STORMWATER AUSTRALIA

Sustainability Workshop

SPEL Basin

SQIDEP (v1.3)

Independent Evaluators

Joint Report

September 2020

AFFLUX CONSULTING
STORMWATER MANAGEMENT SOLUTIONS

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Climate Change Statement

A wide range of sources, including but not limited to the IPCC, CSIRO and BoM, unanimously agree that the global climate is changing. Unless otherwise stated, the information provided in this report does not take into consideration the varying nature of climate change and its consequences on our current engineering practices. The results presented may be significantly underestimated; flood characteristics shown (e.g. flood depths, extents and hazards) are may be different once climate change is taken into account.

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1. Introduction

This document reports on the independent evaluation of an application by SPEL Stormwater (hereafter SPEL) to have Stormwater Australia approve a SPEL Basin under the requirements included in Stormwater Quality Improvement Device Evaluation Protocol (SQIDEP) v1.3 (hereafter referred to as SQIDEP) published in 2019 by Stormwater Australia. SQIDEP v1.3 is available on Stormwater Australia's website at the time of reporting.

This is a joint report prepared by Independent Evaluators, Chris Beardshaw, a Director of Afflux Consulting and Mark Liebman, a Director of Sustainability Workshop. The Independent Evaluators were engaged by Stormwater Australia on a fee for service basis to carry out an independent evaluation of a SPEL Basin which can be described as a modular bioretention system.

Evaluators Independence Declarations

It is declared that both evaluators, Chris Beardshaw and Mark Liebman, are completely independent and neither Independent Evaluator has any conflict of interest with respect to this engagement.

We jointly declare that:

We are not, nor have we ever been employed or commissioned by the Applicant, SPEL Stormwater. We have not been involved in the design or development or monitoring of the SPEL Basin. We have undertaken this assessment without prejudice and in good faith.

Signed: Chris Beardshaw *Signed: Mark Liebman*

Signature: *Signature:*

Statutory Declaration by Independent Monitoring Scientist

Dr Darren Drapper has signed a statutory declaration in accordance with SQIDEP.

Background

Stormwater Australia published the Stormwater Quality Improvement Device Evaluation Process (SQIDEP) in January 2019. The SQIDEP process seeks to *"provide a uniform set of criteria to which stormwater treatment measures can be field-tested and reported. These criteria should guide and inform field monitoring programs seeking to demonstrate pollutant removals for stormwater treatment measures included in pollutant export modelling software. Future revisions of the protocol are anticipated to also include laboratory testing."* (Stormwater Australia, 2019).

The SQIDEP process is shown below in Figure 2. Two pathways for evaluation exist under the protocol and this application involves local field testing. The Independent Evaluators have not been involved with this project prior to this evaluation, for example at QAPP stage and have not been privy to the QAPP.

Review Documents

The following documents form the basis of this independent evaluation:

1) Associate Professor Terry Lucke and Ms Oriana Sanicola, Evaluation of Treatment Performance of SPEL Basin at Sippy Downs, May 2018, Stormwater Research Group, University of Sunshine Coast.
2) Dr Darren Drapper and R. Biggins, SPEL Stormwater, Field Monitoring of a SPEL Basin at University of Sunshine Coast, 90 Sippy Downs Dr, Sippy Downs QLD 4556, Issue 1, 10 October 2019.
3) SPEL Basin Monitoring setup (digital video)
4) SPEL Basin Technical Design Guideline, revised August 2020.
5) Dr Darren Drapper and E. Hancock, SPEL Stormwater, Field Monitoring of a SPEL Basin at University of Sunshine Coast, 90 Sippy Downs Dr, Sippy Downs QLD 4556, SQIDEP Body of Evidence Application Supplementary Report, Issue 1, 31 July 2020.

Sippy Downs SPEL Basin

A SPEL Basin was submitted for evaluation against the SQIDEP protocol in October, 2019. Testing for the system was conducted over the period from March 2017 to April 2018 by the University of Sunshine Coast (USC), with the testing criteria adapted to meet the SQIDEP Protocol (released subsequent to the testing period). USC is an independent organisation that undertook the testing on a fee for service basis.

The basin installation is on Sippy Downs Drive, Sippy Downs and can be seen in Figure 1. Greater description is contained in review documents 1 and 2.

A review of the site and catchment conditions is shown below. The field monitoring claims to have met all of the criteria of the SQIDEP protocol, and this claim is evaluated in this report.

Figure 1. SPEL Basin Field Study Location (Lucke & Sanicola, 2018)

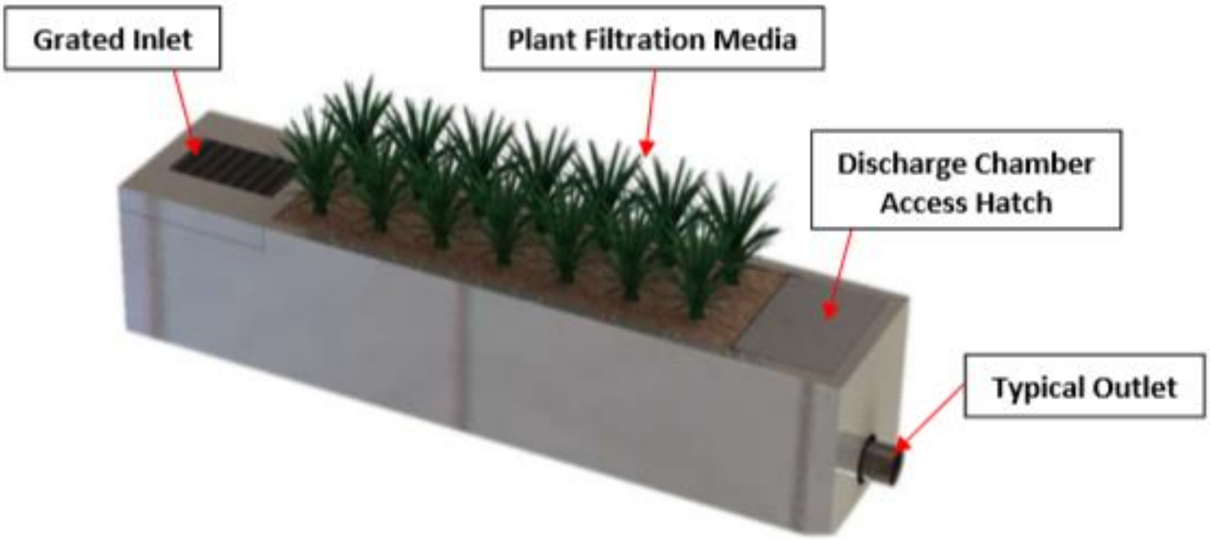


Figure 3. Typical SPEL Basin Schematic (Lucke & Sanicola, 2018)

Figure 1 SPEL Basin Diagram and Catchment Test Location (Drapper, 2019)

