DEVELOPMENT OF A LOW COST HIGH EFFICIENCY STORMWATER LITTER TRAP

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ABSTRACT (200 WORDS MAXIMUM)

Every summer New Zealand newspapers are filled with stories about the amount of litter and debris on our beaches. The major source of this is urban stormwater systems, where every catchpit eventually drains to the sea.

This paper discusses the process and development of a catchpit insert specifically designed to focus on gross pollutants. The other focus of the design was to make a stormwater litter trap that could easily be hand maintained and is affordable; therefore promoting greater uptake by the public.

Developing a stormwater management device is not easy; each contaminant in stormwater has its own removal issues. The contaminant removal issues associated with gross pollutants are as the following:

- Size of the contaminants
- Variable buoyancy
- Decay and release
- Transported load and structural and maintenance implications
- Gross pollutants do not exhibit a first flush phenomena

The paper also discusses the process and observations of the laboratory and field testing and how this a required element in the development to ensure the device would perform in a range of applications and weather conditions

KEYWORDS

Stormwater treatment, Gross Pollutant trap, Catchpit insert, laboratory and field testing

PRESENTER PROFILE

Mike Hannah has 23 years experience in stormwater management. Mike is the technical director of Stormwater 360 New Zealand and co-inventor of the Enviropod Catchpit Filter. Mike has presented his research at conferences in USA, Australia and NZ. Mike with so many year experiences for a young man (41) Mike has devoted his professional life to find solutions to New Zealand’s number one environmental degrader.

1 INTRODUCTION

Over the last 20 years there has been much research both here in New Zealand and overseas into evaluating and improving the performance of the standard roadside catchpit or catch basin.

In 1996 Enviropod New Zealand released the catchpit filter the 'Enviropod.' Fitted with a 200-micron filter the system was designed to capture suspended sediment. In 1998 EnviroPod NZ installed 150 EnviroPod filters fitted with a 3.5 mm screen into Brisbane city to capture gross pollutants.

In 2002 Auckland City Council, Tonkin and Taylor and Auckland University carried out evaluation of four types of commercially available catchpit inserts to ascertain their suitability as an alternative to the proposed pond for use in the Oakley Creek catchment and also as an alterative to the proposed dredging of a settling basin for the CBD catchment to be constructed at Captain Cook Wharf. The study involved a qualitative field assessment and a quantitative laboratory assessment determining the removal efficiency of the inserts at removing different size particles.

This study concluded that the EnviroPod with a 200 micron bag could meet the performance and financial requirements for the city and they system was approved by the Auckland Regional Council. However for reasons unknown to the author these where never installed.

In 2009 Auckland Transport commission GHD to undertake a study to look how to improve the performance of standard Auckland Catchpit. The study involved qualitative field trails looking at the build of material in a catchpit. The result was a simple screen installed over the outlet could double the amount of retained material in the catchpit. The study did not undertake any quantitative assessment of removal efficiency.

In the last 5 years there has been increased awareness over the growing amount of plastic in the world marine environment. Once viewed as unsightly yet non toxic, gross pollutants were considered more a nuisance rather than the major and growing environmental degrader that it is. Recent research has shown that the volume of gross pollutants in our ocean is killing millions. Further the persistent and buoyant nature of the man-made compounds such as plastics and Styrofoam contained in gross pollutants have a cumulative effect accumulating in the environment. Man-made compounds in marine pollution can also leach containments such as estrogen like chemicals and heavy metals contaminating marine bio and travelling up the food train into humans.

This paper looks at the process of developing a catchpit insert -The Enviropod LT (litter trap) -specifically designed to capture gross pollutant, litter and in particular plastic. The Enviropod LT is an evolution of the original Enviropod catchpit filter which was tested by Auckland Council and Tonkin Taylor and was designed to capture sediment with a 200 micron screen

The paper also discusses characteristics of gross pollutants, background research into improving the treatment capabilities of a catchpit and key aspects of the treatment device including storage, hydraulics and treatment mechanisms.

