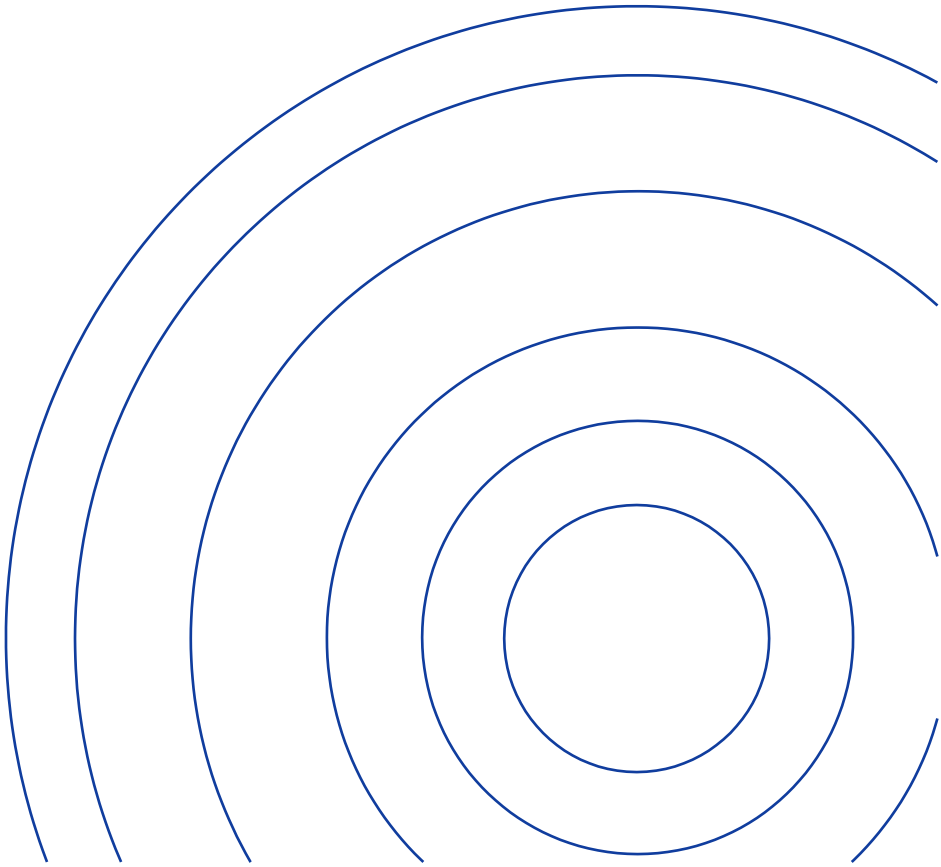
STORMWATER AUSTRALIA

HUMEFILTER INDEPENDENT EVALUATORS REPORT

SQIDEP HumeFilter

Date 10 July 2023

Version v05



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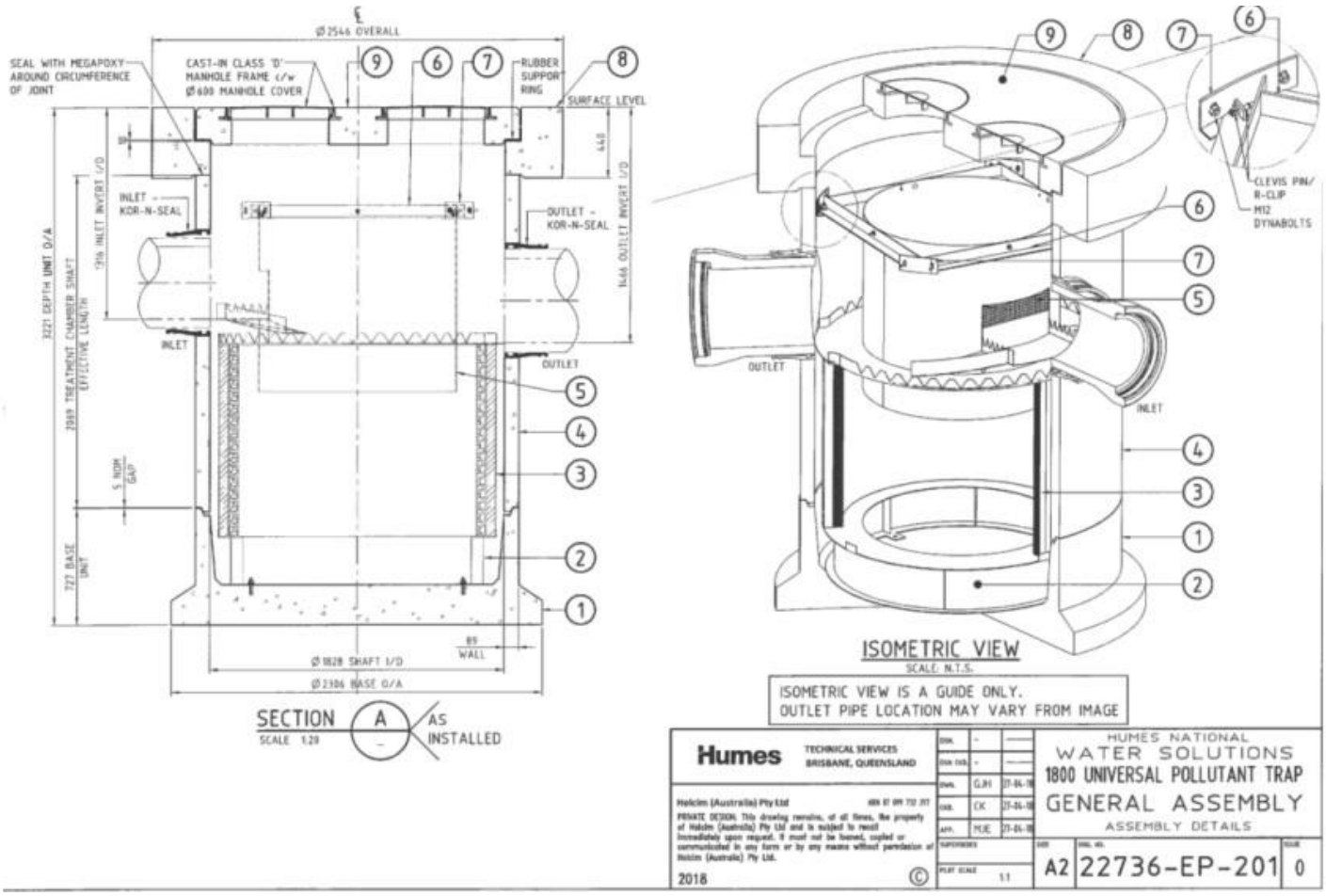
Climate Change Statement

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) 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 Holcim to have Stormwater Australia approve the HumeFilter treatment technology 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, Andrew Allan (Afflux Consulting) and Rod Wiese (Wiese Insight). As part of an internal Quality Assurance process, the report has been reviewed by Chris Beardshaw of Afflux Consulting.

Independent Evaluators were engaged by Stormwater Australia on a fee for service basis to carry out an independent evaluation of a HumeFilter device, which is known as the UPT1800.

The SQIDEP Detailed Performance Reports (Issue 1 and 2) were prepared by Drapper Environmental Consultants. Issue 1 was provided at the same time as the application for an evaluation. Issue 2 was subsequently provided some time later and is intended to supersede the original issue.

Evaluators Statement of Disclosure

Rod Wiese, while working at STORM Consulting makes it known that STORM was engaged to investigate potential locations for field testing to occur in the Melbourne area. This also involved a visit to a laboratory to gain an appreciation of the physical construction of the device. As the nature of the engagement was limited to a specific ancillary task and subsequently no Melbourne site was selected, it should not constitute a conflict of interest and is mentioned to satisfy full disclosure.

Evaluators Declaration of Independence

It is declared that both evaluators, Andrew Allan and Rod Wiese, are completely independent and neither Independent Evaluator has any conflict of interest with respect to this engagement.

They are not, nor have ever been employed or commissioned by the Applicant, Holcim. They have not been involved in the design or development or monitoring of the HumeFilter device and have undertaken this assessment without prejudice and in good faith.

Background

The application submitted by Holcim was preceded by a QAPP (Quality Assurance Project Plan – HumeFilter UPT1800 Issue 1, May 2022) that was reviewed and approved by the same evaluators. This occurred in October 2022.

The subsequent reporting has been provided for review. It includes the SQIDEP Detailed Performance Review Report and related video files. These documents are further described later in this report.

Alignment with QAPP

At the outset, a submission under SQIDEP has to adhere to Quality Assurance procedures, which has occurred in this case.

