied into the BBURWS, then additional supply (pumping and storage) capacity at the BSTP would be required.
Utilising on-site buffer storage for some of the larger irrigation users would decrease the peak instantaneous flow demands, thereby reducing the system pressure drop at peak demand times and extending the peak instantaneous supply capacity of the system.

Furthermore, future demands in the Byron Bay town site should be added to the DN250 pipeline, when and as possible to reduce future demands on the 90 mm loop. Flow limiting fittings, timers, and pressure sustaining fittings may also prove useful to Council in maintaining reticulation pipe supply pressures.

3. BYRON STP UNIT OPERATION CAPACITIES

3.1 BASELINE OF THE EXISTING SYSTEMS

The above discussed modelling of current and future recycled water customers suggests a peak daily demand of 1.92 ML. In addition to understanding the demands of expected customers and the supply capacities of the distribution infrastructure, the capacity of the BSTP recycled plant to produce sufficient recycled water to meet this demand was considered. Planit has modelled key unit operations and transfer pipework at the BSTP in order to identify and prioritise possible upgrades to increase the existing baseline system output to meet future demands. We considered the flow-limiting capacities of the following recycled processes:

- Pipeline transferring UV channel effluent to the chlorine contact tank.
- Chlorine contact tank.
- Tertiary filter feed pumps in the chlorine contact tank.
- Tertiary filters.
- Recycled water buffer tank.

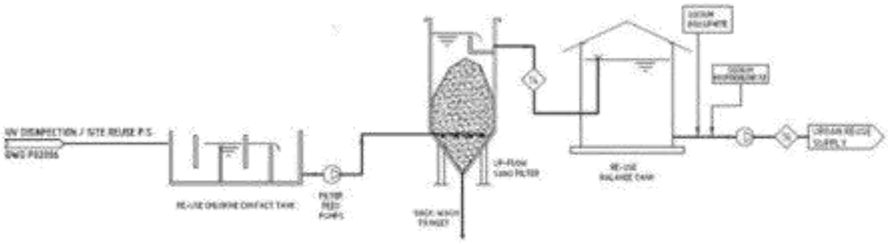


Figure 1: BSTP Recycled Water Treatment Operations*
Pre-twinning of the sand filters

3.1.1 System Modelling

Planit has modelled the unit operations of the STP from the UV tank to the recycled water buffer tank, over 24 one-hourly averaged periods using data sources listed in 3.1.2, to determine priority upgrades to enable an increased water recycled capacity in line with current and future demands. A recent sand filter upgrade included the installation of new duplex sand filter units which increased the potential tertiary filter system flow from 15.0 L/s to 30 L/s (net), subject to filter feed capacity from the duplex submersible pumps in the CCT, to supply from the UV channel and to STP diurnal flows.

Actual flow through the recycled water plant is, however, limited to 20.5 L/s due to the maximum theoretical flow through the pipeline connecting the outlet of the UV channel to the CCT. An estimated representation of the running volumes in the buffer tank under current and future upgrade conditions can be found in Appendix D.

Note that in the SCADA data supplied by SafeGroup reflecting STP operational flows prior to the current upgrades of the tertiary filter capacity, the tertiary filter flows de not generally reach the maximum flow of 15.0 L/s. This reduced flow is possibly due to tertiary filter feed pumps VSD settings, the duty cycle being linked to maintaining a set level in the buffer tank, and the STP diurnal flows

3.1.2 Data

For the purpose of modelling unit operations in the current STP operations and proposed upgrades, SafeGroup provided Planit with the 2011 to 2017 SCADA system data for the following flow meters:

- FIT08002: Inlet to UV channel.
- FIT10008: Tertiary filter feed.
- FIT08010: Inlet to wetlands.

Some segments of data are missing and/or show anomalies and, therefore, were ignored for the purpose of this investigation.

In addition to this SCADA data, some data from STP drawings, as well as the *West Byron Sewerage Treatment Plant Planning Report – Increase in Recycled Water Capacity* (Cardno, May 2011), were used in the preparation of this report.

3.1.3 Assumptions

- Analysis of provided data gives a reasonable representation of plant operation.
- As per data provided by SafeGroup there is sufficient influent supplied to the plant, at all hours, to ensure proposed maximum flows are not restricted by influent supply.
- Seasonal influent changes in the data provided are negligible for the purpose of this investigation.

3.1.4 Current System Baseline

As a baseline, the current theoretical maximum flow through the tertiary treatment unit operations is 20.5 L/s, with the limiting point being flow from the UV tank to the CCT via DN150 transfer pipe; refer to Table 6).

Unit Operation	Maximum Theoretical Flow (L/s)
UV tank flow to CCT	20.5
Chlorine contact tank throughput	29
Tertiary filter feed pumps throughput (2x duty, gross)	33.6
Tertiary filters (2x duty, net)	30

Table 7 – Current Theoretical Maximum Flows at Unit Operations

3.1.5 Influent Water Supply

From data supplied, it appeared that influent water supply to the STP, at a daily average of 88 L/s and an hourly low-flow average of 58.3 L/s from 4:00 a.m. to 5:00 a.m., was not a limiting factor affecting recycled water treatment throughput. In reality, Council learned at the end of this project that overnight diurnal flows to the UV channel from secondary clarifiers drop below 15.0 L/s, intermittently and for short durations. The effect of this limiting flow to the UV channel is that there is reduced recycled water available overnight for supplementing to the buffer tank, thus, reducing maximum available daily volumes for reuse.

3.2 FORECASTED DEMANDS AND CAPACITY REQUIREMENTS.

Each of the recycled plant processes and connections considered relevant in calculating the maximum possible recycled water production are evaluated below. Included are discussions of possible upgrades solutions to increase production and keep pace with the forecast future demands.

3.2.1 UV Tank Effluent Line to CCT

Currently, wastewater is transferred from the UV tank to CCT via DN150 pipeline, with a maximum theoretical flow of 20.5 L/s.

Options for increasing the maximum flow between these unit operations include the following, both subject to available head in the UV tank:

- Adding an additional DN150 pipe to increase flow to 41.0 L/s.
- Increasing the pipe size of the current line to DN200 to increase flow to 37.0 L/s.