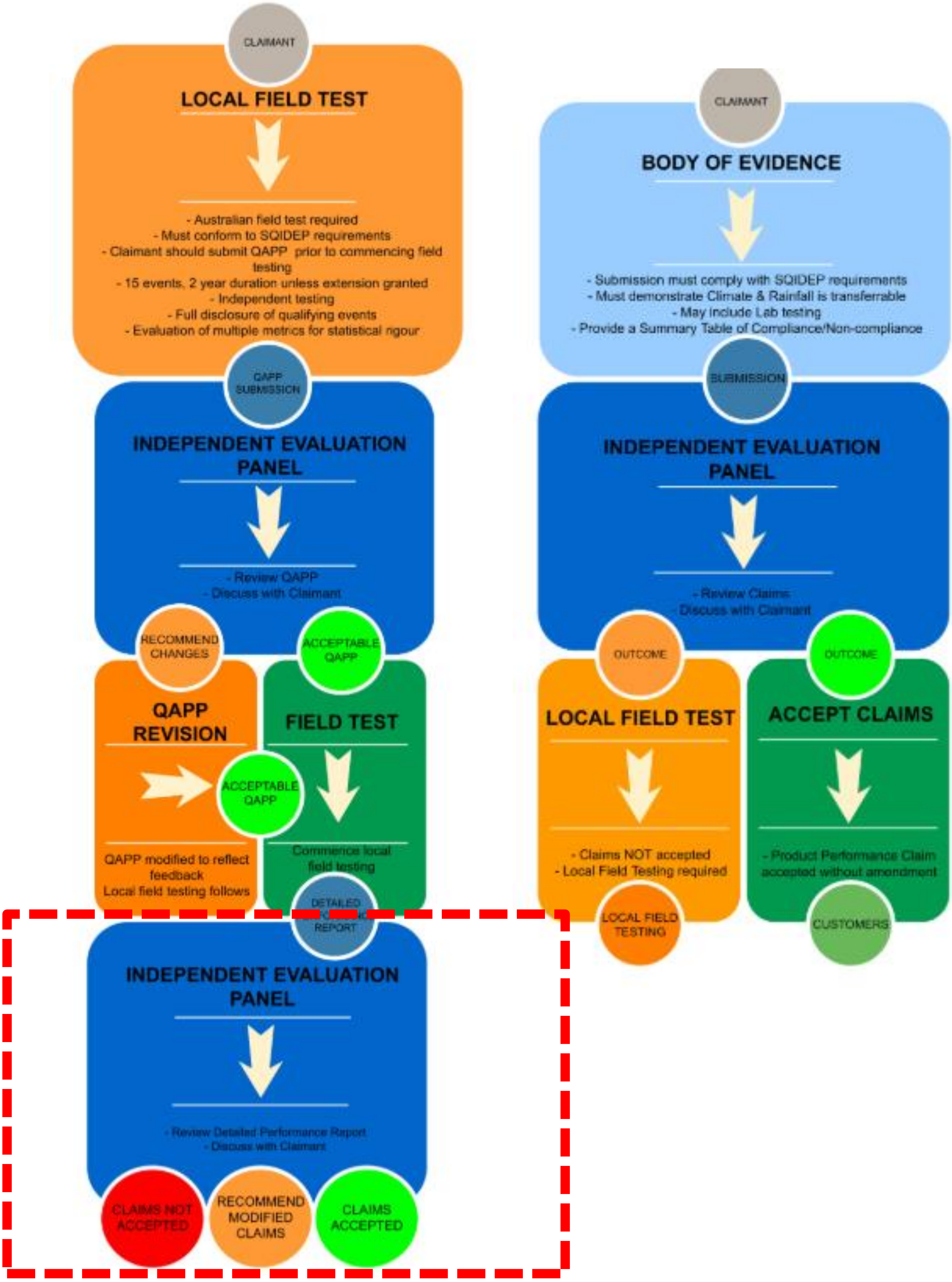


Figure 2 SQIDEP Pathways

Performance Claim

The SPEL Basin performance claim is as follows:

Table 1. SPEL Basin Treatment Claims

Parameter	Claim (%)
Total Suspended Solids (TSS)	86*
Total Phosphorus (TP)	65*
Total Nitrogen (TN)	50*
Total Petroleum Hydrocarbons (TPH)	0
Gross Pollutants	99

*Mean of average CRE and efficiency ratio (ER)

This Body of Evidence (BOE) claim is based only on field test results from the Sippy Downs test site. It is not based on any overseas test data.

It is noted that gross pollutants were not tested however the system tested includes a SPEL Storm Sack draining into a stormwater pit. It is reasonable to assume that any gross pollutants (particle size > 3mm) would be captured in the Storm Sack component of the device. Even if the Storm Sack were to blind and go into bypass the gross pollutants would be captured (up to the high flow bypass rate) within the stormwater pit upstream of the basin.

It is important to note this claim includes the performance benefit of both a Storm Sack and the SPEL Basin filtration components so that any MUSIC model should not have a SPEL Stormsack placed upstream of the device as its already included in the overall performance.

Hydrocarbons were not tested and the claim was revised to exclude it.

Site Background and Assumptions

The catchment is a small road catchment in Sippy Downs, Sunshine Coast. The catchment was checked for changes across the monitoring period (March 2017- April 2018). Aerial photography was taken across this period as can be seen below in Plates 1 to 4.

The broader catchment was maturing across the period, though no specific changes to the road catchments are seen. It is suspected that some of the developing catchment loads may have been transported into the monitored catchment in the early parts of the monitoring program. Otherwise the catchment seems to be in typical condition and suitable for monitoring.

Plate 1 May2016 with SPEL Basin highlighted in red

Plate 2 Dec 2017 with SPEL Basin highlighted in red

Plate 3 Nov 2018 with SPEL Basin highlighted in red

Plate 4 April 2020 with SPEL Basin highlighted in red

Independent checks of the catchment in Google street view were also made refer to Figure 3 below.

Figure 3 Streetview of monitoring station (Google Streetview , Image captured June 2017)

2. SQIDEP Compliance

The key criteria for testing are listed in SQIDEP in *Table 3 – Minimum data and qualifying event requirements for assessment* (SA, 2019) and are repeated here for comparison. Table 1 below assesses the Application for compliance with the criteria included in SQIDEP v1.3.

Table 1 SQIDEP Compliance Table

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
Min number of events	15 or enough events to achieve 90% confidence interval	18 complying events reported. USC reported that influent and effluent results were significantly different at a 90% confidence interval.	Compliance
Min rainfall depth	Sufficient to collect minimum sample volume for lab testing.	USC reported this was initially 2mm of rainfall, but this was revised to 1mm in 10minutes.Lab test results were provided for each complying event.	Compliance
Inter event period	Minimum 6 hours dry	No two events monitored on same day.	Compliance
Device Size	Full size	Used a full size single modular device with a high flow bypass claim of 10 l/s.	Compliance

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
Runoff Characteristics	Target pollutant profile of influent and effluent	The road catchment is representative of a typical catchment. Catchment inflow was analysed for percentage of dissolved nitrogen in the influent. On average 57% of Total Nitrogen influent is comprised of dissolved nitrogen species. This should future-proof this application for any potential changes to this aspect of SQIDEPv1.3. It also confirms the catchment is representative of a broad range of catchments.	Compliance
Runoff volume or peak flow	At least 2 events should exceed the 75% of the TFR and 1 event greater than the TFR. The TFR for the device is claimed to be 10 l/s.	USC has reported peak flow rates for the range of events. 2 events exceed the TFR and a further 3 events exceed 75% of the TFR.	Compliance
Automated sampling	Composite samples on a flow or time weighted basis	Composite samples on a flow weighted basis every 500 L.	
Minimum number of aliquots	80% of field test collections should have at least 8 per event.	USC has reported the number of aliquots. Of the 19 events which triggered sampling, only one	Compliance

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
		event collected less than 8 aliquots.	
Hydrograph coverage	At least 50% of qualifying storms should include the first 70% storm coverage	USC reported the hydrographs however did not report the percentage of coverage. Visual assessment of the hydrographs which also included the sampling time demonstrates in excess of 70% coverage for all complying events. The 22nd November storm had approximately 60% coverage however was a non-compliant storm event (for other reasons). Drapper reported that 7 events did not achieve 80% hydrograph coverage. These were excluded to ensure hydrograph coverage was higher than 80%. Drapper's Supplementary Report reported hydrograph coverage significantly exceeded the minimum coverage requirements of SIDEP v1.3.	Compliance

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
Hydrograph coverage	Multiple peaks should be accounted for (at least 1 occurrence).	Most hydrographs included in the BOE application show multiple peaks with sample collection occurring such that samples were collected near peaks and on rising and falling limbs.	Compliance.
Grab sampling	Not Applicable		Not applicable.
Sampling locations		Sampling occurred upstream of the SPEL sack and up and downstream of the SPEL basin. The subject of this claim is the performance of the SPEL Basin measured by comparison of its upstream location (which is downstream of the SPEL Sack) to its downstream location which is downstream of the Basin outlet. The claim does not include the performance of the SPEL Sack. The claim is independent of the SPEL Sack but inclusive of the filter cartridge which filters flows prior to entry to the Basin.	Compliance

<table>
<tr><th>Performance Criteria</th><th>Performance Requirement</th><th>Monitoring action or result</th><th>Compliance or non compliance</th></tr>
<tr><td>Chemical and physical analytes</td><td>As identified in the QAPP.</td><td>QAPP not sighted.</td><td>Not applicable to a BOE application.</td></tr>
<tr><td>Min and max concentrations within range</td><td>Refer to Table 1 in SQIDEP repeated below:

Table 1 — Typical Untreated Stormwater Contaminant Concentrations
<table>
<tr><th></th><th>Adopted minimum</th><th>Recommended Mean Influent Concentration & (Standard Deviation)[1]</th><th>Adopted maximum average for all qualifying storms: (Mean + 1SD)[2]</th><th>Maximum for any individua event: Mean 2SD</th></tr>
<tr><td>TSS</td><td>Limit of detection</td><td>151 (+220)</td><td>371</td><td>591</td></tr>
<tr><td>TP</td><td>Limit of detection</td><td>0.34 (+0.37)</td><td>0.71</td><td>1.1</td></tr>
<tr><td>TN</td><td>Limit of detection</td><td>1.82 (+1.27)</td><td>3.09</td><td>4.4</td></tr>
</table></td><td>All events where the maximum individual concentration exceeded Table 1 values was excluded from the data set and deemed a non complying event.

The average of TSS, TP and TN influent values were well within the maximum averages in Table 1.</td><td>Compliance.</td></tr>
<tr><td>Analytical methods</td><td>NATA accredited sample handling and analytical methods</td><td>A suite of analytes was analysed by ALS Environmental. ALS have NATA accreditation for their analytical methods.</td><td>Compliance</td></tr>
<tr><td>Flow measurement location</td><td>Inlet, outlet and bypass, as applicable.</td><td>Flow recorded at outlet only.