Section 3 of this report addresses the field monitoring in reference to the approved QAPP.

The assessment concludes that there is good concurrence of the Detailed Performance Report Issue 2 with the Quality Assurance Project Plan – HumeFilter UPT1800 Issue 1 (May, 2022).

Independence of Monitoring Scientist(s)

The SQIDEP Detailed Performance Report has been prepared by Drapper Environmental Consultants (DEC).

The Report clearly outlines contractual relationships between Holcim and DEC, which is appropriate for the testing.

DEC staff have provided statutory declarations attesting to the roles of staff with respect to testing and involvement at various stages of the work program. The staff involved (Darren Drapper and Connor Walsh) are known to have been involved in field monitoring and project management from the field data reviewed.

The report and supplementary information outlines additional contractor involvement at various stages through Manly Hydraulic Laboratory (MHL) and Australian Laboratory Services (ALS).

Both these companies have specialist expertise that is appropriate for the tasks undertaken. MHL is understood to have undertaken prototype testing to confirm (hydraulic) design parameters for the device that was ultimately deployed for testing.

ALS is a specialist laboratory providing analytical testing services for chemical and related parameters. ALS operates under NATA accreditation and provides a comprehensive quality assurance program for testing it undertakes.

Given the nature of tasks performed, Evaluators do not believe that MHL or ALS are in a position to bias field testing, and as such no further documentation is required from these entities.

Based on these considerations, the requirement for Independence of Monitoring Scientists is satisfied.

2. Assessment

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).

Review Documents

The following documents form the basis of this independent evaluation:

- SQIDEP Detailed Performance Report 31/01/23 (Issue 1) (superseded)
- SQIDEP Detailed Performance Report 22/03/23 (Issue 2) (current)
- Appendix C – iAuditor Sample Collection Reports_Timelapse Videos
- Appendix D - ALS Lab testing documentation
- Appendix E – Hydrographs
- Appendix F - Statutory Declarations
- Appendix H - Lab Testing Reports

The following files and documents were also provided:

- Dirty Water Test.MP4
- Filter_S04pc_Q0100_view1_hiRes.avi
- Filter_S04pc_Q0100_view3_hiRes.avi
- Hume Filter_Animation.MP4
- Humes UPT.ppt
- Stormwater Quality Lab Testing- Final Report
- Manly hydraulic testing

Additional information was requested after a meeting between the evaluators and applicants, which was chaired by a senior representative from Stormwater Australia. This has also been reviewed and includes:

- Additional laboratory Quality Assurance information in the form of Sample Receipt Notices
- Sizing spreadsheets supplied on a confidential basis for the purpose of this review
- Additional information on maintenance procedures

Further information was provided on 30th May 2023, upon requests related to the permeability of the pleated filter (PET Non-woven). This included:

- Technical Data – PET Non-woven Filter Media
- Cover letter from Matthew King of Filquip Pty Ltd claiming the material is appropriately permeable

Holcim HumeFilter (application summary)

The Holcim HumeFilter UPT1800 was submitted for evaluation against the SQIDEP protocol on 1 February 2023. Operation and testing of an HumeFilter UPT1800 device installed at 20 Service Street, Maroochydore (Queensland) was conducted over the period from April 2022 through to March 2023.

DEC staff were responsible for commissioning, operation and maintenance of the system as well as collected and prepared samples in response to rain events. Analytical testing was conducted at ALS laboratory.

The field testing was undertaken in line with the Quality Assurance Project Plan reviewed by independent evaluators and signed off.

The independence of Holcim agents involved in the reporting and sampling process has been demonstrated by Statutory declarations provided by personnel involved in the process.

According to the claim submitted, the HumeFilter is a *'new technology incorporating hydrodynamic and filtration into a compact, precast concrete package. A family of models ranging in size from 1200mm to 3600 mm diameter contains a Filter mechanism which includes zones to target a range of pollutants based on physical and chemical parameters. The device is intended to be located offline from the main stormwater flow path, with low flows diverted into the device re-entering after treatment has occurred.'*

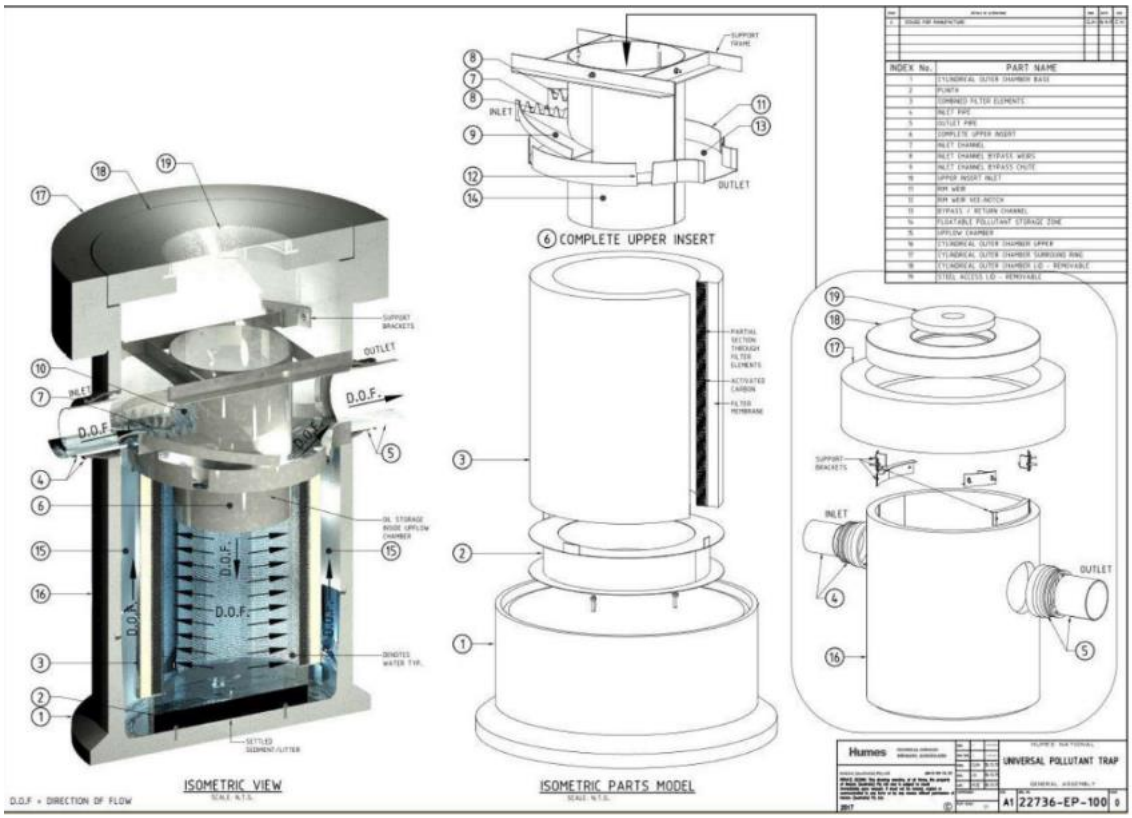
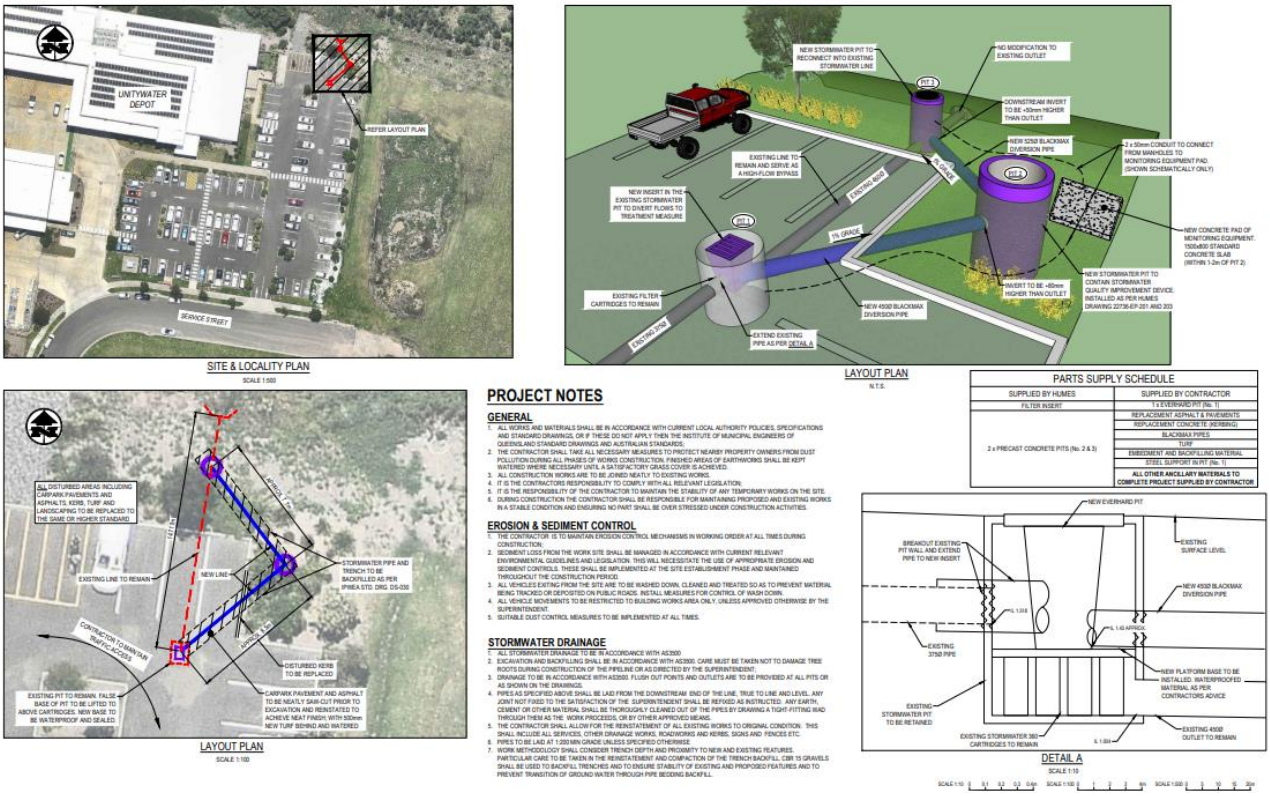