Due to the increased earthworks, and a requirement for disruption to plant operation relating to replacing the existing line, adding an additional line to twin the existing one is considered the preferred option.

3.2.2 Chlorine Contact Tank

The maximum theoretical flow through the CCT is 29 L/s, restricted by the tank volume, the need for a minimum chlorine contact time of 30 minutes. It is possible to increase the maximum flow through this unit operation by expanding the tank to increase the hydraulic retention time, subject to additional capacity in the chlorine dosing equipment. This was not deemed a viable or priority upgrade and therefore was not reviewed at this stage.

3.2.3 Tertiary Filters

Upon completion of the planned install of a second tertiary sand filter, the maximum flow through the tertiary filter has increased from 15 L/s to 30 L/s, with 3.6 L/s of the 33.6 L/s maximum capacity of the tertiary filter feed pump being utilized for backwashing of the filter units. Currently the feed pumps to the tertiary filter units would be required to operate without standby in order to achieve maximum flows.

3.2.4 Recycled Water Buffer Tank

There are no known restrictions on influent flow to the recycled buffer tank, however, modelling was conducted to ensure the buffer capacity is sufficient in order to deal with variations in flows and recycled demands. Due to the fixed capacity of this tank, some future elevated demands (i.e., beyond present capacities) could be met by coordinating recycled water production and its demands/use, to ensure buffering capacity is best utilised. Using data compiled in the future recycled demand modelling the capacity of the recycled buffer tank was considered over an average 24-hour period and it was shown that using the current plant configuration that the buffer tank capacity would be exhausted, with recycled demand exceeding production capacity by 150 kL/d.

The buffering capacity of the recycled water buffer tank is considered sufficient for current and future modelled demands, however, an additional standby buffer tank should be considered for maintenance on the buffer tank and related infrastructure, and the secure operation of the BBURWS.

3.3 SUMMARY OF UPGRADE PRIORITIES

Modelling of current recycled water treatment unit operations, including current tertiary filter upgrades, suggests the maximum daily recycled water treatment production capacity is 1.77 ML/d. Considering forecast demands, including future tie-ins at the West Byron Harvest Estate, we forecast demands of 1.92 ML/d, which exceeds the present daily supply capacity of recycled water.

Beyond the additional tertiary filter installation, we recommend the following STP recycled water treatment unit operations upgrades, in this order of priority:

- Install additional transfer pipe connecting the UV tank to the CCT. After this addition, the recycled water production maximum flow is estimated at 29 L/s (2.5 ML/d), as restricted by chlorine contact time.
- Upgrade the filter feed pumps to duplex duty/standby capacity of 33.6 L/s, take advantage of the parallel duplex operational capacity of the tertiary sand filters capacity, of 33.6 L/s gross, and 30 L/s net recycled water production.
- Consider upgrades to the CCT by expanding the existing tank capacity or building new, assuming that filter and piping head losses would support this. However, this is not a high priority as it would only gain additional recycled capacity of 100 kL/d (2.6 MLD – 2.5 MLD). At that time, consider also re-routing the UV tank flow to the tertiary filters in advance of the chlorine disinfection to gain process efficiencies; however, this would be a larger upgrade.

Given the predicted growth of recycled water customers, only the upgrades concerned with the transfer pipeline from UV outlet to CCT inlet would be needed in the near future, given that this upgrade alone would produce an additional 830 kL/d of recycled water.

STP Process	Current Flow Capacity	Restriction	Phase 1 Estimated Flow Capacity	Requirement for Increased Flow	Probable Cost (O.O.M.)
150mm Pipeline (UV to CCT)	20.5 L/s	Theoretical pipe transfer and possible practical restrictions	41 L/s	Install additional capacity via, e.g., additional 150 mm transfer piping	$25,000
Chlorine Contact Tank (CCT)	29 L/s	30 min minimum contact time for chlorine	29 L/s	Expand or replace CCT to increase capacity.	TBD
Tertiary Filter Feed Pumps	33.6 L/s	Pump capacity (1 duty, 1 standby)	33.6 L/s	Consider full duty operation, or pump upgrades for greater duty/standby capacity	$75,000
Sand Filters	30 L/s	Maximum flow through sand filters with ~1.5 L/s (per filter) utilised as backwash	30 L/s	N/A	N/A
Buffer Tank	1 ML	Volume capacity	1 ML	Buffering capacity managed via time-of-use demand management	N/A

Table 8 - Customer Classifications and Demand Profiles

Note: The capacity of the recycled water buffer tank does not limit output during normal operations, however, upgrade of additional standby recycled water buffer tank should be considered for duty / standby operation during planned or unplanned maintenance.

4. SUMMARY

The forecast peak daily demand from future BBURWS users is up to 1.92 ML/d. The current BBURWS distribution infrastructure was modelled as being capable of the predicted future recycled water demands.

Although the distribution system is considered capable of delivering the expected future demands, the existing STP operations cannot supply the forecast future BBURWS peak daily demand of up to 1.92 ML/d; initial modelling suggests that the existing STP works can supply less than 1.77 ML/d treated effluent. In fact, after this report was completed, Council discovered that overnight flows from the BSTP secondary clarifiers to the UV units intermittently drop below 15 L/s. The overnight lower flows will decrease the ability to accumulate stored recycled water inventories in the buffer tank and is discussed further below.

Refer to the appendices for a database of demands/users, and for figures for modelled hourly average supplies and demands that would reflect this.

The most flow-limited systems are those at the Byron Bay Golf Course and the Clarkes Beach WCs; however, modelling at this time suggests these locations will have acceptable pressure during forecast future peak demands. We recommend installation of pressure monitoring at the Byron Bay Golf Course, and also the reading of the potable water meter at the Rec Grounds to measure the back-up flow (if any) that is provided to the BBURWS from the RPZ recently installed there, as a reflection of low supply pressure events in the BBURWS.