The likely hydraulic retention of the device is considered small and therefore it is unlikely to</td><td>Compliance</td></tr>
</table>

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
		retain or detain flows to any material extent. Accordingly, the claim does not include a claim for a volumetric reduction and so flow monitoring of the outlet only is acceptable	
Precipitation Measurement	A pluviometer is required	A pluviometer was used to monitor rainfall in 0.2mm increments.	Compliance
Rainfall recording interval	5 minutes or less.	Not reported but based on reported rainfall hyetographs it appears to report at a high frequency.	Unknown.
Rainfall recording increments	<0.25mm	0.2mm adopted.	Compliance
Pluviometer calibration	To be calibrated twice during the monitoring period.	Dr Drapper has signed a statutory declaration stating that the pluviometer was calibrated annually by Drapper Environmental Consultants.	Unknown.

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
Performance Indicators	The target pollutants and testing rationale must be described in the QAPP and Detailed Performance Report.	QAPP was not submitted as part of the application. Claiming TSS, TP and TN and Gross Pollutant reductions. TSS, TP and TN were measured. The initial claim included hydrocarbons by inference however these were not tested and it was agreed to remove these from the claim. Gross pollutants were not specifically measured however it is considered that gross pollutants are solids with a particle size greater than 3mm and which could not physically flow through the device. It is noted that a floatable gross pollutant may become buoyant and flow out of the system during extreme high flow bypass events. However the gross pollutant claim is considered justifiable on the basis of the nature of the device which includes a littler basket and filter	Compliance.

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
		cartridge of sorts – both of which would typically be credited with gross pollutant capture. The caveat here is that every installation of SPEL Basin must include a SPEL Sack at the entry pit.	
Performance Indicators	ER and CRE. If CRE average and median > 10% difference inspect dataset.	Both ER and average CRE was reported. The evaluators determined the median CRE and found median CRE aligned very closely with ER and the difference was less than 10%. The difference between ER and average CRE was found to be > 10%. It was agreed with the Applicant that an average of ER and average CRE would be adopted as a conservative approach that enables both metrics to be used and gives them equal weighting. We note that adoption of average CRE in lieu of median CRE reduced the	Compliance.

Performance Criteria	Performance Requirement	Monitoring action or result	Compliance or non compliance
		final agreed pollutant reductions by a few percentage points.	

In summary, Table 1 shows there is a high degree of compliance with SQIDEP v1.3. It is considered unlikely that the rainfall gauge was calibrated a second time during the analysis however the Independent Evaluators have assessed the significance and risk of a non conformance as low. In addition, using historical rain radar records we have verified that field test pluviograph rainfall records generally match radar records.

A number of other checks on the data have been performed and are reported below.

Comparison of Inflow Concentrations

Influent concentrations are impacted by a range of factors including antecedent conditions and catchment activity. Antecedent conditions allow accumulation of pollutants between events and it is possible to examine reported influent concentrations to identify indicative trends.

The inflow concentrations from this study were compared to previous studies of road catchments for cross-reference. In particular, the pollutant concentrations of TSS, TP and TN were extracted from Duncan (1999) which examined 42 (road) sites across Australia. A follow-up study, and one that is in close proximity to Sippy Downs was conducted by Drapper and Lucke (2015) for catchments within the South-East Queensland region. The pollutants concentrations from both studies are summarised below along side the inflow concentrations found at Sippy Downs (Table 1). Full graphs are shown in Appendix A.

The most noticeable point between the studies is the pollutant concentration range. Drapper and Lucke (2015) cited that the inflow concentrations observed in that study were significantly different to results of Duncan (1999). And similarly, the Sippy Downs concentration ranges vary differently to those of the comparison studies, however they are still considered realistic. This highlights the difficulty of quantifying pollutant runoff parameters, and consequently, modelling inflows. It is noted that Sippy Downs appears to be on the low end of the spectrum which would yield a conservative result. Any MUSIC generic node developed from this Application would be applicable to both clean and dirty sites.

We also note mean TSS influent concentrations, at 147mg/L are about 50% of default MUSIC road EMC values but not untypical for a new well sealed road, mean TN concentrations at 1.72 mg/L are not far off typical MUSIC default values at 2.2 mg/L while the TP loads were considered to be about 33% of default MUSIC values for a sealed road, i.e. low.

Table 1: Typical pollutant concentrations for road catchments

	Duncan (1999) study	Drapper and Lucke (2015) study	Current study – Sippy Downs
TSS (mg/L)	60 – 700 (n=42)	1.45 – 5800 (n=325)	16 – 1130 (n=19)
TP (mg/L)	0.1 – 0.8 (n=25)	0.08 – 26 (n=325)	0.03 – 1 (n=19)
TN (mg/L)	1 – 9 (n=17)	0.38 - 8.5 (n=325)	0.2-8.9 (n=19)

Dissolved Inorganic Nitrogen

This claim is for TSS, TP and TN. It does not include subspeciation of nitrogen. However the Independent Evaluators have assessed the influent concentrations to determine if there were unusually high organic nitrogen loads which might skew the claim and not be consistent with a site that is reasonably representative.

We found that dissolved nitrogen is the dominant (> 50% by mass) form of nitrogen on this site. The testing and analysis finds that the device performance is statistically significant in relation to TN removal and this indicates the device is removing both particulate and some forms of dissolved nitrogen.

Pollutant removal and statistical analysis

The statistical analysis and methodology for determining significance was reviewed. It was found that the steps taken follow standard procedures for evaluating stormwater data. Typically stormwater concentration data is not normally distributed, as denoted from a Shapiro-Wilk normality test. Log10 transformation does result in normality of the data. Paired Student T-test can be used on the transformed dataset to test significance between data sets.

Afflux Consulting undertook its own Paired Student T-test and found the same result as those reported by the Stormwater Research Group (see Appendix B).

Reported Concentrations Analysis

While the performance of the device is based on changes between influent and effluent concentrations as reported and elsewhere the influent concentrations are examined (see above) for representativeness of the recommended installation type, it is considered worthwhile to examine the influent concentrations with respect to antecedent conditions to gain an understanding of how the catchment is behaving.

Pollutant concentrations in runoff are influenced by a range of conditions that include the type, intensity and timing of catchment activity, and can be influenced by specific events that add to loadings, and detailed analysis is beyond a simple correlation with antecedent dry weather (ADW)conditions.

In general, it is expected that

- prolonged ADW will lead to increased pollutant concentrations; and
- some pollutants (e.g. Total Suspended Solids) will exhibit a more definitive correlation with ADW.

Influent concentrations are listed in Table 2 for three ranges of ADW. Given the nature of the catchment (e.g. road) it is not expected that TP or TN pollutant will be significant and it is not possible to draw any definitive conclusions from these results, however they show (on average) higher results for TSS for longer ADW periods and gives some level of comfort that the catchment is behaving in terms of currently accepted build and wash off conceptual models.

Table 2 Comparison of Concentrations and Antecedent Conditions

	Date	Antecedent Dry Period (Hrs)	TSS (mg/L)	TP (mg/L)	TN (mg/L)
SHORT ADWP (<24Hrs)	13/06/2017	13	107.00	0.16	2.30
	7/07/2017	11	256.00	0.55	8.90
	8/07/2017	11	196.00	0.24	2.30
	23/09/2017	11	142.00	0.24	3.00
	3/10/2017	11	72.00	0.08	0.70
	21/11/2017	13	61.00	0.04	0.40
	22/11/2017	11	22.00	0.04	0.10
	29/11/2017	11	34.00	0.04	0.10
	AVERAGE		111.25	0.17	2.23
MEDIUM ADWP (>24Hrs, <100Hrs)	29/03/2017	14	42.00	0.04	0.40
	12/11/2017	37	176.00	0.15	0.70
	4/03/2017	51	30.00	0.04	0.50
	AVERAGE		82.67	0.08	0.53
LONG ADWP (>100Hrs)	14/03/2017	267	25.00	0.03	0.20
	20/03/2017	146	1130.00	1.00	7.30
	18/05/2017	242	134.00	0.11	1.40
	5/07/2017	336	122.00	0.08	0.90
	1/11/2017	123	137.00	0.13	1.40
	25/12/2017	254	16.00	0.05	0.70
	31/12/2017	121	41.00	0.05	0.70
	18/04/2018	264	46.00	0.03	0.50
	AVERAGE		206.38	0.19	1.64

The catchment condition has also been considered for any correlations to reported data. As can be seen in the background information some adjacent catchment development was occurring in the early parts of the testing period (**Error! Reference source not found.**). Reviewing the data it can be seen that in general the TSS loadings are higher in the first 6 months of the testing period, with the catchment settling down after this period. There could be some correlation with the vegetation growth within the system, however an establishment chronology is not given and could not be assessed. Certainly, the vegetation is well established by June 2017 (Figure 3).