Figure 1. HumeFilter schematic design

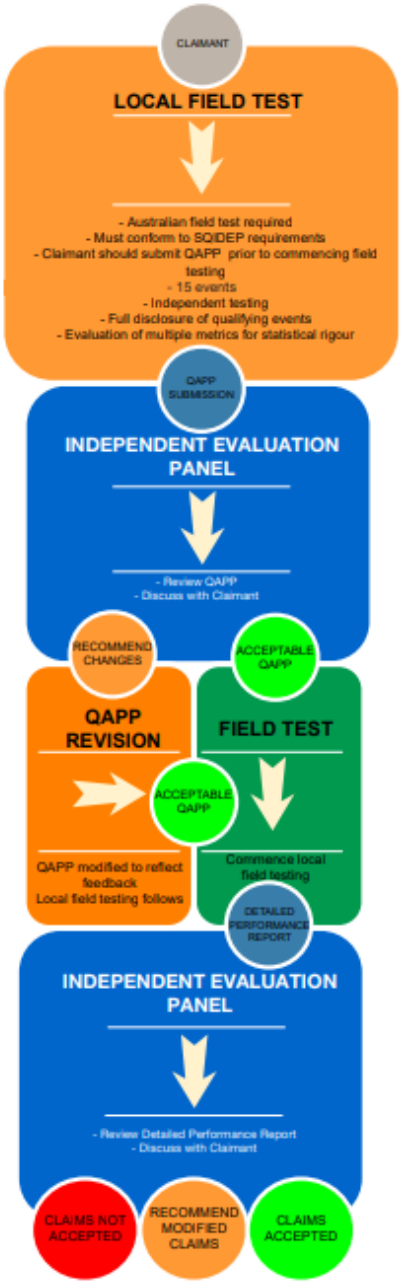
Particulars on the catchment area, characteristics, design, installation of the HumeFilter UPT1800 and sampling location is contained in reference documents prepared by Bligh Tanner and provided for review, as shown in Figure 2.



Source: *Bligh Tanner*

Figure 2. HumeFilter sample setup

Under the SQIDEP protocol, there are separate pathways to demonstrate whether a device is able to achieve pollutant reduction under field conditions. This claim is being assessed under the Field Evaluation pathway, which includes an assessment of field testing/ monitoring across a range of storm events and independent evaluation of claims, as indicated in Figure 3.



Field Evaluation Pathway

Figure 3. SQIDEP Pathway- Field Evaluation

Performance Claim

The performance claim is stated in the application, while the subsequent DPR sought to revise these claims based on additional testing that occurred. The applicant felt that it provided a more robust dataset of statistical validity.

It should be noted that the claim has been made for treatment of metals species in addition to commonly regulated pollutants (i.e. as for compliance for Best Practice stormwater standards). The SQIDEP process was designed to be neutral in the extent of claims, provided a defensible methodology was presented and supported by results.

At the QAPP stage the intent to consider a claim for metals was indicated. As such we feel it is appropriate to consider claims for Copper and Zinc. Both the submitted and revised claims are provided in Table 1.

The performance claim for the family of devices ranging from UPT1200 to UPT3600 has also been included based solely on field trials of the UPT1800. However, it is noted that laboratory testing using synthetic stormwater has also been undertaken for the UPT1200 device, which can be considered in context.

For the purposes of assessment, the data provided from the Maroochydore Study will be reviewed to see if it satisfies the requirements of SQIDEP, although it is noted that there is significant background information submitted at the earlier QAPP stage, which provides additional context.

It should be noted that these claims are contingent on the device being sized (designed) and installed correctly, and with appropriate maintenance undertaken.

Table 1. Holcim HumeFilter pollution reduction claim

Pollutant	Removal claim (FE application)	Removal claim (revised in DPR Issue 2)
Total Suspended Solids (TSS)	88%	89%
Total Phosphorous (TP)	73%	75%
Total Nitrogen (TN)	47%	50%
Gross Pollutants	90%	90%
Copper	51%	57%
Zinc	53%	64%

It is noted that gross pollutants were not quantitatively tested, however the claim is made for a substantial reduction in this pollutant category. The QAPP included a methodology to capture visual evidence of influent and effluent streams. Based on the physical nature of the device and its mode of operation (i.e. water passing through the device is treated through fine filters, allowance for storage of material in a sump along with recommended clean out triggers and a restricted diversion flow rate into the device), it is expected that gross pollutants will be removed from the treated effluent stream and prima facie this could be considered a legitimate claim.

It should be noted that gross pollutants are likely to be washed downstream when the device is operating in bypass mode, unless they are removed prior. It is also noted that relatively little storage volume for captured gross pollutants is provided in the device. This limitation should be made clear in any promotional material.

Site Background and Assumptions

The catchment is a carpark adjacent to an active industrial facility of around 3,800m^2. During the testing period, it is expected this will have had typical traffic volumes with vehicles entering and exiting at shift changes. As a 'typical' site, we would expect the nature of vehicular attendance to be characteristic of many urban setting in terms of vehicle age and type.

SQIDEP intends that the 'use' of the testing area should have similar characteristics to the ultimate intended market for the product being tested.

As such the site is a reasonable proxy to urban settings and could equate to commercial carparks, road applications and other similar instances.

The assessment that follows will focus primarily on the ability of the treatment to address loadings. In higher utilisation sites, it could be expected that the longevity of the treatment could be questioned, but this would become an additional assessment of maintenance requirements (i.e. cleanout and replacement).

3. SQIDEP Compliance

Quality Assurance Project Plan

The SQIDEP Detailed Performance Report was compared to the Quality Assurance Project Plan. The independent evaluators deemed that the DPR was consistent with the QAPP as described below in Table 2.

Table 2. QAPP

Performance Claim Requirement	QAPP Commentary	Evaluator Response
Data Quality Objectives	Data quality objectives are not explicitly mentioned in the QAPP but are effectively covered in the Testing Protocol described under Section 4.3.1 which details sample collection and analytical methodologies.	The DPR sets out clear requirements for data quality requirements consistent with providing a statistically robust data set. This includes full disclosure across all events, including those that did not meet qualifying criteria for laboratory analysis.
Organisational roles and responsibilities	Organisational roles and responsibilities are articulated, although the role of DEC is noted as an intermediary between the claimant and the analytical contactor. It will be important to establish the independence of DEC throughout. In other reviews some form of attestation (e.g. statutory declaration) has been provided.	These have been adequately described and statutory declarations are well articulated and independently witnessed.
Description of test site	The test site has been adequately described and is considered appropriate for the testing proposed. Additional pollutants, if detected will need to be justified and further revisions to field testing could be included subject to agreement.	The test site is adequately described as a 'typical' carpark at an industrial facility. The presence of metallic pollutants is identified as from vehicles. The receiving environment is identified as a sensitive receptor and would appear to justify their inclusion.