The potential BSTP upgrade with the highest payback and priority is to increase the flow capacity between the UV channel outlet to the inlet of the CCT. This is a relatively low-cost solution causing limited operational disruptions, and potentially yields an increase of ~600 kL/d or more of treated effluent. The upgrade of tertiary filter feed pumps to include a stand-by unit is recommended for duty standby operation. Additional upgrades, including expansion of the CCT, have not been prioritised at this point as they offer little payback in terms of added flow capacity.

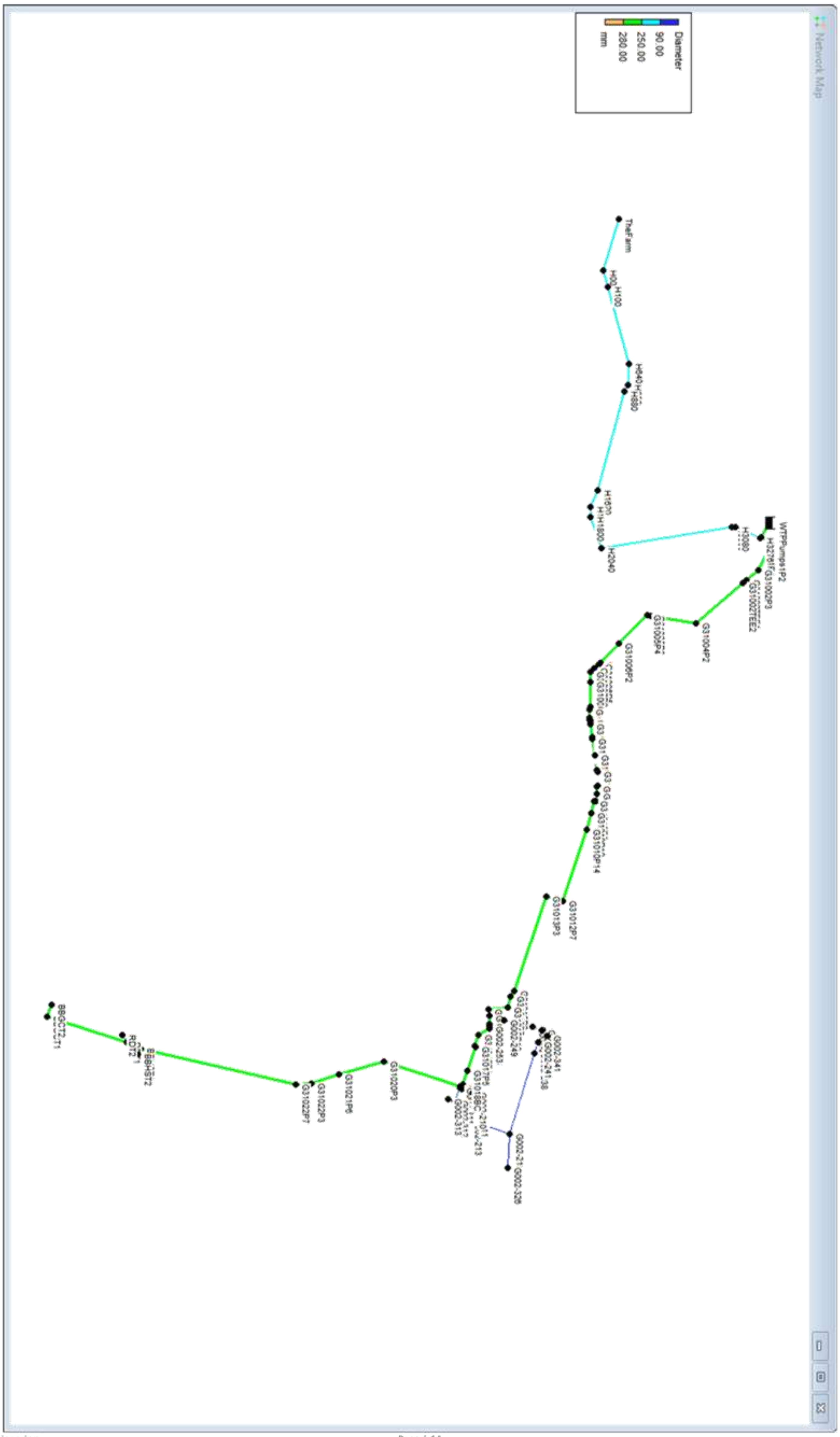
The current capacity of the recycled buffer tank is 1 ML and is considered to be sufficient for current demands. It is recommended, however, that a second recycled water buffer tank also be considered for the additional purpose of scheduled maintenance and unforeseen outages of the existing buffer tank, as part of future upgrades. Given the overnight flow reductions from the clarifiers discovered late in this project, additional buffer tank storage is further recommended in order to allow recycled water production and retention of inventories to meet forecast future peak flow demands.

The prioritised BSTP operations upgrades will increase recycled water production capacity, and it will be important to link time-of-day buffer tank volume to forecast peak instantaneous flows to meet user demands.

Future large irrigators will likely require on-site water storage in order to buffer the BBURWS distribution piping against high peak instantaneous flows. This would ensure reticulation system pressures are maintained. The sizing of these on-site buffering requirements would require additional modelling based on seasonal peak and daily use as well as site-specific variables for potential future users.

Expansions to the west will likely require upgrade to the supply pumping infrastructure, in addition to time-of-day use restrictions to large irrigation users.

APPENDIX A - EPANET MODEL



APPENDIX B - Users Modelled

BBURWS Connections		Peak Flow L/s	Pattern
A. Current Recycled Water Irrigation Sites			
1	Byron Herb Nursery	0.25	DayWatering
2	EnviTE Nursery	0.31	DayWatering
3	Cavanbah Centre	2.66	IrrigationNight
4	Byron Recreation Grounds	0.96	IrrigationNight
5	Byron Bay Bowling Club	0.42	IrrigationNight
6	Byron High School	1.17	IrrigationNight
7	Red Devils Park	0.71	IrrigationNight
8	Byron Bay Golf Course	10.19	BBGC
B. Toilet Connections			
1	Railway Park Exeloo	5	OTB
2	Fish Heads Public Toilets	5	ITB
3	Pool Toilets	5	OTB
4	APEX park Exeloo	5	OTB
5	Surf Club Urinals	5	OTB
6	Clarks Beach Public Toilets	5	OTB
7	Recreation Grounds	5	OTB
8	Cavanbah Centre	5	OTB
9	Byron Bay Bowling Club	5	ITB
C. Future Residential			
1	Harvest Estate	300	Lots
D. Future BBURWS Connections: (Toilet)			
1	The Beach Hotel		ITB
2	The Railway Hotel		ITB
3	The Northern Hotel		ITB
4	Toilets at Red Devils Park		OTB