We note that the Evaluators have not been given any recent photographs of the installation and the health and robustness of the vegetation in the device approximately 3 years after commission is unknown.

Table 3 – All Observed Removal Efficiency Results

Date	Rain depth (mm)	TSS (mg/L) (LOD = 5)			TP (mg/L) (LOD = 0.01)			TN (mg/L) (LOD = 0.1)		
		IN	OUT	CRE	IN	OUT	CRE	IN	OUT	CRE
14/03/2017	47.8	25	5*	90%	0.03	0.02	33%	0.2	0.1*	50%
20/03/2017	6.2	1130	9	99%	1.00	0.03	97%	7.3	0.3	96%
29/03/2017	6.4	42	12	71%	0.04	0.04	0%	0.4	0.4	0%
18/05/2017	15.0	134	10	93%	0.11	0.01	91%	1.4	0.4	71%
13/06/2017	34.0	107	10	91%	0.16	0.01*	94%	2.3	0.2	91%
5/07/2017	9.8	122	5*	98%	0.08	0.02	75%	0.9	0.4	56%
7/07/2017	5.0	256	20	92%	0.55	0.03	95%	8.9	0.6	93%
8/07/2017	5.4	196	10	95%	0.24	0.03	88%	2.3	0.4	83%
23/09/2017	6.6	142	12	92%	0.24	0.05	79%	3.0	1.3	57%
3/10/2017	43.4	72	9	88%	0.08	0.02	75%	0.7	0.4	43%
1/11/2017	4.4	137	14	90%	0.13	0.12	8%	1.4	0.8	43%
12/11/2017	5.6	176	17	90%	0.15	0.05	67%	0.7	0.4	43%
21/11/2017	23.8	61	5	92%	0.04	0.01	75%	0.4	0.2	50%
22/11/2017	45.0	22	5*	77%	0.04	0.03	25%	0.1	0.1	0%
29/11/2017	27.8	34	15	56%	0.04	0.01	75%	0.2	0.1	50%
25/12/2017	19.2	16	6	63%	0.05	0.02	60%	0.7	0.7	0%
31/12/2017	11.2	41	12	71%	0.05	0.04	20%	0.7	0.7	0%
4/03/2018	13.0	30	5*	83%	0.04	0.03	25%	0.5	0.3	40%
18/04/2018	28.4	46	6	87%	0.03	0.02	33%	0.5	0.4	20%
Mean	18.8	147	9.8		0.16	0.03		1.72	0.43	
Average CRE		84%			59%			47%		
Efficiency Ratio		93%			81%			75%		

**Values below Limit of Detection (LOD) are given as LOD to be conservative*

A number of anomalies, which have subsequently been addressed in a supplementary report prepared by Drapper Environmental Consultants, were also seen in the qualifying events (Table 5 in USC, 2019) and are shown below.

- TSS below LOD – shown in orange highlights – makes minimal difference to overall averages
- Less than 8 aliquots – shown in green. This applies to less than 20% of the total number of samples and therefore meets the criteria
- 50% of storms to have at least 70% of hydrograph coverage – the supplied graphs seem to indicate this, but further clarification was sought and confirmed as noted below.

It is noted the supplementary report addressed these points as follows:

1) A sensitivity analysis was undertaken to determine the impact of reporting at the LOD and 50% of the LOD. It was found by Drapper that reporting at the LOD or 50% of the LOD as is prescribed by SQIDEP makes about 1-2% difference. We note that USC was not consistent in their reporting of LOD events but this was corrected by Dr Drapper in the Supplementary Report.

2) It is noted that some other minor reporting errors by USC were corrected in the Drapper Supplementary Report.

3) The Drapper Supplementary Report also identified the percentage of hydrograph coverage. Only one of the storms (22/11) recorded less than 70% of the hydrograph coverage and this was later excluded due to excessively high pollutant concentrations (outlier) anyway.

Table 5 – Removal Efficiency Results Excluding Statistical Outliers (after Grubbs [6])

Date	Rain depth (mm)	TSS (mg/L) (LOD = 5)			TP (mg/L) (LOD = 0.01)			TN (mg/L) (LOD = 0.1)		
		IN	OUT	CRE	IN	OUT	CRE	IN	OUT	CRE
14/03/2017	47.8	25	2.5	90%	0.03	0.02	33%	0.2	0.1*	75%
29/03/2017	6.4	42	12	71%	0.04	0.04	0%	0.4	0.4	0%
18/05/2017	15.0	134	10	93%	0.11	0.01	91%	1.4	0.4	71%
13/06/2017	34.0	107	10	91%	0.16	0.01*	97%	2.3	0.2	91%
5/07/2017	9.8	122	2.5	98%	0.08	0.02	75%	0.9	0.4	56%
8/07/2017	5.4	196	10	95%	0.24	0.03	88%	2.3	0.4	83%
23/09/2017	6.6	142	12	92%	0.24	0.05	79%	3.0	1.3	57%
3/10/2017	43.4	72	9	88%	0.08	0.02	75%	0.7	0.4	43%
1/11/2017	4.4	137	14	90%	0.13	0.12	8%	1.4	0.8	43%
12/11/2017	5.6	176	17	90%	0.15	0.05	67%	0.7	0.4	43%
21/11/2017	23.8	61	5	92%	0.04	0.01	75%	0.4	0.2	50%
22/11/2017	45.0	22	5	77%	0.04	0.03	25%	0.1	0.1	0%
29/11/2017	27.8	34	15	56%	0.04	0.01	75%	0.2	0.1	50%
25/12/2017	19.2	16	6	63%	0.05	0.02	60%	0.7	0.7	0%
31/12/2017	11.2	41	12	71%	0.05	0.04	20%	0.7	0.7	0%
4/03/2018	13.0	30	5*	83%	0.04	0.03	25%	0.5	0.3	40%
18/04/2018	28.4	46	6	87%	0.03	0.02	33%	0.5	0.4	20%
Mean	20.4	83	9.3		0.09	0.03		0.96	0.42	
Average CRE		**83%**			**54%**			**42%**		
Efficiency Ratio		**89%**			**65%**			**56%**		

**Values below Limit of Detection (LOD) are given as LOD to be conservative*

The final SQIDEP Compliant Storm results is extracted from Drapper's Supplementary report and shown below:

Table 3. Amended SPELBasin SQIDEP-compliant Results

Event Date	Rainfall Depth (mm)	TSS Inlet	TSS Outlet	TSS CRE %	TP Inlet	TP Outlet	TP CRE %	TN Inlet	TN Outlet	TN CRE %
14/03/2017	47.80	25.00	5.00	80%	0.03	0.02	33%	0.20	0.10	50%
20/03/2017		Excl.	Excl.		Excl.	Excl.		Excl.	Excl.	
29/03/2017	6.40	42.00	12.00	71%	0.04	0.04	0%	0.40	0.40	0%
18/05/2017	15.00	134.00	10.00	93%	0.11	0.01	91%	1.40	0.40	71%
13/06/2017	34.00	107.00	10.00	91%	0.16	0.01	94%	2.30	0.20	91%
5/07/2017	9.80	122.00	5.00	96%	0.08	0.02	75%	0.90	0.40	56%
7/07/2017	5.00	256.00	20.00	92%	0.55	0.03	95%	Excl	Excl	
8/07/2017	5.40	196.00	10.00	95%	0.24	0.03	88%	2.30	0.40	83%
23/09/2017	6.60	142.00	12.00	92%	0.24	0.05	79%	3.00	1.30	57%
3/10/2017	43.40	72.00	9.00	88%	0.08	0.02	75%	0.70	0.40	43%
1/11/2017	4.40	137.00	14.00	90%	0.13	0.12	8%	1.40	0.80	43%
12/11/2017	5.60	176.00	17.00	90%	0.15	0.05	67%	0.70	0.40	43%
21/11/2017	23.80	61.00	5.00	92%	0.04	0.01	75%	0.40	0.20	50%
22/11/2017	45.00	22.00	5.00	77%	0.04	0.03	25%	Excl	Excl	
29/11/2017	27.80	34.00	15.00	56%	0.04	0.01	75%	0.20	0.10	50%
25/12/2017	19.20	16.00	6.00	63%	0.05	0.02	60%	0.70	0.70	0%
31/12/2017	11.20	41.00	12.00	71%	0.05	0.04	20%	0.70	0.70	0%
4/03/2018	13.00	30.00	5.00	83%	0.04	0.03	25%	0.50	0.30	40%
18/04/2018	7.55	46.00	6.00	87%	0.03	0.02	33%	0.50	0.40	20%
Average		92.17	9.89	**84%**	0.12	0.03	**56%**	0.91	0.40	**44%**
ER			**89%**			**73%**			**56%**	

The final claim is as follows:

Table 1. SPEL Basin Treatment Claims

Parameter	Claim (%)
Total Suspended Solids (TSS)	86*
Total Phosphorus (TP)	65*
Total Nitrogen (TN)	50*
Total Petroleum Hydrocarbons (TPH)	0
Gross Pollutants	99

*Mean of average CRE and efficiency ratio (ER)

Rainfall Review

The monitoring site was equipped with both a tipping bucket rainfall gauge and (outlet) flow meter to assist with identification of qualifying storm events (depth/ duration), determination of antecedent dry weather periods and to assist with determination of required sampling frequency (i.e. number of aliquots).