Measuring rainfall	A tipping bucked pluviometer is proposed and capable of measuring rainfall in 0.2mm increments. It is noted that the Sunshine Airport BoM station is approximately 5.5km from the site and any data that can be obtained from this site could provide a useful point of reference	A tipping bucket pluviometer is provided and statutory declarations indicated it was calibrated in accordance with manufacturer instructions. The site is adequately described if additional data checks on storm occurrence and nature are required.
Storm events sampled	Storm events are sampled according to a programmed response to rainfall using an automated flow sampler.	Description of sample program and methodology is provided. It is noted that some adjustment to sample collection protocols to support obtaining hydrograph coverage within the limitations of sample collection equipment was required early in the field program. This should not affect the validity of the samples collected. and is satisfactory to achieve the requirements of SQIDEP.
Flow monitoring	Flow monitoring is into the device using an ultrasonic flowmeter. To substantiate flow rates information on any calibration or curve relationships between depth and flow should be provided, and calculated flow rates used for determining performance. No flow monitoring is proposed for outlet and is considered satisfactory based on the nature of the device (i.e. no alternate exit locations).	The flow monitoring is undertaken with an ultrasonic device that measures depth and velocity. It is understood the Starflow QSD 6527A has been installed (Drapper, *pers comm*). This device has been reviewed and is considered appropriate for the field assessment. Calibration of the device was undertaken in April 2022 and the certificates subsequently provided.
Sampling location	Sampling locations proposed upstream and downstream of the device.	Sampling locations are at the inlet and outlet to the device and are considered suitable.
Sampling equipment	Sampling equipment is automated flow sampler that activates a sample regime in response to rainfall.	Sampling equipment is able to collect sufficient samples to ensure good storm coverage in the majority of events. Sample program was adjusted early in field program to account for catchment rainfall response. The operation of the sampling equipment is described, along with regular maintenance activities to ensure correct operation. iAuditor files have been provided for events which provide evidence of site attendance and monitoring of sampling components.

	As the correct operation of this unit is critical importance, it would be useful to have specific information in the sampling equipment, including any operational methods that should be adhered to, and a statement attesting to this fact.	Statutory declarations provided include reference to monitoring and maintenance of equipment as required.
Sampling methodology	The sample methodology is considered appropriate to produce composite samples. The methodology is adaptable to respond to storms of varying duration, although it is noted that limitations will occur if storm events are excessively long.	Sample collection methodology is appropriate, and graphs presented allow a clear understanding of sample collection relative to storm duration. Where storm coverage is less than optimal this is indicated, and data provided.
Sampling Quality Assurance and Quality Control	The QAPP provides a description of the Quality Assurance Plan which contains information on the standards governing sample collection, handling and transport. On site filtering will be undertaken to assist in sample preparation, and Chain of Custody information will be maintained throughout. It is expected that sample preservation and transportation will achieve acceptable holding times form the various analytes and methods.	Site sample collection was in accordance relevant standards as provided in the report. Site records and laboratory submission data have been provided and minor discrepancies in dates between record sets satisfactorily explained. Metals were not proposed to be tested in the QAPP however the DPR has included this assessment for Copper and Zinc. In addition to the analytical program, field monitoring included the use of video capture of flow streams for the purpose of qualitatively assessing gross pollutants. These were used to capture flow condition at 30 second intervals based on the detection of movement.
Laboratory analysis	It is noted that the analysis of the sample will be undertaken at a NATA endorsed laboratory service which is accredited for analysis.	ALS was engaged to undertake required analysis. Full sets of relevant documentation have been provided.

Laboratory Quality Assurance and Quality Control	NATA endorsed laboratories undertake an internal set of quality assurance processes including duplicate testing, spike testing and blank testing. The Quality Assurance reports should be included in final documentation submitted to substantiate claims.	In addition to laboratory QA procedures, field methodology allowed for the collection of blind replicates for comparison testing. All relevant quality assurance documentation has been provided for review.
Data management	Data management is not explicitly covered in the QAPP, however it is apparent that there will be extensive documentation collected by the various automated processes (e.g. rain gauge, samplers) and through laboratory interface (e.g. CoC).	Data management is considered to be more than adequate for the purposes of this assessment. All information required to be supplied to assist with evaluation has been made available in a timely manner, is of high quality and generally internally consistent.
Reporting	It is expected that a report will be produced which is consistent with structure expected in the SQIDEP. We are familiar with the reporting templates which have been used by DEC on other SQIDEP assessment reports and expect that the data will be similarly presented.	Report has been prepared and provides an easy-to-follow format consistent with guidance tables provide in SQIDEP.

SQIDEP Assessment

The SQIDEP provides a structured framework in which to present evidence and information. Compliance with all elements of SQIDEP Table 3- Minimum data and qualifying event requirements for assessment (SA, 2019) can be used as a basis for determining if the Field Evaluation pathway has been met.

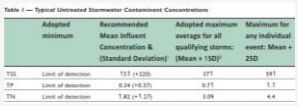
Table 3 provides and explicit assessment against each performance criteria, and has been prepared following receipt of supplementary information. Table 3 provides a status against each of the Performance criteria.

Note that while the initial USC testing included events that subsequently did not meet qualifying event criteria the data collected is none-the-less useful as it adds to the robustness of the entire dataset. As such, and where appropriate, this has been referenced.

Table 3. SQIDEP Assessment

Performance Criteria	Performance requirement	Monitoring action or result	Outcome
Min number of events	15 or enough to achieve 90% confidence interval	A total of 24 events were recorded. Statistical testing indicated that confidence interval requirements are met	Complies for TSS, TP and TN. Metals did not achieve qualifying event criteria.
Min rainfall depth	Sufficient to collect minimum sample volume for lab testing.	Sample volumes ranging between 1.0 and 9 litres, and are expected to be sufficient. The majority of samples have 2 litres or more based on quoted aliquot numbers. Some samples have requested a reduced range of analytical testing based on insufficient sample volume and will be considered in statistical/ sensitivity analysis.	Complies
Inter event period	Minimum 6 hours dry	This was achieved by 'locking out' sample equipment between events.	Complies
Device Size	1800mm chamber	The device is one of a family for which	Complies

		scaling relationship has been provided for both hydraulic performance (e.g. head loss) and contact time with treatment (filter) elements. Information has been provided to assess similar treatment parameters for other device sizing.	
Runoff Characteristics	Target pollutant profile of influent and effluent	This has been described in the report, and supporting videos and explanations provided.	Complies
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 30 l/s for the 1800mm family variant	3 events exceed 75% of TFR (22.5L/s) with a minimum of 8 aliquots on: 11th May 2022 21st Oct 2022 14th Feb 2023 2 events exceeded TFR with more than 8 aliquots: 11th May 2022 14th Feb 2023 An additional 2 events exceeded TFR with 5 and 7 aliquots respectively: 13th April 2022 25th April 2022	Complies
Automated sampling	Composite samples on a flow or time weighted basis	Sampling trigger was 0.6 mm rainfall within a rolling 30-min period. A flow volume of 1,000 L past the flow meter was also required to initiate subsequent sample collection. All subsamples collected during a runoff event were composited within the sampler in a 9 L bottle. Each	Complies

		subsample collected was ~200 mL.	
Minimum number of aliquots	80% of field test collections should have at least 8 per event.	Minimum number of aliquots was 5 and 7 and occurred early in field collection. 80% requirements met across the fill dataset.	Complies
Hydrograph coverage	At least 50% of qualifying storms should include the first 70% storm coverage	Visual inspection of storms indicate that hydrograph coverage is achieved.	Complies
Hydrograph coverage	Multiple peaks should be accounted for (at least 1 occurrence).	Visual inspection confirms this has been achieved.	Complies
Grab sampling	Not applicable	N/A	
Sampling locations	The locations must be upstream and downstream of the device to enable true assessment of water quality performance. There are also specific requirements for effective function of the monitoring equipment.	The locations are considered appropriate for this study.	Complies
Chemical and physical analytes	As identified in QAPP	Chemical tests and methodologies are appropriate	Complies
Min and Max concentrations within range	Refer to Table 1 SQIDEP repeated below 		
Analytical methods	NATA accredited sample handling and analytical methods	NATA laboratory used. Relevant QA documentation provided	Complies
Flow measurement location	Inlet, outlet and bypass as applicable	Flow measured at inlet. Due to physical nature of device outlet flow can be assumed to be same the same as	Complies

		inlet with minor storage delays.	
Precipitation measurement	A pluviometer is required	A pluviometer was utilised and results provided	Complies
Rainfall recording interval	5 minutes or less	Rainfall is recorded in 0.2mm tipping bucket	Complies
Rainfall recording increments	0.25mm adopted	Rainfall is recorded in 0.2mm tipping bucket	Complies
Pluviometer calibration	To be calibrated twice during the monitoring period.	Pluviometer was calibrated on three occasions	Complies
Performance indicators	The target pollutants and testing rationale must be described in the QAPP and Detailed Performance Report.	The QAPP was complied with.	Complies
Performance indicators	ER and CRE. If CRE average and median > 10% difference inspect dataset.	Statistical assessment has been provides in the report. Variance in CRE noted for TN species and factored into assessment process and conclusions. Significant variance was noted in Zinc analysis. This has not been pursued as a basis of claim.	-

Data Quality

The field collection of water samples is of critical importance and has been verified in several ways as follows:

- Detailed logs (iAuditor) were prepared at the time samples were collected and have been provide for review. These include photos of samples, sampling settings and information of any issues flagged. The relevant Laboratory Chain of Custody is provided for a reference.
- Chain of Custody information and Sample Receipt Notifications (SRN) from the laboratory. These draw a clear line of site from the field collection to the point at which the samples become the responsibility of ALS.
- Time lapse photography of effluent streams (taken at 30 seconds when triggered by movement).