APPENDIX C - RESIDENTIAL DIURNAL PATTERNS

Harvest Estate - Peak Flow

No. ET 300 ET

Time	Peak Hour (l/s/ET)	Ave Day (l/s/ET)
1:00	0.005	0.00
2:00	0.004	0.00
3:00	0.004	0.00
4:00	0.004	0.00
5:00	0.009	0.00
6:00	0.015	0.01
7:00	0.032	0.01
8:00	0.049	0.02
9:00	0.043	0.02
10:00	0.033	0.02
11:00	0.027	0.01
12:00	0.032	0.01
13:00	0.021	0.01
14:00	0.026	0.01
15:00	0.025	0.01
16:00	0.035	0.02
17:00	0.037	0.02
18:00	0.042	0.02
19:00	0.036	0.02
20:00	0.029	0.01
21:00	0.023	0.01
22:00	0.020	0.01
23:00	0.017	0.01
24:00	0.008	0.00

APPENDIX D - CURRENT RECYCLED

Current Recycled Supply of 1.77 ML/d With Modelled Future Demands of 1.92 ML/d

TIME	Reuse water supply (L/s)	Reuse Buffer Tank Volume (kL)	Modelled Reuse Demand (L/s)
12:00:00 AM	20.5	10.8	17.5
1:00:00 AM	20.5	21.6	17.5
2:00:00 AM	20.5	32.4	17.5
3:00:00 AM	20.5	43.2	17.5
4:00:00 AM	20.5	70.2	13
5:00:00 AM	20.5	72	20
6:00:00 AM	20.5	66.6	22
7:00:00 AM	20.5	57.6	23
8:00:00 AM	20.5	46.8	23.5
9:00:00 AM	20.5	39.6	22.5
10:00:00 AM	20.5	34.2	22
11:00:00 AM	20.5	28.8	22
12:00:00 PM	20.5	25.2	21.5
1:00:00 PM	20.5	19.8	22
2:00:00 PM	20.5	14.4	22
3:00:00 PM	20.5	9	22
4:00:00 PM	20.5	0	23
5:00:00 PM	20.5	-16.2	25
6:00:00 PM	20.5	-43.2	28
7:00:00 PM	20.5	-84.6	32
8:00:00 PM	20.5	-136.8	35
9:00:00 PM	20.5	-171	30
10:00:00 PM	20.5	-172.8	21
11:00:00 PM	20.5	-149.4	14

Priority Upgrade to Twin the DN150, With Constant Production of 29 L/s Recycled Water, Modelled Future Demands of 1.92 ML/d

TIME	Reuse water supply (L/s)	Reuse Buffer Tank Volume (kL)	Modelled Reuse Demand (L/s)
12:00:00 AM	29	41.4	17.5
1:00:00 AM	29	82.8	17.5
2:00:00 AM	29	124.2	17.5
3:00:00 AM	29	165.6	17.5
4:00:00 AM	29	223.2	13
5:00:00 AM	29	255.6	20
6:00:00 AM	29	280.8	22
7:00:00 AM	29	302.4	23
8:00:00 AM	29	322.2	23.5
9:00:00 AM	29	345.6	22.5
10:00:00 AM	29	370.8	22
11:00:00 AM	29	396	22
12:00:00 PM	29	423	21.5
1:00:00 PM	29	448.2	22
2:00:00 PM	29	473.4	22
3:00:00 PM	29	498.6	22
4:00:00 PM	29	520.2	23
5:00:00 PM	29	534.6	25
6:00:00 PM	29	538.2	28
7:00:00 PM	29	527.4	32
8:00:00 PM	29	505.8	35
9:00:00 PM	29	502.2	30
10:00:00 PM	29	531	21
11:00:00 PM	29	585	14

Report No. 4.4 **Byron Bay Integrated Water Management Reserve**
Directorate: Infrastructure Services
Report Author: Bryan Green, Water Sewer Systems Environment Officer
File No: I2020/53

Summary:
This report is in response to questions raised by the Waste and Water Sewage Advisory Committee, and subsequent recommendation 19-540 and 19-597 that a report be submitted to Council an update whether Byron Bay Wetland Cells are lined (or not), report on information provided by State authorities and Historical Society regarding the existence and whereabouts of the Sand Mine Drain in the vicinity of the Byron STP.

RECOMMENDATION:

That Council note the report

Attachments:

1 West Byron Sewerage Treatment Plant Wetlands - Cell J Infiltration Trial.tr5, DM515792 , page 789⇩

REPORT

The following questions were required to be answered from Council Resolution 19-540. These questions address Council Resolution 19-597:

.

19 - 540 **Resolved** that Council adopt the following Committee Recommendation(s):

Report No. 4.2 Byron Bay Integrated Management Reserve Update
File No: I2019/1588

Committee Recommendation

1. That Council note the report

2. That Council acknowledge that Wetland cells at Byron Bay STP are lined as follows:

    a) Cells D, E, and I are lined;
    b) Cell H behaves as if its lined; and
    c) F and G are not lined

3. That Council contact relevant state authorities and Byron Bay Historical Society to search their archive for reports on the Sand mining activities around Byron Bay and Suffolk Park and especially near Byron Bay STP

4. When this information has been assembled, Council consider a site visit for committee members.

5. That listing for Byron Bay STP Catchment of sewage load resulting from Development Consents after 9 December 2002 (or similar) be brought to the next WWSAC.

6. That Council note that Byron Bay STP capacity was reassessed in recent years.

7. That Council note that when ADWF reaches 80% of plant capacity (assessed in 2002 as 6.95 ML/day) Condition 6 requires action by Council.