This information is presented in the report in tabular and graphical format and described against protocol requirements. The closest BOM gauge depths are shown in Appendix C.

Checks were carried out to examine the historical rainfall record (historic radar) and a number of selected events as a 'sensibility check' to verify the on-site measurements were in line with what should be expected.

Events

Radar records were used to examine historic rainfall. This is able to provide an indication of rainfall occurrence and intensity. Figure 4 shows radar results for the 7th July and the corresponding flow rates provided in 'SQIDEP BOE Application - Supporting Information'.

In general terms:

- Higher rainfall intensities should manifest as higher peak flows through the device:
- Flow peaks through the device should match altered intensity as a storm front passes; and
- The duration of an event (from start to finish) should match the radar record.

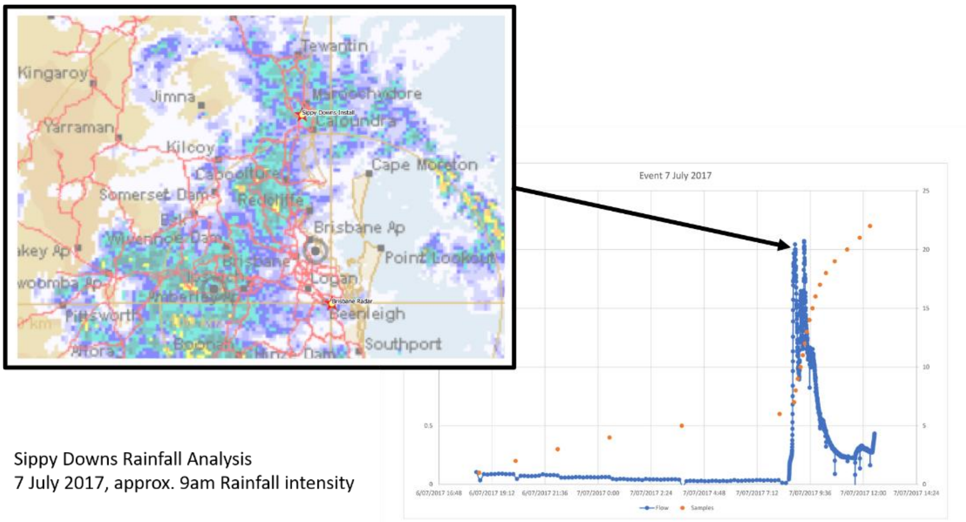


Figure 4 Radar Rainfall Checks

For the majority of events provided for analysis the observations indicate a reasonable match in storm and flow peaks between the site recordings and meteorological results, with two exceptions for the 8th July 2017 and 23 September 2017.

Both these days report relatively low flow through the device (i.e. less than 0.5l/s) and reported rainfall depth for these events were 5.4 mm and 6.6 mm respectively. Scrutiny of the flow rainfall depth for other days indicates a higher order of flow response. As such, it is possible that the characterization of the storm event is incorrect and has been plotted incorrectly. Given the overwhelming correlation of the other events to the data, the rainfall and event data is generally accepted.

Note that it is possible that the sample collected on the 8th July was as a result of continuing flow generated by the event on the 7th July, however the radar record does not appear to indicate that there was sufficient rainfall on the 23rd September to generate the tabled data.

Cherry Picking of Storm Events

SQIDEP v1.3 does not explicitly require that sequential storm events be monitored and reported. None the less, the Independent Evaluators have checked for evidence of cherry picking.

We have reviewed all storms that were excluded from the data set. Dr Drapper included in his Detailed Report a summary of the rainfall and storms that occurred during the monitoring period. This table is extracted and shown below:

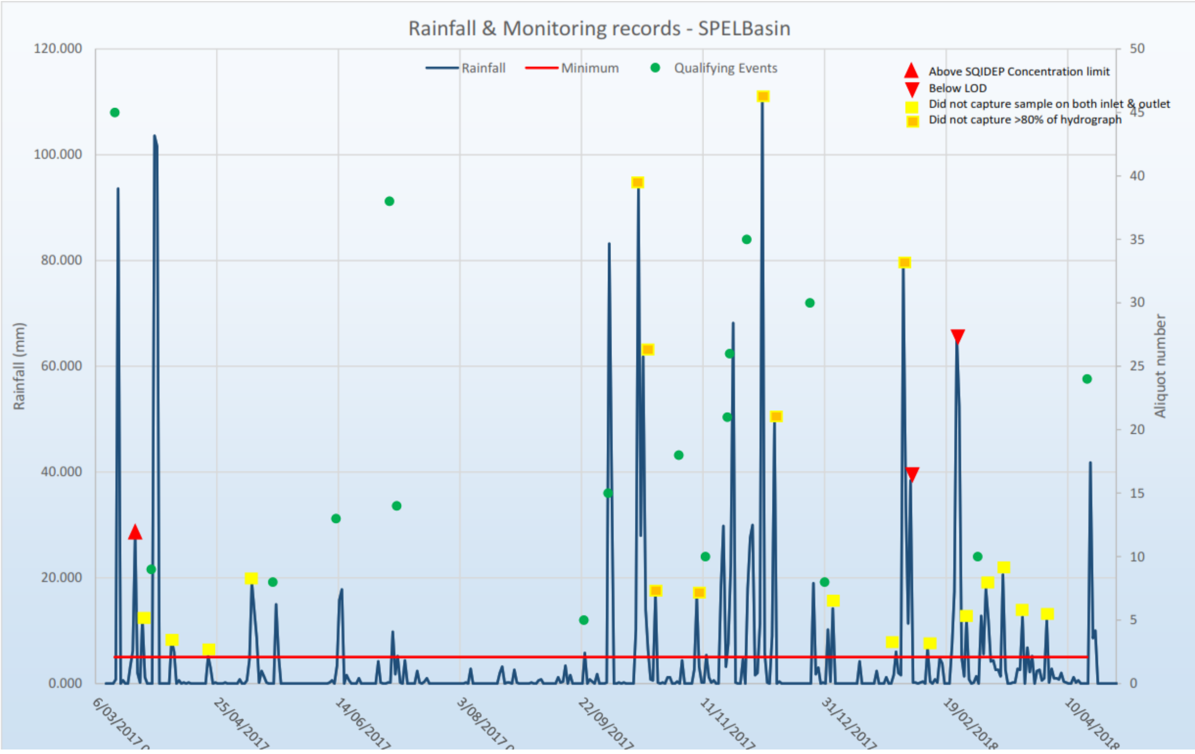


Figure 5 Reported rainfall and monitoring records.

The chart shows that there were 6 recorded storm events, intense events with an average depth of about 50mm which failed to capture more than 80% of the hydrograph and were therefore discarded. There are also a number of events where either the inlet or outlet sample was not obtained presumably due to mechanical or some kind of equipment failure or simply because no outflow occurred. These are credible events and are considered typical of any monitoring dataset noting that flow and quality monitoring equipment is notoriously unreliable.

Analysis of the spread of reported events also indicates some events where performance was high and equally some events where performance was not great. A “cherry picked” dataset would, by definition, only include events with good performance. The duration of the monitoring period, which is considered relatively short at 13 months, is indicative of a study which did not wait for high performing events to occur.

At the request of the Evaluators, Dr Drapper also provided data logs for storm events which were excluded and these demonstrated that there was a failure of equipment to record for example the first 100mm of rainfall. It is noted this is not a fully independent data analysis however it adds to the body of evidence to demonstrate cherry picking was not undertaken.

On a first principles basis and assuming good faith by all parties, this study has the hallmarks of a robust scientifically sound assessment, i.e. it was undertaken with as much independence as is feasible, i.e. independent measurement, independent reporting and oversight and independent evaluation (peer review) and is considered representative of typical field conditions and therefore repeatable under typical conditions.

3. Evaluation of Enduring Performance

The Independent Reviewers have endeavoured to consider the long term enduring performance of the SPEL Basin.

The device includes an ion exchange element. The cation exchange capacity of the media has been confirmed to have a long life-time at typical hydraulic loading rates and this indicates the device would not need to have its media replaced to maintain chemical water quality outcomes within the life expectancy of the media.