For the laboratory data, we have been able to review the SRNs and check for evidence of sample integrity. The SRN include standard sections which confirm the sample receipt and temperature upon arrival, comments around whether samples have been collected in appropriate containers such as not to lead to deterioration in transit, and whether holding times have been met.

Sample arrival analysis is included in Table 4.

Table 4. Laboratory SRN and Quality Assurance summary

Arrival temperature				
At or below 6 degrees	Above 6 degrees			
17	10	Of the 10 samples above 6 degrees on arrival, 5 were within 2 degrees. Samples were chilled on collection, and as such the small divergences are unlikely to affect interpretation of results. Larger temperature divergences should be addressed through sensitivity assessment.		
Sample preservation and containers				
No compliance issues noted	Issues noted	Commentary		
23	4	Breaches related to the 'wrong' bottle being used. Laboratories provide sample containers for specific tests which are checked off upon arrival. It is possible to substitute containers in the field. Referencing photos in iAuditor with offending samples do not expect this to effect the interpretation of results.		
Holding time breaches				
No holding time issues noted	Issues noted	Commentary		
3	27	Holding time breaches in the main relate to pH, which is a parameter subject to rapid decay. Other breaches related to Nitrite (10), Dissolved Reactive Phosphorus (9) and Reactive Phosphorus (RP) and appear to be more the delay in instructions arriving at the laboratory.		

Taken as a whole the data quality is acceptable for the purposes of making comparative assessments between influent and effluent. Issues identified are considered minor and relate to the practicalities in conducting a real time field monitoring program.

Through statistical evaluation we should consider any identifiable trends in the datasets which have different holding time issues, although overall there appears to the requisite 15 samples for each individual parameter.

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.

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).

The concentration ranges for influent quality falls within the expected ranges when compared with previous studies, including aggregated data from other published SQIDEP assessments.

It is apparent that the quality of runoff from different locations is highly varied, however the range of influent pollutants compares favourably with other (published) SQIDEP data which has also gone through a similar process of data validation.

We also note mean TSS influent concentrations, at 160mg/L are approaching the default MUSIC road EMC values for a sealed road, and not untypical for a new well sealed road, mean TN concentrations at 1.75 mg/L are not far off typical MUSIC default values at 2.2 mg/L while the TP loads were considered to be about 50% of default MUSIC values for a sealed road.

Table 5. Typical pollutant concentrations for road catchments

	Duncan (1999) study	Drapper and Lucke (2015) study	Previous SQIDEP Assessments completed	Current study – HumeFilter
TSS (mg/L)	60 – 700 (n=42)	1.45 – 5800 (n=325)	15 – 357 (n=25)	14 – 419 (n=20)
TP (mg/L)	0.1 – 0.8 (n=25)	0.08 – 26 (n=325)	0.04 – 0.49 (n=25)	0.03– 0.92(n=24)
TN (mg/L)	1 – 9 (n=17)	0.38 - 8.5 (n=325)	0.3-4.0 (n=20)	0.2-4.2 (n=24)

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.

Data was log transformed and tested for normality distribution and concluded that the result pairs for TN were likely normally distributed, while for others not.

An explanation for the non-normality was provided, indicating that a number of samples were at or below the LOD, and therefore represented similar datasets.

Significance testing was performed on all datasets and concluded significance at the 90 percent level of confidence.

Limited sensitivity testing was undertaken by removing 'outlier' results likely to disproportionally influence the results, and to 'adjust' sample results that were at close to LOD by reducing these to 50% of reporting limits. The sensitivity testing showed minimal change in the magnitude of the treatment effect.

Typically stormwater concentration data is not normally distributed, as denoted from a Shapiro-Wilk normality test. Log_{10} 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.

In addition to the statistical analysis, the DPR report includes a range of reporting metrics and box plots for influent and effluent pairs which visually indicate a treatment effect.

As part of the review we have undertaken a simplified Paired Student T-test on raw data that was presented in the analysis above (i.e. no log transformation) and concluded similar order of magnitude treatment effect. These results are provided in Appendix A.

Reported Concentrations Analysis (Antecedent)

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 6 for three ranges of ADWP. These show a general trend to increased pollutant accumulation for longer antecedent periods.

Table 6. Comparison of Concentrations and Antecedent Conditions

	Sample Date	Antecedent Dry Period (days)	TSS (mg/l)	TP (mg/l)	TN (mg/l)
SHORT ADWP (<1 week)	10/05/2022	1	14	0.06	1.4
	11/05/2022	1	144	0.12	1.3
	22/10/2022	1	150	0.28	1.4
	5/07/2022	1	-	0.03	0.7
	21/07/2022	2	37	0.11	0.6
	30/11/2022	2	64	0.14	0.7
	21/10/2022	2	392	0.82	4.1
	23/05/2022	3	13	0.07	0.5
	4/07/2022	3	17	0.04	3.8
	20/05/2022	3	90	0.11	0.9
	12/07/2022	7	-	0.11	0.2
	19/07/2022	7	-	0.09	0.7
AVERAGE			102	0.165	1.358
MEDIUM ADWP (>1 month)	8/12/2022*	8	108	0.22	1.6
	19/10/2022*	9	79	0.42	1.9
	23/02/2023	9	419	0.62	3.4
	1/11/2022	10	416	0.92	3.7
	25/04/2022	12	47	0.04	0.5
	6/06/2022	14	44	0.28	0.9
	22/09/2022*	20	50	0.09	0.9
	14/02/2023	25	367	0.48	3.3
AVERAGE			191	0.384	2.025
LONG ADWP (>1 month)	20/01/2023	43	151	0.28	1.2
	2/09/2022	43	-	0.37	1.8
	13/04/2022	Initial sample	393	0.57	2.3
			272	0.407	1.7667

Sensitivity Analysis

Sensitivity testing has been undertaken to complement the assessments claimed in the DPR report.

Selected samples have been removed from the dataset based on various data quality indicators after an inspection of laboratory quality assurance documentation, while retaining a requisite number of events to allow statistical significance testing. Table 7 summarises the various sensitivity assessments and the likely impact on claimed removal rates.

Table 7. Sensitivity Assessment Summary

Sensitivity test undertaken	Description	Change	Implication
Removal of samples arriving at the laboratory with elevated temperatures	Samples listed on SRNs with elevated temperatures more than 4 degrees above laboratory recommended values	All changes in values are within 10%, and generally higher than full dataset.	Negligible and supports a conservative approach to claim.
Removal of samples with (technical) holding time breaches	Samples listed on SRNs with analysis requests received outside recommended holding times	All changes in values are within 5% and can be considered negligible when compared with full dataset.	Negligible

The design of the SQIDEP included a recognition that different performance metrics, may result in slight changes in overall assessment, but that it was important that across all performance metrics there was an observable trend to have confidence in the interpretation of results.

Sensitivity testing considered the implication of data quality in accordance with laboratory procedures to flag holding time and sample preparation criteria. It appears that technical breaches in sample delivery have not resulted in significant differences that would affect the interpretation of results. Inclusion of the full dataset provides more conservative claim basis.

This approach was enabled due to the presence of supporting and contemporaneous information from both the laboratory and in-field records.

Rainfall Review

Rainfall data was collected at the site in a pluviometer for nearly a year. This was presented as a graph in Appendix A of the DPR report. The same period of record was obtained from the Sunshine Coast Airport (station 040861) as graphed independently. The comparison is shown below in Figure 4 and Figure 5. There are notable differences in the rainfall data however these are readily explained by the fact that the BOM data is accumulated into daily data as well as being in a different location. Given these facts the rainfall data appears to correlate quite well and there is a high level of confidence in the site records.