19 - 597 **Resolved** that Council adopt the following Committee Recommendation(s):

Report No. 14.3 Report of the Water, Waste and Sewer Advisory Committee Meeting held on 14 November 2019
File No: I2019/1588

Committee Recommendation

1. That Council note the minutes of the Water, Waste and Sewer Advisory Committee Meeting held on 14 November 2019.

2. That Council adopt the previous minutes and that the item be put in the next Agenda clarifying the sentence at 4.2 about the behaviour of Wetlands cells H and J.

Res 19-540 point 1: *That Council note the report*

Noted – no action required.

Res 19-540 point 2: *That Council acknowledge that Wetland cells at Byron Bay STP are lined as follows:*

a) Cells D, E, and I are lined;
b) Cell H behaves as if its lined; and
c) F and G are not lined

And **Res 19-597 point 2:** *(…) the item be put in the next Agenda clarifying the sentence at 4.2 about the behaviour of Wetlands cells H and J.*

Staff Response: According to the Byron Wetlands Construction Site Engineer, during the 2004-05 construction period:

- Cells E, I and J are lined with a clay liner; unfortunately no works-as-executed records are available for this work.
- These cells were excavated down to indurated sand, bund walls raised from the indurated sand, sealed with clay lining.
- Due to budget constraints, Cell D was lined with mixture of compacted imported fill.
- Research conducted shows Cell H could not be identified whether the Cell is lined or has not been lined. However, it must be noted that during the 10 years of observation Cell H has shown characteristics and behaviours that the cell has been lined with organic materials. This suggests evaporation appears to be the only mechanism evident thereby limiting impact to groundwater, levels and quality. .

Cell G and F were existing cells with community committees nominating retaining these cells as habitat / treatment cells.

No records to date have been found to identify if these two cells were lined or not.

The Site Engineer's reporting may be in disagreement with other sources to claim the wetland cells are not lined; however, this could be attributed to a difference in terminology and understandings of what lining technique of lining was used.

According to the report West Byron Sewerage Treatment Plant Wetlands – Cell J Infiltration Trial (DM515792), Cell J showed evidence of leakage and percolation of up to 2 mm/day. However, evidence from other similar ecosystems showed that over a number of years benthic material such as suspended solids, detritus and other materials sealed of wetlands, thereby creating a natural liner. To further support this theory, during Council's operational maintenance of the Cells, the lengthy drying times suggest that evaporation is the only mechanism at play.

Res 19-540 point 3:

That Council contact relevant State authorities and Byron Bay Historical Society to search their archive for reports on the Sand mining activities around Byron Bay and Suffolk Park and especially near Byron Bay STP.

Staff Response: The response from NSW Minerals Council, which is the leading industry association representing the state's minerals industry (http://www.nswmining.com.au/) claimed they have no knowledge of a sand mine drain in the area and Council contact Norm Graham, NPWS. Council Staff has submitted this report to the committee at previous meetings.

Further, Council is waiting on a response from the Historical Society.

The documents tabled include:

- The EIS surface and groundwater conceptual and numerical models of the Byron Bay STP area and surroundings.

- Specific studies of proposals for remediation of the Sand Mine Drain upstream from the Byron Bay STP area.
- A geology and geomorphology Study combine with a historical study of the mineral sand mining activities in the Byron Bay area.
- The 2009 Belongil Creek Flood Study.
- The 2015 Belongil Creek Floodplain Risk Management Study and Plan.
- Technical Memorandum - Sandmining drain/track status and impact on Belongil catchment

The table below shows information recently collated in relation to the Sand Mine Drain.

Document Location	**Date**	**Document title**	**Author**	**Relevant information**
E2020/3308	2001-05-01	West Byron Bay Sewerage Treatment Plant - Effluent Management Study, Phase 2	PPK Environment & Infrastructure Pty Ltd. A Parsons Brinckerhoff Company	Surface and Ground Water information of the BBSTP The 2001 EIS information was based on this report
E2016/73776	2001-08-30	Byron Bay Sewerage Augmentation Scheme - Environmental Impact Statement for NSW Department of Land and Water Conservation and Byron Shire Council - Volume Two	Environmental Resources Management Australia Pty.	Subchapter 9.2.2 Drainage Network - Belongil Catchment
E2016/73776	2001-08-30	Byron Bay Sewerage Augmentation Scheme - Environmental Impact Statement for NSW Department of Land and Water Conservation and Byron Shire Council - Volume Two	Environmental Resources Management Australia Pty.	Groundwater boreholes in relevant areas for this investigation, Groundwater model, impacts and conclusions
E2020/3310	2003-10-09	Proposal to Reduce Groundwater		Complete study of the drain, including Remediation Options, etc

		Flow from the Sandmine Drain near Byron Bay		
E2020/3298	2004-05-03	The Geology and Geomorphology of The Cape Byron Headland Reserve and The History of Mineral Sand Mining in the Byron Bay Area	Cape Byron Headland Reserve / Southern Cross University	Information of the area and the mining activity related including historical documentation
E2020/3299	2006-03-01	Tyagarah Drain Remediation Trial Project - Concept Design - Draft	Prepared by David Pont (Southern Cross University) for the NSW Department of Environment and Conservation (NPWS) and Byron Shire Council as a community service	Complete study of the drain, including Remediation Options, Ecology, Hydrology, Hydraulics, etc.
E2018/22152	2009-11-12	Belongil Creek Flood Study	SMEC AUSTRALIA PTY LTD	The Belongil Creek Flood Study constitutes the first stage of the management process for the Belongil Creek catchment. It has been prepared for Byron Shire Council by SMEC Australia Pty Ltd to define flood behaviour under current conditions. The study has been completed in accordance with the NSW Floodplain Development Manual, 2005.
E2015/16795	2015-03-01	Belongil Creek Floodplain Risk Management Study and Plan	BMT WBM Pty Ltd	This Floodplain Risk Management Study (FRMS) draws together a wide range of floodplain management options which have been investigated and is the result of a detailed investigation and consideration of flood risk across the study area.
E2019/3138	2018-11-13	Technical Memorandum - Sandmining drain/track status and impact on Belongil	Australian Wetlands Consulting Pty Ltd	Assessment of the disused sandmining track/drain system that runs north from the West Byron Sewage Treatment Plant (WBSTP). The aim of the assessment is to provide a report on the

		catchment		current status of the track/drain and its impact on the Belongil Creek catchment.