However the media may be subject to blocking and reduced hydraulic conductivity from occlusion by sediment. The SPEL Basin system includes a littler basket and filter cartridge. Both of these can be easily maintained, without replacement, and will add significantly to the life expectancy and functionality of the device as they prefilter sediment.

A sensitivity analysis of the device was undertaken by modelling its performance in MUSIC with a 40% reduced high flow bypass rate. Assuming the hydraulic conductivity and consequently the high flow bypass was reduced by 40% (indicative of partially clogged filter media) the performance of the device would reduce by 2-3%, i.e. marginally.

It was agreed with SPEL to include a requirement in their Technical Design Guideline that if the media was observed to not fully drain down to its lowest level within 2 hours that the media be investigated and if required replaced. This would ensure that hydraulic conductivity was maintained at reasonable levels and the TFR would be maintained in turn ensuring that the claimed treatment train effectiveness would be achieved in the longer term.

It is noted that it is not possible nor required of the Evaluators to determine the life of the device or the media and we are confident that under similar conditions to the test site that the device will have a reasonable life expectancy. It is recommended that SPEL continues to monitor at least the hydraulic performance of the SPEL Basin to confirm its long term performance and range of media life-expectancy under both light and heavy pollutant loading rates.

4. Discussion

Our independent evaluation finds that:

1) As shown in Table 1, The testing regime and results comply with SQIDEP protocol requirements.
2) In addition, the catchment parameters, expected runoff concentrations, and rainfall mapping to event recording are within standard, or expected guidelines though it is noted this site is considered "clean" or lightly loaded relative to default EMC values adopted in MUSIC. Of itself, this implies that, based on diminishing returns, the performance claims are more difficult to achieve and therefore conservative however the device itself may demonstrate clogging more prematurely on more heavily loaded sites. In this sense the field test may not have stress tested the device as much as it will experience in the real world. None the less the claim is considered valid and generally representative.
3) The field study appears to be a scientifically sound study and would be repeatable under similar conditions which it is noted are deemed representative.
4) There will be some sites where media life is reduced due to higher sediment loads and we note this SQIDEP claim and this independent evaluation do not involve a claim against expected media life. This however is addressed in part by the need for the asset owner to observe draining times and if draining times fall below 2 hours to then investigate if the media is blocked and needs replacing.
5) The cation exchange capacity of the media is reportedly very high and indicates the CEC is very unlikely to limit media life.
6) We were unable to assess the longer term vegetative health of the system though during the investigation rigorous and healthy plant growth was evident.
7) We did not find evidence of cherry picking of storm events.
8) We found that the dominant forms nitrogen in this study were dissolved nitrogen indicating that filtration, absorption and adsorption are occurring.

Final Agreed Pollution Reduction Performance

The final agreed pollutant reduction performance can be seen in

Table 1. SPEL Basin Treatment Claims

Parameter	Claim (%)
Total Suspended Solids (TSS)	86*
Total Phosphorus (TP)	65*
Total Nitrogen (TN)	50*
Total Petroleum Hydrocarbons (TPH)	0
Gross Pollutants	99

*Mean of average CRE and efficiency ratio (ER)

Figure 6 and includes total suspended solids, total phosphorus, total nitrogen, and gross pollutant claims.

Based on the testing regime and submitted results TSS, TP, TN and gross pollutants can be evaluated in this process. It is however acknowledged that by association and by reference to other scientific studies hydrocarbons will be removed though no credit given.

Table 1. SPEL Basin Treatment Claims

Parameter	Claim (%)
Total Suspended Solids (TSS)	86*
Total Phosphorus (TP)	65*
Total Nitrogen (TN)	50*
Total Petroleum Hydrocarbons (TPH)	0
Gross Pollutants	99

*Mean of average CRE and efficiency ratio (ER)

Figure 6 Final Agreed Pollutant Reduction Performance

Scalability and Hydraulic Loading Rate

The question of scalability of these results has been considered as part of this review. The design treatment rate of 10L/s was tested in the field and at least 4 events out of the qualifying 18 events approach or exceed this value. Of these larger events there is a spread of CRE values, with some well below the claimed reductions and some above. Viewing these results more critically it would seem that the antecedent conditions, and shape of the hydrograph are just as important precursors to the CRE as the actual flow rate. Clearly more field data may better define these correlations, however given the 90% confidence rate already, the care taken to remove outliers and non-qualifying events and defined SQIDEP protocol it is accepted that natural variations will occur and that a treatment rate of 10L/s is an acceptable limit.

How this 10L/s plays out in installations is a further consideration. SPEL have stated that their preference is to procure the application in 10L/s modules. If this is adhered to then this should have a level of acceptable saleability. Given that these are modules are only procured by one manufacturer applying this limit this should minimise the misuse of this limit – the same cannot be said for many other nutrient removal applications in the market. However, this should strongly be written into any technical guideline associated with the modules, so that any prospective purchaser or asset owner is aware of this limitation.

We note that this study tested a SPEL Basin accepting runoff from an 850m^2 catchment. Using a City of Gold Coast template this produces an annual hydraulic load rate of about 215m/year. We would therefore consider that a hydraulic loading rate up to 250m/year would be an acceptable load rate for the device. Should the load rate for example increase to say 500m/year then the same results found in field study would not be repeatable.

Limitations of Acceptance

The limitations of the acceptance of these testing results include:

1. The results are for a road based catchment. The results lie within acceptable inflow limits for this type of catchment and based on the analysis are found to be acceptable. This does not necessarily relate to other catchment types, though it is

noted that hard stand catchments will behave similarly. Cleaner, roof catchments may not achieve the same pollutant reduction targets.

2. The results are for a hydraulic loading rate up to 250m/year. Should the hydraulic load rate exceed this, the results and life expectancy of the media would be expected to decline in line with excessive loading on the device.

3. The results are reliant on the maintenance of the device being consistent with the manufacturers guidelines and those that are contained in the report. Most importantly the cleaning of the Storm Sack and filter cartridge at regular intervals.

4. The life expectancy of the device and the media is unknown. In discussions with the manufacturer the testing is consistent to at least the 6 year mark. It is suggested that an estimated lifespan of both media and the whole device be written into any technical guidelines as the filter material will deteriorate over time.

5. The acceptance of these results is reliant on the installation being similar to that shown in this analysis. Alternative installations may result in different outcomes.

Recommendation for Associated Technical Guidelines

The results of this analysis can be seen to be reliant on a number of factors, a number of which could be tied strongly to a set of technical installation and maintenance guidelines. As such it is strongly recommended that the SQIDEP results be tied to a product guideline to ensure future consistency.

5. Conclusions

Based on the results presented and the analysis shown in this report, the authors are satisfied that the BOE Application complies with the SQIDEP protocol and the performance reduction claims shown at Figure 6 have been agreed.

It is recommended that these results and acceptance be packaged with the MUSIC nodes and a technical guideline.

6. References

Duncan, H.P. (1999), *Urban Stormwater Quality: A Statistical Overview, Report 99/3*, Cooperative Research Centre for Catchment Hydrology, February 1999.

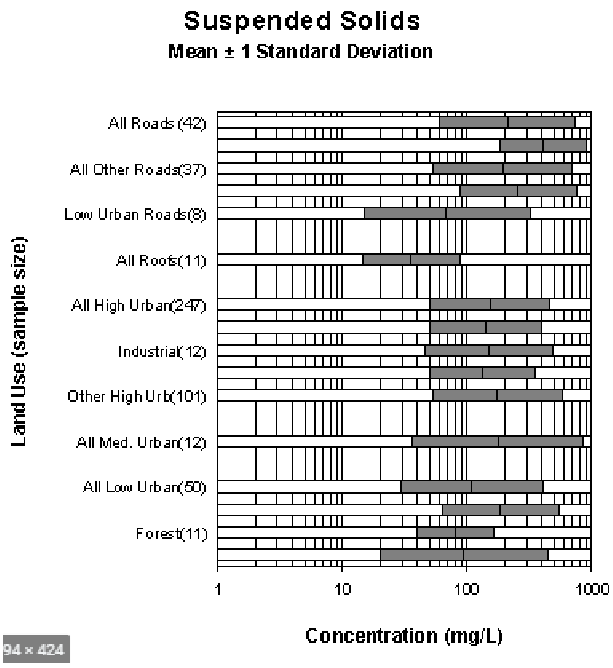
Drapper, Darren & Lucke, Terry. (2015). *Characterisation of Stormwater Pollutants from Various Catchment types in South-east Queensland*.