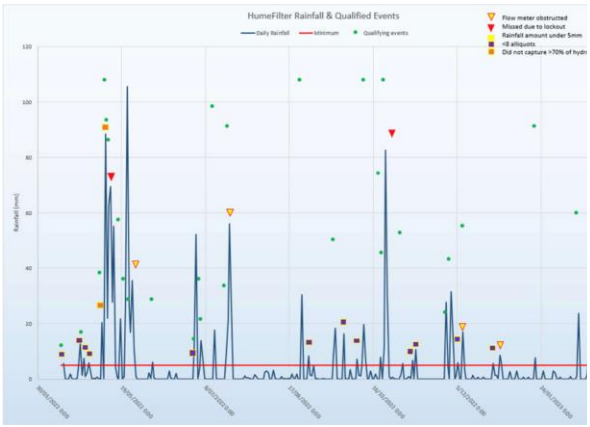


Figure 4. Site rainfall data

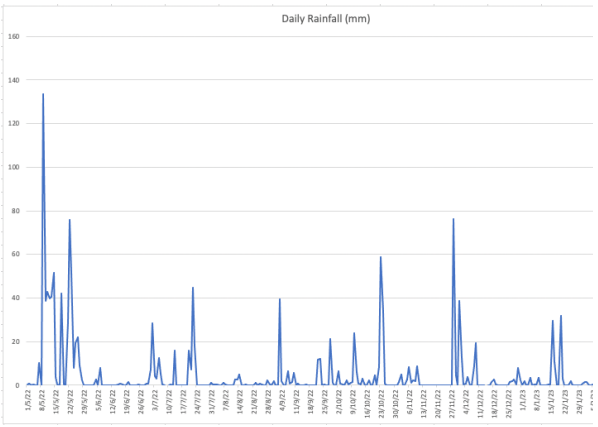


Figure 5. BOM data from Sunshine Coast airport

Cherry Picking of Storm Events

SQIDEP v1.3 does not explicitly require that sequential storm events be monitored and reported however it is prudent to examine the likelihood of “cherry-picking” storm events that may over-state the actual performance of the device.

Figure 4 above provides a good graphic of the non-qualifying events (with explanation) that strongly suggests that there is no cherry picking of storm events.

Scalability and Hydraulic Loading Rate

The applicant has requested consideration for a family of devices with a total of 6 units ranging from 1200mm diameter to 3600mm diameter and the size of the unit tested is 1800mm. The treatable flow rate for each of the sizes has been determined by Holcim to be limited to achieve a specific contact time with the media located between the perimeter screens.

From the information submitted we understand the treatment effect is based on a combination of treatment area and contact/ residence time. Sizing spreadsheets have been provided on a confidential basis to assist with assessments.

The controlling factor for sizing relationships appears to be the volume of the GAC component which is varied in annular thickness to achieve a similar design criteria across all device sizes in the family.

Data provided shows that the media treatable flux for the family of devices remains relatively consistent varying only 2-3% which could also be influenced by rounding errors. While the evaluators are not qualified in areas of chemistry, our understanding of the behaviour of media is that it able to assimilate chemicals based on contact. While considered novel in a stormwater application these GAC technologies are widely used in wastewater and odour control where there is established practice to increase the contact volume for different treatment flow rates. As such, it is appears a reasonable basis that the media/GAC volume is used to provide the flow claims, but we would feel comfortable if additional evidence was provided to support this.

The increase in pleated filter area for the larger devices is not as profound as the media volume. Instead of maintaining the flux rate, the pleated filter flux increases as the size device size increases. The UPT3600 has a pleated filter flux 2.5 times that of the UPT1800 that was field tested. This does raise concerns where the pleated filter can become the hydraulic control therefore restricting flows to the media and reducing the TFR. There has been no evidence provided that the increased flux has been tested and therefore the applicant was questioned on this matter.

A letter and datasheet was subsequently provided on 30th May 2023 from Filquip Pty Ltd who claim that the permeability of the pleated filter is 400L/m2 /s (@ 200Pa) which is assumed to be utilised in the family of devices. This would allow up to 99.9% blockage to occur in the UPT3600 with a hydraulic head of approximately 20mm before the TFR is compromised. Although no testing of this has been provided the assessors are satisfied that the assumptions are very conservative and deemed suitable in this application.

Similarly, the internal screen is not included as it is assumed that this is quite pervious and unlikely to restrict flows. However, it is noted that the flux rate per square meter increases dramatically such that the larger devices would be more susceptible to blockage.

Note: A Table on device scaling relationships has been removed from the original evaluation report in order to protect the intellectual properties of the devices as requested by the applicant.

MUSIC Node

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry standard software program that is widely used in Australia for the sizing and conceptual design of stormwater treatment trains.

As such, it is appropriate that some guidance is provided to enable the proposer inclusion of Holcim HumeFilter in a stormwater quality modelling environment.

The Holcim documentation report provides an approach to developing a MUSIC node based on pollutant reduction and bypass rate at 30 litres/ second. In each case the reduction on pollutants is essentially a straight-line function for each of the pollutants and is modelled as a generic node with reduction appropriate reduction values.

Bypass parameters should be set as appropriate for each size of device in the family. The configuration proposed in the report is satisfactory if these conditions are included.

The MUSIC node accurately represents the reductions for TSS, TP and TN for the tested device. MUSIC nodes for other devices in the family should be adjusted to account for variance in the TFR (as per section of device scaling).

The reviewers have reservations with the claim relating to Gross Pollutants. In particular, the ability for the device to store captured Gross Pollutants has not been optimised and will affect maintenance operations.

Table 8. MUSIC node verification

Pollutant	Influent range	Effluent Range	Reduction
Total Suspended Solids (TSS)	1000	110	89%
Total Phosphorous (TP)	5	1.25	75%
Total Nitrogen (TN)	50	25	50%
Gross Pollutants	Noting limited storage		90%

No information has been provided on metals, however it is noted that, in addition to defining the transfer function for pollutant reductions if these are eventually verified, there will be a corresponding requirement to develop pollution generations for different catchment types.

Evaluation of Enduring Performance

The Independent Reviewers have endeavoured to consider the long-term enduring performance of the HumeFilter Device.

Volume storage

The nominated maintenance regime seems appropriate but clearly depends on the nature of the catchment. If there is considerably more sediment or gross pollutant loading expected then the unit will require more frequent maintenance if an upstream sediment capture device is not installed. The storage volume of the UPT is limited as it is not focused on gross pollutant removal and therefore primary capture would be recommended upstream if higher loadings are expected.

Media replacement

The media comprising granulated activated carbon (GAC) pellets have a finite number of sites for adsorption and other processes. The suggestion is to change this every two years however this is not based on any scientific assessment. The evaluators believe this maintenance regime to be sufficiently conservative.

Subsequent to the briefing meeting the applicant confirmed that the lifespan of the GAC is greater than the 2 years suggested. A separate spreadsheet has been provided for review which provides information on 'average' influent concentration for major pollutants and base exchange capacity for the GAC (i.e. how much it can remove on per weight basis) and typical loading rates. These suggest that the devices could operate effectively for a prolonged time (i.e. decades) and as such we are satisfied that the indicated maintenance and inspection period is conservative.

Although GAC is widely used in various water treatment systems it's use in stormwater field may be considered novel. As such it worthwhile to undertake the required chemical analysis in future to better estimate lifespan of the media so that an efficient media replacement regime may be defined.

From discussions with the claimant, we understand the GAC to be an 'off the shelf' product that can be purchased direct from the device supplier or any other reputable source, however it would be beneficial to include GAC specifications if these were to be sourced independently of Holcim. We note that these have been provided (i.e. Acticarb EA1000- 4,0mm (Bureau Veritas IS) 9001 Certification indicated).

Filter backwash

Holcim recommend dumping of 2000L of water for backwashing. Additional specification on this is recommended as the "dumping" rate may vary considerably from contractor to contractor. A slow rate would likely be inadequate to effectively wash the filter and therefore more rigorous specification would benefit the enduring performance of the filter.

Subsequent to a review meeting with the applicant, a backwash rate of 5-10L/s for a volume of 2,500 - 5,000L has been recommended. This is considered sufficient for device tested (UPT1800) where the backflush rate is approximately 20-30% of the TFR and about the same volume of the unit.

Further consideration is recommended for backwash specification for the remaining family units to aid in effective maintenance procedures.