There is no evidence in any of the above-noted reports of any historical sand mine drains in the vicinity of the Byron Bay STP or wetlands.

Further to Question 2, above, BSC staff found no evidence in any of these documents regarding any impact from the Byron Bay STP or wetlands to the Industrial Estate or Belongil Catchment due to a sand mining drain intersecting operational lands. Regardless, if segments of any historical drains from sand mining still exist, it is highly improbable that are still directly hydraulically connected to the Belongil Catchment because of the soil compaction from railway ballast, Ewingsdale Road and the Industrial Estates compacted buildings foundations and compacted road bases.

Council has no evidence from water quality monitoring that there is uncontrolled short-circuiting of nutrients from the Byron Bay STP to the Belongil Catchment.

Res 19-540 point 4:

When this information has been assembled, Council consider a site visit for committee members.

Staff Response: Recommended when information from Byron Bay Historical Society has been received.

Res 19-540 point 4:

That listing for Byron Bay STP Catchment of sewage load resulting from Development Consents after 9 December 2002 (or similar) be brought to the next WWSAC

Staff Response: See report I2019/2155

Res 19-540 point 5:

That Council note that Byron Bay STP capacity was reassessed in recent years

Staff Response: Noted

Res 19-540 point 6:

That Council note that when ADWF reaches 80% of plant capacity (assessed in 2002 as 6.95 ML/day) Condition 6 requires action by Council.

Staff Response: Noted, See report I2019/2155 on this agenda.

West Byron Sewage Treatment Plant Wetlands

Cell J Infiltration Trial

8th March 2005 to 6th April 2005

Michael Bingham and John Murtagh

Background:

West Byron Sewage Treatment Pant Wetlands are a composite of five complete, constructed effluent polishing wetland cells (cells E, F, G, I, J) one incomplete (D) and another utilised as wildlife habitat (H).

Cell E (2.07ha) was completed including planting with five varieties of wetland macrophytes (reeds) December 23 2005. Cells F (2.14ha) and G (1.96ha) are planted primarily with melaleucas and are bisected by what is known as the ‘central channel’, they have been in use since the early nineties. Cell I (3.77ha) encloses the ‘typha’ paddock that developed when effluent discharged from the old wetlands and wetted this area over the years.

Cell J (3.51ha), the subject of this trial, was completed in April 2004 and is planted out with six varieties of wetland macrophytes.

Cell J description:

Cell J is 3.51ha in area; it is surrounded by berms constructed with clay cores on the all sides excluding the inflow (northern) side. Cell J has a sloping bed of 1:1000; this means that the base at the outflow (southern end) is 300mm lower than the inflow end.

The cell base was covered with a variable 300mm layer of blended topsoil medium for the macrophytes to grow in. This topsoil was a blend of 50%sand, 40% organic material (sludge, soil and composted plant matter) and clay (10%).

Cell J is filled utilising a ‘bubbler’ pipe system and outfall is controlled using six adjustable ‘flood gate’ structures, another floodgate connects cell I and J towards the southern end of the common berm. The invert of the outfall structures is 3.29m AHD. The base is higher, along most of its length, than the base of cell I. Cell I was mostly dry throughout the trial and no seepage was evident from cell J into cell I along the common berm.

At the commencement of the trial Cell J had approximately 90-95% vegetation cover comprising of the six wetland macrophyte species and a variety of terrestrial weed species. (Macrophyte planting numbers, layout and species list are available if required).

Purpose:

Since none of the wetland cells have been lined with impervious material the infiltration trial was conducted to quantify water losses through evapotranspiration and percolation. The results and conclusions should provide useful information in discerning the wetlands water budget and may also provide some confidence to government agencies such as DIPNR regarding impacts on water tables.

Method:

Cell J was ‘filled’ until water covered the top end of cell J at a depth of approximately 200mm; this meant that water depth at the outfall (southern) end of cell J was approximately 500mm. The cell was left for 4 days to allow water levels to equalize since the macrophytes provide some hydraulic resistance to the spread of water and could influence depth readings if measurements commenced immediately after flooding.

The cell was locked down to prevent accidental flows into the cell and measuring devices installed.

The measuring devices were composed of two 30 cm plastic rulers attached to two outfall structures. The rulers were set at the 20cm mark against permanent marks made on the outfall structures in the case that they may become dislodged they could be reset. Measurements to the nearest millimetre were taken daily. The time and measurement along with rainfall data were entered onto a spreadsheet along with any erroneous observations. Measurements were then converted to AHD.

Some on-site weather information was obtained from a local weather station. Unfortunately the station was offline for part of the trial; it was reinstalled after servicing on the 11th of March. David Bonner provided the data collected since then. Evaporation was also estimated from the pan evaporation recordings at Alstonville weather station.

A water quality sample was taken from the cell before discharge of the waters on Wednesday the 6th April.

Erroneous observations:

- After flooding the cell a wet spot developed along the eastern side of cell J, indicating some losses along this side these losses were considered minimal and could not be measured.
- A minor dribble was evident in the collection drain along the southern end this stopped after 7 days. These losses were also considered to be of irrelevant volumes.
- The trial was also utilised to control some of the terrestrial weeds. Considerable ‘browning off’ of terrestrial weeds such as paspalum was observed as the trial progressed.

Results:

Daily measurements of cell evaporation and the corresponding pan evaporation at Alstonville are given in the Appendix. Over several weekends, when the reading was a composite of several days, the mean daily evaporation and the corresponding mean pan evaporation were used in the analysis.

Because the cell evaporation measurements were taken at different times each day, individual recorded values spanned 19-31 hours. This introduced an error when the observed evaporation was treated as a daily rate but no attempt was made to adjust the rates because the errors were self correcting with an over-reading on one day being followed by an under-estimate on the next. Such errors increased the scatter around the trend line that was used in the analysis but did not have an important effect on the parameters of the line.

Figure 1 shows the scatter plot between pan evaporation at Alstonville and cell evaporation.