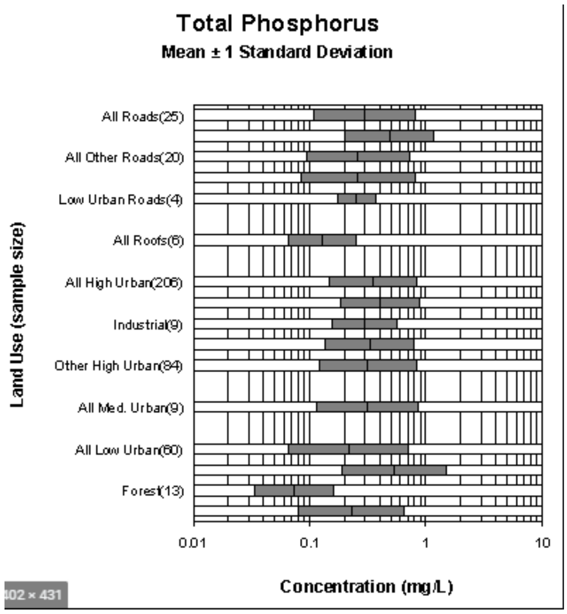
Drapper D., (2019), *SQIDEP Body of Evidence Application Supporting Information*, Drapper Environmental Consultants, Springfield Lakes, QLD

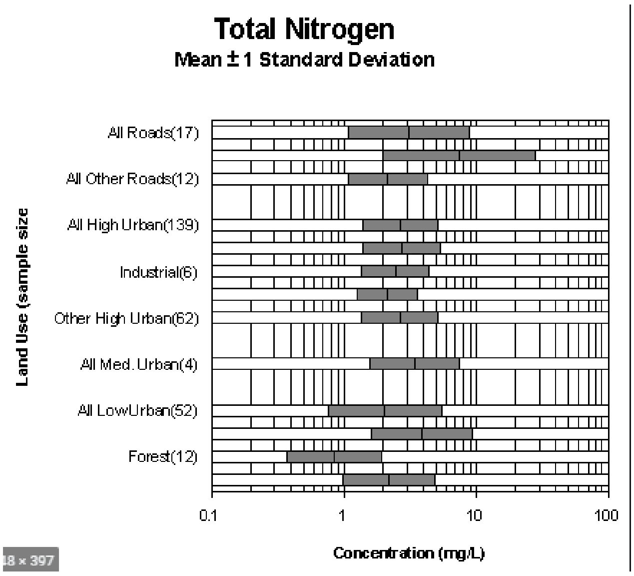
Lucke T., Sanicola O., (2018), University of Sunshine Coast, *Evaluation of Treatment Performance of SPEL Basin at Sippy Downs,* University of Sunshine Coast

7. Appendix A – Typical Concentrations

Typical concentration graphs from Duncan et. al (1999) for road catchments:







Typical pollutant concentrations from Drapper et. al (2005):

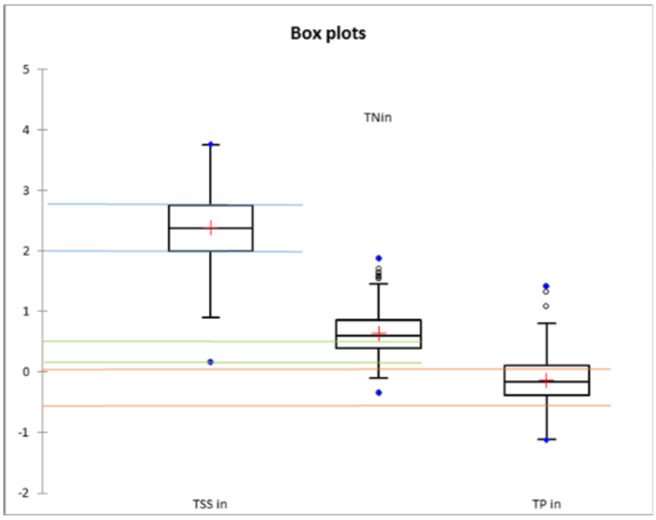


Figure 3. Boxplot comparison of BCC and additional SEQ data (log mg/L) for Roads Land Use

Table 7. Student's t tests on commercial land use

	TSS	TN	TP
t (Observed value)	73.9512	3.0504	0.877
DF	423	423	423
p-value (Two-tailed)	**< 0.0001**	0.024	0.381
alpha	0.05	0.05	0.05

8. Appendix B – Statistical check

Shapiro-Wilk Normality Test

Normality test of raw TSS data:

Shapiro-Wilk Test		
	in	*out*
W-stat	0.89021	0.949454
p-value	0.046703	0.447941
alpha	0.05	0.05
normal	no	yes

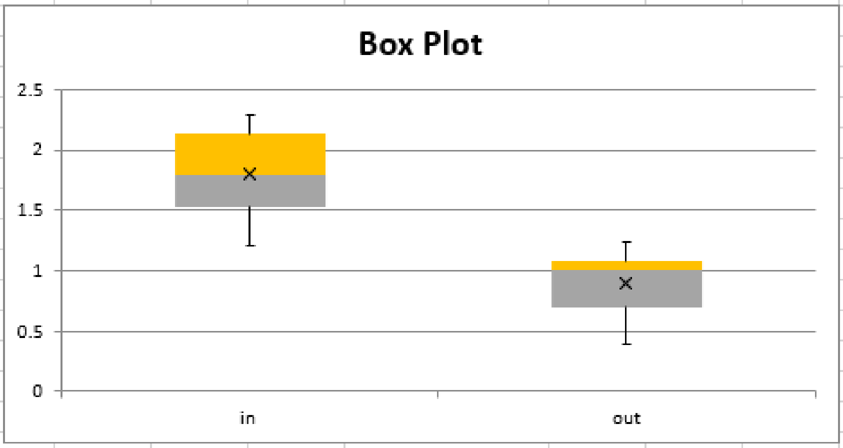
Normality test of raw TP data:

	in	*out*
W-stat	0.801047	0.710221
p-value	0.002097	0.000151
alpha	0.05	0.05
normal	no	no

Normality test of raw TN data:

	in	*out*
W-stat	0.830236	0.8366
p-value	0.005436	0.006744
alpha	0.05	0.05
normal	no	no

TSS transformed - results



Descriptive Statistics

	in	out
Mean	1.797892	0.893738
Standard	0.083818	0.061526
Median	1.78533	1
Mode	#N/A	1.079181
Standard	0.345589	0.25368
Sample V	0.119432	0.064354
Kurtosis	-1.34987	-0.29839
Skewness	-0.11609	-0.73453
Range	1.088136	0.832509
Maximum	2.292256	1.230449
Minimum	1.20412	0.39794
Sum	30.56416	15.19355
Count	17	17
Geometri	1.765498	0.851578
Harmonic	1.732373	0.799946
AAD	0.299273	0.212597
MAD	0.308209	0.176091
IQR	0.595626	0.380211

Multiplier: 2.2

	in	out
Min	1.20412	0.39794
Q1-Min	0.327359	0.30103
Med-Q1	0.253851	0.30103
Q3-Med	0.341775	0.079181
Max-Q3	0.165151	0.151268
Mean	1.797892	0.893738
Min	1.20412	0.39794
Q1	1.531479	0.69897
Median	1.78533	1
Q3	2.127105	1.079181
Max	2.292256	1.230449
Mean	1.797892	0.893738
Grand Min	0	
Outliers	None	None

Shapiro-Wilk Test

	in	out
W-stat	0.93771	0.907402
p-value	0.292026	0.090434
alpha	0.05	0.05
normal	yes	yes

d'Agostino-Pearson

	in	out
DA-stat	3.426803	1.879548
p-value	0.180252	0.390716
alpha	0.05	0.05
normal	yes	yes

T Test: Two Paired Samples

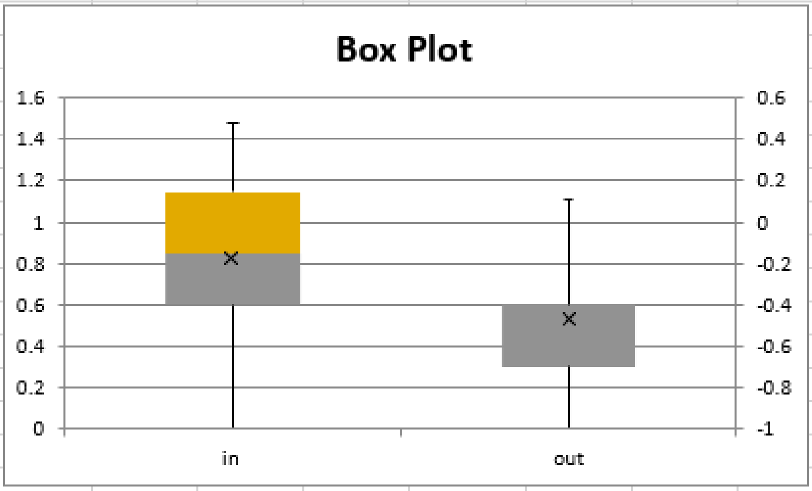
SUMMARY — Alpha 0.05 — Hyp Mear 0

Groups	*Count*	*Mean*	*Std Dev*	*Std Err*	*t*	*df*	*Cohen d*	*Effect r*
1.39794	16	1.822889	0.340681					
0.39794	16	0.924725	0.226345					
Differenc	16	0.898163	0.345739	0.086435	10.39123876	15	2.59781	0.937031