Filter replacement

The cartridge filter is able to be replaced independently of the media component. In the event that the filter becomes clogged it is possible to remove this and replace it with a new supply from the manufacturer or if preferred, from a third-party supply.

It is noted however that the specification of the filter material is fundamental to achieving the contact time for water passing through the media layer and has been determined from the laboratory testing completed at MHL.

As such there is a relationship between the hydraulic and water quality treatment performance which should remain 'in balance' for the device to function as intended.

As with the media component it would be beneficial for HOLCIM to monitor the performance of filter elements over time and to build up a database of applications and cartridge longevity.

Discussion

Our independent evaluation finds that:

- The field study for the UPT1800 appears to be a scientifically sound study and would be repeatable under similar conditions which it is noted are deemed representative.
- As shown in Table 2, the testing regime and results for key pollutants do comply with SQIDEP protocol requirements.
- In addition, the catchment parameters, expected runoff concentrations, and rainfall mapping to event recording are within standard, or expected guidelines. The site appears to have been occupied during the testing period, and no significant disturbances were identified in a review of aerial photographs taken during the monitoring period (5). In addition, the influent concentrations suggest the site is comparable with other field testing undertaken on other SQIDEP assessments and is considered “clean” or lightly loaded relative to default EMC values adopted in MUSIC. This implies that, based on diminishing returns, the performance claims are more difficult to achieve and therefore conservative.
- Based on the device tested and field results we are comfortable with recommending the claimed treatment removal rates of the UPT1800 for non-metal pollutants.
- For other devices in the family we note that here are in effect two data points for the device, that is UPT1800 (field) and UPT1200 (laboratory).
- The evaluation of laboratory test data does not explicitly follow the requirements of the SQIDEP against which this evaluation is made, however it does appear to be a credible piece of work that should carry some weight. As such it has been included in this review to assist in substantiating the scale relationship between family devices which are predicated on media volume and contact times.
- As a novel application of GAC we feel that the confidence in the device will be enhanced though additional bench scale testing (i.e. column testing) of GAC. We acknowledge that some laboratory testing has been completed for a smaller device and can be used to establish a level of confidence in the scaling relationships at the lower end of treatable flows that will be enhanced if it can be established though a complementary process to apply to all scale ranges.
- As such we recommend offer a provisional acceptance of TFR as indicated, with Stormwater Australia to engage with the applicant to determine a pathway and timeline for this to be upgraded/ verified. This may not require the same level of field testing if an agreed laboratory pathway is confirmed.
- We have not determined the effective life span of the treatment elements (namely media and filter) however have note that a maintenance regime is recommended that will allow the effective performance of these elements. This may be optimised with further monitoring.
- The SQIDEP protocol does not assess the effective life of the media and is unable to verify any claim by the supplier in this regard.
- Maintenance regimes have been recommended and largely rely on back flush of the device. Rates and volumes provided for the UPT1800 seem appropriate and further clarification is sought regarding the larger devices.
- Periodic replacement of filter cartridges can occur, as too the media component. From our understanding of the device operation of any replacement of filter elements should require an

'exact' specification to ensure that residence and contact times within the device are maintained for full treatment effect.

- Based on information provided the device is likely to perform well for typically expected service life (i.e. several years) when deployed in similar situations. Nonetheless HOLCIM should provide guidance on how and when the viability of media should be measured as part of its operational guidelines.
- We did not find evidence of cherry picking of storm events.
- The final claimed Pollution Reduction Performance was developed after consideration of sensitivity of testing results to slight changes in protocol parameters and ensures a robust claim.
- The final claim for TSS, TP and TN removal for the UPT1800 has been revised from the initial submission and includes additional data. Table 9 provides an outcome of our evaluation for key regulated pollutants.
- The claim for Gross Pollutants is supported with reservation as the storage size has not been optimised for capture/storage of gross pollutants (e.g. collection sump sizing).
- Any acceptance of the Gross Pollutant claim should be qualified along with guidance on the intended function of the device. This should include commentary on the volume of the internal storage chamber and its ability to accept catchment loadings, and implications for maintenance intervals.

Table 9. HOLCIM HumeFilter performance claim

Pollutant	Final Claim (DEC report)	Outcome
Total Suspended Solids (TSS)	89%	Accept*
Total Phosphorous (TP)	75%	Accept*
Total Nitrogen (TN)	50%	Accept*
Gross Pollutants	90%	Limited storage

**for the UPT1200 and UPT1800 device configurations. Recommend provisional acceptance for other family sizes subject to additional laboratory data being presented.*

Holcim have also requested the claimed performance of both Copper and Zinc reductions be assessed. Table 10 shows the requested reductions and the sample pairs contained in the DPR report (version 2).

Table 10. Metals performance claim

Species	Performance claim	Number of samples
Copper	57%	13
Zinc	64%	11

Neither of the metals species has provided a minimum of 15 samples, and as such will not be able to satisfy the same statistical requirements for other pollutants.

As such we have no choice but to reject these claims and recommend that additional testing be undertaken to augment the dataset.

Further considerations for metals

As the assessment of metal species is novel in the respect that it falls outside the normally regulated dataset we feel that additional consideration is warranted.

Copper and Zinc are different form TN/ TP etc as they can be toxic at elevated concentrations when in the dissolved phase. Nutrients are generally not toxic, but at high concentrations in receiving water environments will impact on ecological health.

It is envisioned that the proposed treatment system will remove Metals by a combination of:

- Deposition (i.e heavy particulate matter resident in sump)
- Adsorption into GAC
- Physical removal of material through particulate in filter.

Depending on the water chemistry there may be some movement between these partitions and will be influenced by a range of factors that may be impractical to fully quantify.

For the majority of stormwater events rainfall is expected to fall at close to neutral or be slightly acidic. As such it can be expected that there will be some mobilisation of metals species into an aqueous phase. There may be site specific factors that affect water chemistry which could further influence the mobility of metal species.

The testing undertaken appears to have been on total metals, and will account for removal of both particulate and dissolved metals. Based on the expected treatment mechanisms it is likely that physical removal of solid components could make up the majority of these removals, and no targeted testing data has been provided to provide an alternate interpretation.

Without this additional evidence it is difficult to draw definitive conclusions.

Stormwater Australia are developing a complementary laboratory protocol, so there is scope to use these processes to assist in gaining a better understanding of the relative contribution of treatment processes as follows.

- Bench scale laboratory testing is undertaken
- Synthetic storms recipes are selected (2-3) and influents prepared. These should be based on an assessment of aqueous component that would bypass the sump. A residence time/ Stokes Napier relationship should be used to determine these.
- Sufficient volumes of the chosen storms to pass through a treatment train of GAC and 20 micron filter with design residence times (~12seconds). The MHL data can be used to size this. The size of the treatment elements should be based on a ‘flux’ basis and an assessment of the expected lifetime of elements based on loadings.
- Effluent samples are collected and analysed for both total and dissolved phase analysis and should give treatment effect. Under controlled laboratory conditions it should be possible to ensure all necessary sample preparation and preservation requirements are undertaken to increase confidence in accepting results.
- After the experiment, the GAC and filter should be chemically examined to establish any mass balance relationship between influent, retained (GAC and filter) and effluent.
- Reporting on these results would form the basis of accepting a more definitive claim.

Limitations of Acceptance

The limitations of the acceptance of these testing results include:

- The treatable flow rates and associated performance claims for the family of devices are provided in Table 11. These should be considered as provisional and for full acceptance supplementary laboratory testing should be considered.

Table 11. Pollutant Removal Performance

Device Designation	TFR (l/s)	Pollutant Removal
1200	12	TSS 89% TP 79% TN 50%
1800	30	
2400	55	
3000	100	
3600	160	

- 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.
- The results are reliant on the maintenance of the device being consistent with the manufacturer's guidelines and those that are contained in the report.
- The life expectancy of the device and the media is unknown although it is expected that regular monitoring and maintenance will be a useful tool to predict when replacement elements are required.
- Performance is contingent upon the installation being similar to that shown in this trial. 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.

Conclusions

HOLCIM have submitted for assessment a Field Evaluation to demonstrate that performance claims for the HumeFilter proprietary device have been tested.

Evaluators have reviewed the supplied material and concluded that the HumeFilter UPT1800 is capable of achieving removal rates for TSS, TP and TN at the tested scale and loadings. Laboratory evidence has been provided for the next smaller size device in the family which would support the treatment performance and the flow rate/ flux loadings across the media treatment element, but as a novel application we have recommended a provisional acceptance subject to separate laboratory testing.

Evaluators have not found sufficient evidence to support the reduction in metals species and have recommended additional methods to support these claims.