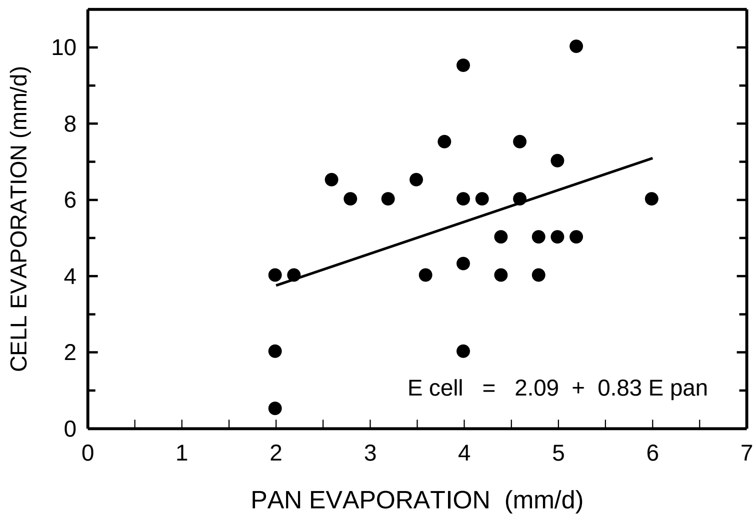


Figure 1 The relation between pan evaporation at Alstonville and cell evaporation.

The trend line had a slope of 0.83 and an intercept of 2.09 mm/d.

The slope represented the net effect of three factors:

1. The pan coefficient which adjusted for differences between pan and reference evapotranspiration, and would equal 0.8 for the exposure conditions at Alstonville;
2. The crop coefficient that adjusted for differences between reference and plant evapotranspiration. Published coefficients for wetland species (FAO 1998) vary during the year, rising to a mid-growing season value of 1.2 for a reed swamp in standing water, cattails and bulrushes.
3. Differences in evaporation rates between Alstonville and Byron Bay. Measurements of evapotranspiration (Penman-Monteith calculation) at Byron Bay during July 2002 to December 2003 averaged 153% of the pan evaporation at Alstonville (David Bonner pers comm.). The difference was even larger when the pan readings were adjusted to reference evapotranspiration to correspond to the Penman-Monteith calculation. The difference between the two localities is much larger than would be expected and should be confirmed before it is used to adjust Alstonville readings to Byron Bay equivalents. Until that is done, the reference evaporation rates at the two localities were assumed to be the same for the current investigation.

With a pan coefficient of 0.8 and an Alstonville/Byron Bay adjustment of 1.0, the slope of 0.83 translates to a crop coefficient of 1.04. That was accepted as a reasonable late-season coefficient for the wetland species, but also note the following discussion on seasonal effects.

The intercept of 2.09 mm/d was taken as an estimate of the mean percolation rate from the cell.

Extrapolation of results to other months

Several factors could change the cell evaporation in other months:

- Based on published coefficients, the crop coefficients could fall as low as 0.6 in the coldest months, and rise to 1.2 in the warmest. These changes would alter the slope of the trend line;
- The rate of percolation would vary with the hydraulic head between the water level in the cell and the height of the surrounding watertable.

Because of these effects, the estimates of cell water use could be improved by repeating the current experiment during mid-winter, and again during mid-summer.

Conclusions:

Using the current results and the mean pan evaporation at Alstonville, and ignoring any monthly differences in the crop coefficient and rate of percolation, the estimated monthly rate of water removal is given in Table 1.

Table 1 The estimated evapotranspiration and percolation from cell J using the parameters from the trend line in Figure 1, and ignoring the possibility of monthly changes in the crop coefficient and rate of percolation.

Month	Evapo-transpiration (mm/d)	Percolation (mm/d)	Total (mm/d)	Total (ML/mth)
January	4.81	2.09	6.90	7.5
February	4.15	2.09	6.24	6.1
March	3.57	2.09	5.66	6.2
April	2.74	2.09	4.83	5.1
May	2.24	2.09	4.33	4.7
June	2.08	2.09	4.17	4.4
July	2.24	2.09	4.33	4.7
August	2.91	2.09	5.00	5.4
September	3.82	2.09	5.91	6.2
October	4.23	2.09	6.32	6.9
November	4.57	2.09	6.66	7.0
December	5.06	2.09	7.15	7.8
Mean	3.41	2.09	5.50	72.0 /yr

Note:
The trial can easily be repeated whenever any of the mature cells are flooded for weed management.

APPENDIX - DAILY RESULTS

Recording date	Water removed (mm/d)	Alstonville pan evaporation (mm/d)
9/3/05	5	4.8
10/3/05	10	5.2
11/3/05	4	4.8
14/3/05	4.3	4.0
15/3/05	7.5	3.8
16/3/05	7.5	4.6
17/3/05	2.0	4.0
18/3/05	4.0	2.2
20/3/05	6.5	5.4
21/3/05	6.0	6.0
22/3/05	6.0	3.2
23/3/05	6.0	4.6
24/3/05	5.0	5.2
25/3/05	5.0	5.0
26/3/05	5.0	4.4
27/3/05	6.0	2.8
28/3/05	6.0	4.2
29/3/05	6.0	4.0
30/3/05	6.5	2.6
31/3/05	0.5	2.0
1/4/05	2.0	4.8
2/4/05	3.6	6.5
3/4/05	4.4	6.9
4/4/05	5.0	6.3
5/4/05	4.0	4.0
6/4/05	2.0	5.7

5

Report No. 4.5 **Nutrient Loading in the Belongil**
Directorate: Infrastructure Services
Report Author: Bryan Green, Water Sewer Systems Environment Officer
File No: I2020/56

Summary:

This report is in response to questions raised by the Waste and Water Sewage Advisory Committee, and subsequent recommendation that a report be submitted to Council to address the following:

18-690 **Resolved** that Council adopt the following Committee Recommendation(s):

Report No. 4.5 Nutrient Loading in the Belongil
File No: I2018/1704

Committee Recommendation 4.5.1

1. That Council note that consent conditions in clause 11 of the approval under Council res 02-1329 have been exceeded for short periods during the past 15 months

2. That Council determine a new methodology to calculate nutrient discharge into the Belongil to satisfy both Council Resolution 02-1329 and the Recycled Water Management Strategy 2017-27

3. That Council consider measures for overcoming these exceedances.

RECOMMENDATION:

That the committee note the report

REPORT

Committee recommendation

1. That Council note that consent conditions in Clause 11 of the approval under Council Re 02-1329 have been exceeded for short period during the past 15 months.