T TEST

	p-value	*t-crit*	*lower*	*upper*	*sig*
One Tail	1.5E-08	1.75305			yes
Two Tail	3.01E-08	2.13145	0.713932	1.082395	yes

TN transformed - Results



Descriptive Statistics

	in	out
Mean	-0.17461	-0.47054
Standard	0.097522	0.07825
Median	-0.1549	-0.39794
Mode	-0.1549	-0.39794
Standard	0.402093	0.322631
Sample V	0.161679	0.104091
Kurtosis	-0.21441	-0.31649
Skewness	-0.24342	-0.32029
Range	1.477121	1.113943
Maximum	0.477121	0.113943
Minimum	-1	-1
Sum	-2.96841	-7.99917
Count	17	17
Geometri	#NUM!	#NUM!
Harmonic	#NUM!	#NUM!
AAD	0.302776	0.246774
MAD	0.243038	0.243038
IQR	0.544068	0.30103

Multiplier 2.2

	in	out
Min	0	0
Q1-Min	0.60206	0.30103
Med-Q1	0.243038	0.30103
Q3-Med	0.30103	0
Max-Q3	0.330993	0.511883
Mean	0.825388	0.529461

Min	-1	-1
Q1	-0.39794	-0.69897
Median	-0.1549	-0.39794
Q3	0.146128	-0.39794
Max	0.477121	0.113943
Mean	-0.17461	-0.47054

Grand Min -1

Outliers None None

Shapiro-Wilk Test

	in	out
W-stat	0.965171	0.910285
p-value	0.729681	0.101154
alpha	0.05	0.05
normal	yes	yes

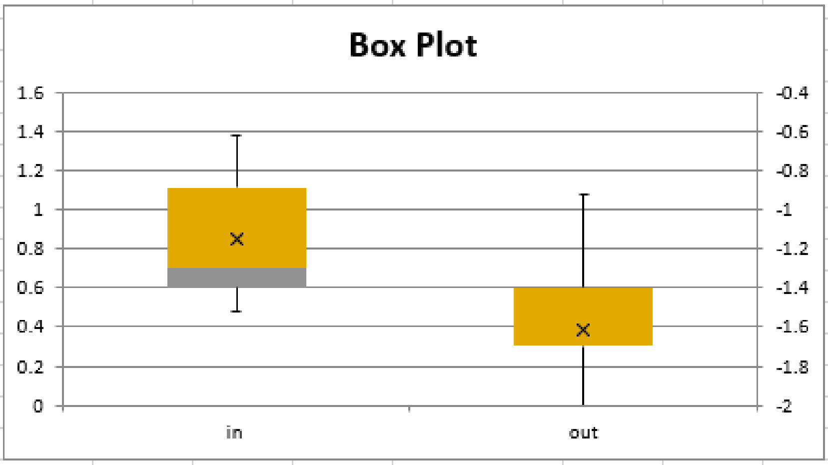
d'Agostino-Pearson

DA-stat	0.218801	0.390662
p-value	0.896371	0.822562
alpha	0.05	0.05
normal	yes	yes

T Test: Two Paired Samples								
SUMMARY		Alpha	0.05		Hyp Mear	0		
Groups	*Count*	*Mean*	*Std Dev*	*Std Err*	*t*	*df*	*Cohen d*	*Effect r*
-0.69897	16	-0.14184	0.391129					
-1	*16*	*-0.43745*	*0.30195*					
Differenc	16	0.295608	0.291321	0.0728303	4.05886	15	1.014715	0.723479

T TEST					
	p-value	*t-crit*	*lower*	*upper*	*sig*
One Tail	0.000514	1.75305			yes
Two Tail	*0.00103*	*2.13145*	*0.14037*	*0.450842*	*yes*

TP transformed - Results



Descriptive Statistics		
	in	*out*
Mean	-1.14914	-1.61072
Standard	0.075171	0.072421
Median	-1.30103	-1.69897
Mode	-1.39794	-1.69897
Standard	0.309937	0.298598
Sample V	0.096061	0.089161
Kurtosis	-1.19802	0.253664
Skewness	0.504691	0.451427
Range	0.90309	1.079181
Maximum	-0.61979	-0.92082
Minimum	-1.52288	-2
Sum	-19.5354	-27.3822
Count	17	17
Geometri	#NUM!	#NUM!
Harmonic	#NUM!	#NUM!
AAD	0.270031	0.235102
MAD	0.20412	0.30103
IQR	0.511883	0.30103

Multiplier	2.2	
	in	*out*
Min	0.477121	0
Q1-Min	0.124939	0.30103
Med-Q1	0.09691	0
Q3-Med	0.414973	0.30103
Max-Q3	0.266268	0.477121
Mean	0.850861	0.38928
Min	-1.52288	-2
Q1	-1.39794	-1.69897
Median	-1.30103	-1.69897
Q3	-0.88606	-1.39794
Max	-0.61979	-0.92082
Mean	-1.14914	-1.61072
Grand Min	-2	
Outliers	None	None

Shapiro-Wilk Test		
	in	*out*
W-stat	0.886455	0.921314
p-value	0.040514	0.155427
alpha	0.05	0.05
normal	no	yes

d'Agostino-Pearson		
DA-stat	3.16666	0.963127
p-value	0.20529	0.617817
alpha	0.05	0.05
normal	yes	yes

T Test: Two Paired Samples								
SUMMARY			Alpha	0.05		Hyp Mean	0	
Groups	*Count*	*Mean*	*Std Dev*	*Std Err*	*t*	*df*	*Cohen d*	*Effect r*
-1.52288	16	-1.12578	0.304255					
-1.69897	16	-1.6052	0.307495					
Differenc	16	0.479424	0.369255	0.092313738	5.193421	15	1.298355	0.801633

T TEST					
	p-value	*t-crit*	*lower*	*upper*	*sig*
One Tail	5.46E-05	1.75305			yes
Two Tail	0.000109	2.13145	0.282662	0.676186199	yes

Appendix C – Rainfall at Palmwood across testing period

2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Graph												
1st	0	0	0		0	0	0	0	0	0	0	48.0
2nd	0	0	19.8		0	0	0	0	0	0	0	↓
3rd	8.2	0	0		0	0	0	0	0	72.6	0	10.2
4th	30.6	0	↓		0	0	0	0	0	24.0	0	5.0
5th	8.2	0	↓		0	0	0	0	2.4	0	0	73.6
6th	↓	0	15.0	*7.0*	0	0	10.8	0	0	0	0	0
7th	3.4	0	0	*6.4*	0	0	0	14.0	0	0	3.8	0
8th	0	0	0		0	0	5.0	0	0	0	22.0	0
9th	0	16.4	0		8.4	0	0	0	0	0	3.2	13.0
10th	0	0	0		14.8	0	0	0	0	0	↓	35.0
11th	0	0	0		11.6	0	4.2	0	0	0	↓	0
12th	0	0	0		0	0	0	0	0	0	↓	9.2
13th	0	0	0		0	↓	0	0	0	0	↓	0
14th	0	7.6	7.2		0	19.6	0	0	0	5.4	↓	0
15th	55.0	0	64.6		0	10.4	0	0	0	43.4	↓	0
16th	0	0	0		0	0	0	0	0	45.2	↓	0
17th	0	0	↓		0	3.0	0	0	0	92.8	↓	0
18th	0	0	↓		0	0	0	0	0	39.6	22.0	0
19th	0	0	51.2		16.8	0	0	0	0	15.4	33.6	0
20th	0	26.4	13.2		5.2	0	0	0	0	0	5.0	0
21st	0	0	20.4		0	0	0	0	0	5.0	21.6	0
22nd	25.0	0	20.2	*5.4*	0	0	0	0	0	23.4	16.8	0
23rd	0	0	7.4		0	0	0	0	2.2	0	45.8	0
24th	0	0	0		0	0	0	0	0	0	0	0
25th	0	0	10.6		0	0	0	5.4	0	0	0	0
26th	0	0	0		0	0	0	0	0	0	0	17.0
27th	0	11.2	0		0	0	0	0	0	0	11.4	↓
28th	0	0	0		0	0	0	0	0	0	0	7.4
29th	0		5.4		0	0	0	0	0	0	15.0	0
30th	0		153.0		0	3.8	0	0	0	0	47.8	0
31st	0		52.2		0		0	0		0		0
Highest Daily	55.0	26.4	153.0	*7.0*	16.8	10.4	10.8	14.0	2.4	92.8	47.8	73.6
Monthly Total	130.4	61.6	440.2	*18.8*	56.8	36.8	20.0	19.4	4.6	366.8	248.0	218.4

Annual total for 2017 = *1621.8* mm View all monthly data Plot year of daily data