The reduction in Gross Pollutants is accepted with reservation due to the limited storage capacity and it is suggested that it should not be marketed as a primary GPT.

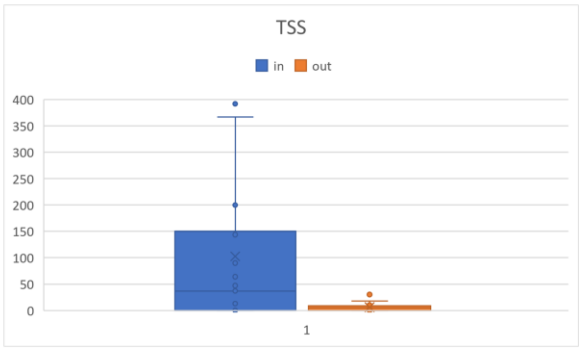
Refining specific backflush requirements in terms of flowrates and volumes for the larger devices is recommended as more experience is gained.

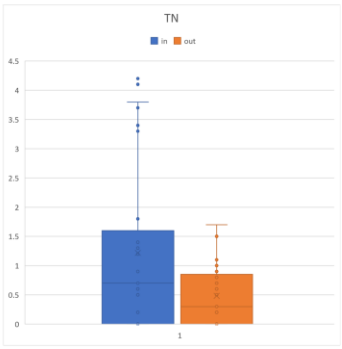
4. References

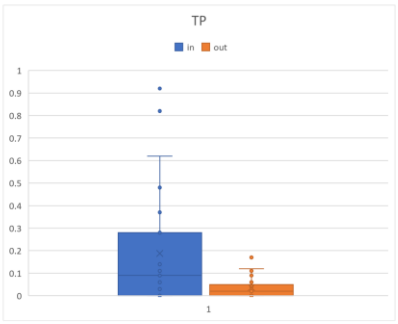
Stormwater Australia, Stormwater Quality Improvement Device Evaluation Protocol v 1.3, Stormwater Australia, 2018

Appendix A - Statistical analysis and confirmation

SQIDEP Evaluation- HumeFilter.
Statistical Summary. Data Supplied (n=16- 20)







Descriptive Statistics	TSS		TP		TN	
	in	out	in	out	in	out
Mean	160.31	9.6875	0.2725	0.0525	1.765	0.7
Standard Error	38.197	1.6875	0.0594	0.0094	0.3121	0.1044
Median	117	7.5	0.13	0.04	1.25	0.55
Mode	#N/A	5	0.11	0.04	0.7	0.3
Standard Deviation	152.79	6.75	0.2658	0.042	1.3956	0.4668
Sample Variance	23345	45.563	0.0706	0.0018	1.9477	0.2179
Kurtosis	-0.875	4.88	0.8207	2.0079	-1.123	-0.266
Skewness	0.853	2.0647	1.2905	1.4114	0.776	0.8486
Range	406	25	0.89	0.16	4	1.5
Maximum	419	30	0.92	0.17	4.2	1.7
Minimum	13	5	0.03	0.01	0.2	0.2
Sum	2565	155	5.45	1.05	35.3	14
Count	16	16	20	20	20	20
Geometric Mean	91.049	8.1937	0.1689	0.0382	1.2729	0.5602
Harmonic Mean	47.025	7.2286	0.1055	0.0267	0.8939	0.4471
AAD	124.05	4.8594	0.2078	0.0305	1.1945	0.38
MAD	124.05	4.8594	0.2078	0.0305	1.1945	0.38
IQR	199.5	7.25	0.3125	0.0425	2.625	0.625

SQIDEP Evaluation- HumeFilter.
Statistical Significance.
Supplied data (n=16, n=17)

T-TEST (2 DATASETS, UNEQUAL VARIANCE) ALL DATA

TSS

t-Test: Two-Sample Assuming Unequal Variances

Significance Level	0.1

	Variable 1	*Variable 2*	
Mean	160.3125	9.6875	
Variance	23344.62917	45.5625	
Observations	16	16	
Hypothesized Mean Difference	0		
df	15		
t Stat	3.939491438		
P(T<=t) one tail	0.000655646		
t Critical one-tail	1.340605608		
P(T<=t) two tail	0.001311292		
t Critical two-tail	1.753050356		is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

TP

t-Test: Two-Sample Assuming Unequal Variances

Significance Level	0.1

	Variable 1	*Variable 2*	
Mean	0.2725	0.0525	
Variance	0.070630263	0.001767105	
Observations	20	20	
Hypothesized Mean Difference	0		
df	20		
t Stat	3.656590179		
P(T<=t) one tail	0.00078395		
t Critical one-tail	1.325340707		
P(T<=t) two tail	0.001567901		
t Critical two-tail	1.724718243		is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

TN

t-Test: Two-Sample Assuming Unequal Variances

Significance Level	0.1

	Variable 1	*Variable 2*	
Mean	1.765	0.7	
Variance	1.947657895	0.217894737	
Observations	20	20	
Hypothesized Mean Difference	0		
df	23		
t Stat	3.236534449		
P(T<=t) one tail	0.001822816		
t Critical one-tail	1.31946024		
P(T<=t) two tail	0.003645633		
t Critical two-tail	1.713871528		is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

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SQIDEP Evaluation- HumeFilter.
Statistical Significance.
Sensitivity 1- remove elevated arrival temperature (n= 17)

T TEST (2 DATASETS, UNEQUAL VARIANCE) SENSITIVITY 1

TSS

Significance Level	0.1

t Test: Two Sample Assuming Unequal Variances

	Variable 1	*Variable 2*	
Mean	153.8235294	10.11764706	
Variance	22601.40441	45.86029412	
Observations	17	17	
Hypothesized Mean Difference	0		
df	16		
t Stat	3.937233106		
P(T<=t) one tail	0.000588856		significance
t Critical one tail	1.336757167		0.1
P(T<=t) two tail	0.001177711		
t Critical two tail	1.745883676		Is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

TP

Significance Level	0.1

t Test: Two Sample Assuming Unequal Variances

	Variable 1	*Variable 2*	
Mean	0.307058824	0.053529412	
Variance	0.075197059	0.002011765	
Observations	17	17	
Hypothesized Mean Difference	0		
df	17		
t Stat	3.762004771		
P(T<=t) one tail	0.000776944		
t Critical one tail	1.33337939		
P(T<=t) two tail	0.001553888		
t Critical two tail	1.739606726		Is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

TN

Significance Level	0.1

t Test: Two Sample Assuming Unequal Variances

	Variable 1	*Variable 2*	
Mean	1.982352941	0.764705882	
Variance	1.967794118	0.226176471	
Observations	17	17	
Hypothesized Mean Difference	0		
df	20		
t Stat	3.389459774		
P(T<=t) one tail	0.001455625		
t Critical one tail	1.325340707		
P(T<=t) two tail	0.00291125		
t Critical two tail	1.724718243		Is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

SQIDEP Evaluation- HumeFilter.
Statistical Significance.
Sensitivity 2- remove technical holding time breaches (n=16- 17)

T TEST (2 DATASETS, UNEQUAL VARIANCE) SENSITIVITY 2

TSS

t Test: Two Sample Assuming Unequal Variances

Significance Level	0.1

	Variable 1	*Variable 2*	
Mean	159.375	12.75	
Variance	23025.71667	77.13333333	
Observations	16	16	
Hypothesized Mean Difference	0		
df	15		
t Stat	3.858648665		
P(T<=t) one tail	0.000773185		significance
t Critical one tail	1.340605608		0.1
P(T<=t) two tail	0.00154637		
t Critical two tail	1.753050356		is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

TP

t Test: Two Sample Assuming Unequal Variances

Significance Level	0.1

	Variable 1	*Variable 2*	
Mean	0.308235294	0.06	
Variance	0.061302941	0.00205	
Observations	17	17	
Hypothesized Mean Difference	0		
df	17		
t Stat	4.066348527		
P(T<=t) one tail	0.000401557		
t Critical one tail	1.33337939		
P(T<=t) two tail	0.000803114		
t Critical two tail	1.739606726		is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES

TN

t Test: Two Sample Assuming Unequal Variances

Significance Level	0.1

	Variable 1	*Variable 2*	
Mean	1.970588235	0.870588235	
Variance	1.544705882	0.252205882	
Observations	17	17	
Hypothesized Mean Difference	0		
df	21		
t Stat	3.38340331		
P(T<=t) one tail	0.001402602		
t Critical one tail	1.323187874		
P(T<=t) two tail	0.002805205		
t Critical two tail	1.720742903		is t stat < Critical
			One Tailed YES
			Two Tailed YES
			Equal Variance check YES