Clause 11 states

Nutrient Load Limit for West Byron STP

- Nutrient loads discharged to Belongil Creek, as measured at the outlet of the constructed wetland, shall not exceed 1,502 kg per year for Total Nitrogen and 300 kg per year for Total Phosphorus.
- Council shall continuously monitor nutrient loads discharged to the Belongil Creek. Determination of nutrient loads shall be based on a minimum of weekly sampling continuously averaged over a two month period, converted to an equivalent annual load.
- In the event that the equivalent annual nutrient load for either Total Nitrogen or Total Phosphorus exceeds 80% of the applicable limits specified in this Approval Condition, Council shall investigate feasible management strategies to reduce loads below 80%.
- In the event that the equivalent annual nutrient load for either Total Nitrogen or Total Phosphorus exceeds 100% of the applicable limits specified in this Approval Condition, Council shall meet to discuss appropriate courses of action to prevent further exceedances.

As this is an annual nutrient load calculation, it is not clear how the question relates to exceedance of nutrient loads for short periods during the past 15 months.

As per Council EPA licence 3404, Total Nitrogen and Total Phosphorus samples are collected fortnightly at the constructed wetland outlet and calculated using the EPA approved “source monitoring” method, EPA Load Calculation Protocol.

Nevertheless, if the question relates to the previous 15 months from the meeting date, 18 October 2018, then there was a 80% and 100% percentile Total Nitrogen exceedance during the April 2017 to April 2018 EPA reporting period. There may be other plausible reasons for these exceedances and will require further investigation however the most feasible may be the high rainfall during the March / April / May / June 2017 months and the February / March / Apr 2018 months. See table below.

During high rainfall events the flows through the wetlands are accelerated thereby reducing hydraulic retention time i.e. the high flows limit wetland plants ability to uptake the nutrients thereby skewing the monthly nutrient load output consequently the annual average nutrient loads.

Byron Bay STP

Nutrient Load to Belongil Creek - BB EPA P4 **27 Apr 2017 - 26 Apr 2018**

Pollutant Load

	Consent Cor	Wednesday, 15 January 2020		
	SS	**TP**	**TN**	**Weir Daily Flow Readings (EPA4)**
Units	kg/day	kg/day	kg/day	kL/day
10/05/2017	15.041	0.301	6.092	7,520
24/05/2017	20.725	0.296	5.848	7,402
7/06/2017	2.733	0.164	3.991	5,467
21/06/2017	5.373	0.322	7.308	10,747
5/07/2017	2.933	0.117	3.520	5,867
19/07/2017	1.131	0.091	1.674	2,263
2/08/2017	1.078	0.065	1.704	2,156
16/08/2017	4.365	0.109	2.095	2,182
30/08/2017	1.121	0.090	1.906	2,242
13/09/2017	3.673	0.147	2.375	2,448
27/09/2017	5.002	0.459	3.668	4,168
11/10/2017	2.675	0.268	2.354	2,675
25/10/2017	4.874	0.244	3.461	4,874
8/11/2017	11.546	0.475	5.977	6,792
22/11/2017	8.568	0.306	4.651	6,120
6/12/2017	3.107	0.435	5.282	6,214
20/12/2017	7.761	0.247	3.845	3,528
3/01/2018	13.965	0.908	7.262	6,982
17/01/2018	31.594	0.363	4.697	2,796
31/01/2018	16.856	0.626	6.501	4,816
14/02/2018	15.452	0.569	5.083	4,066
28/02/2018	12.215	1.120	8.551	10,179
14/03/2018	13.545	0.527	5.493	7,525
28/03/2018	9.441	0.472	5.015	5,900
11/04/2018	12.926	0.259	3.533	4,309
24/04/2018	4.135	0.331	4.796	8,270
Observed Daily Loads (kg)	231.8	9.3	116.7	137,509
Average Daily Pollutant Concentration (kg/kL)	0.0017	0.0001	0.0008	
Total Actual Annual Flow (kL)				1,843,519
Annual Pollutant Load (kg)	**3,108**	**125**	**1,564**	
Annual Pollutant Licence Limit (kg)	**N/A**	**300**	**1,502**	

2. That Council determine a new methodology to calculate nutrient discharge into the Belongil to satisfy both Council Res 02-1329 and the Recycled Water Management Strategy 2017-27.

In 2016 Council engaged Australian Wetlands Consultancy to design and install a v-notch weir to measure wetland discharge flows from EPA4.

The v-notch weir enabled accurate measurement of flows to support annual nutrient load calculations whereas previous wetland discharge flows were calculated using a complex water mass balance calculation which included rainfall and evapotranspiration.

3. That Council consider measures for overcoming these exceedances.

It is almost impossible to mitigate against increased nutrient loads during high rainfall events. Literature reviews identify this is a natural occurring event across most natural wetlands.

Therefore it is not financially viable to conduct research and develop innovation to overcome these incidences.

The abstracts below are provided to further support the observations in the Byron Wetlands that it is challenging to prevent high nutrient release during high rainfall events and therefore are not unique when compared to natural wetland systems.

Committee members can access these abstracts via the link provided and purchase the full article at their own cost.

Resources:

1. Raisin G.W; Mitchell D.S; Croome R.L, September 1997,*The effectiveness of a small constructed wetland in ameliorating diffuse nutrient loadings from an Australian rural catchment,* viewed 15 25 January 2020 [https://www.sciencedirect.com/science/article/abs/pii/S0925857497000165]

2. Chescheir, G.M., Gilliam, J.W., Skaggs, R.W. *et al. Nutrient and sediment removal in forested wetlands receiving pumped agricultural drainage water,* viewed 15 January 2020, 30 [https://link.springer.com/article/10.1007/BF03160842#citeas]