2 BACKGROUND

Voyde described the process of catchpit. Runoff, and associated attached pollutants, enter a catchpit and mix with the standing water within. This generates turbulence and washout of dissolved and sediment-attached pollutants. Some of the denser sediments will settle in the catchpit under gravity (Memon and Butler 2002). The resulting layer of sludge in the base of the catchpit provides a source for potential sediment re-suspension.

In 1995 Godfrey and Jarrett from the University of Auckland published the result of their study into catchpit performance at the NZWWA conference. The study looked at the performance of a standard Auckland City Council catchpit is removing particles between 380 microns and 2.5 mm, some of the conclusions were as follows;

- Sediment generally only build up to 200 mm from the water surface of the catchpit
- After this height the catchpit sand retention would rapidly decrease until the catchpit was not retaining any of the sand.
- The standard catchpit was less effective at removing smaller particle under 400 micron and when flow rate increases.
- The study inserted a modification which increased the sump volume preventing re-suspension and enhancing settling.

Another study from the UK by Pratt and Addams examined the trapping efficiency of gully pits found that the volatile fraction of sediment retained was only 7% of the total mass suggesting that organic material or material with a lower specific gravity was not being trapped in the pits. The study also concluded that rainfall intensity and associated inflow would greatly affect the retention capability with roughly half the storms monitored have a higher suspended solids concentration in the effluent than the influent. i.e. re-suspension. The Pratt and Addams study estimated the removal efficiency to be approximately 5%.

Auckland University on behalf of Auckland City and Tonkin and Taylor tested the EnviroPod with a 200 micron bag(Butler et all). The study found that 97% removal of particles over 100 micron particles and 98% of street sweeping could be removed. The study also determined that a standard Auckland catchpit could remove 49% of Particles 100 -500 micron in size and only 58% for street sweeping. Furthermore the Standard catchpit reduced efficiency as flow rates increased. With the EnviroPod there was no reduced efficiency with the increase in flow rate. This study used sand and silicon particles that do not represent the organic or low-density particles commonly observed in stormwater sediment.

A further study at Auckland University (Fassman and Kwan) in 2006, showed that the sediment retention level in a standard Auckland catchpit on the influent flow rate and the associated scouring of previously retained sediment.

To conclude, the key to enhancing the performance of a catchpit in removing sediment is prevention of re-suspension. Energy dissipation of inflow and isolation of retained sediments are mechanisms to achieve this. However these studies all have looked at sediment retention of a catchpit not gross pollutant capture. Not all gross pollutant can be removed through sedimentation. Litter and plastic are often large but light objects which are buoyant and float when transported by stormwater runoff. Because of this buoyant nature of some gross pollutants effective removal can only be obtained by screening.

2.1 GROSS POLLUTANT CHARACTERISTICS

Gross Pollutants in our waterways and on our beaches are unsightly and unattractive. The volume of gross pollutants being exported is a concern. This volume tends to settle out in our receiving water bodies smothering and clogging them. The organic component is a considerable source of nutrients (phosphorous and nitrogen) into ours waterways. Excess nutrients affect dissolved oxygen levels in the water bodies and can lead to algal blooms. The entanglement by, and ingestion of marine litter by organisms, is the most noticeable short-term impacts. Plastic litter in particular, is estimated to lead to the worldwide mortality either directly or indirectly of one million seabirds, 100,000 marine mammals (including 30,000 seals) and 100,000 turtles globally every year either through entanglement or ingestion.

To date there has been limited research carried out on quantifying the loads and effects of bed load or gross pollutants. Work by Allison at the Cooperative Research Centre for catchment Hydrology, Melbourne, Australia examined gross pollutant loads and identified a relationship between gross pollutants, organic matter and nutrients.

Hannah in 2006 undertook a detailed examination on material over 1 mm being entrained in stormwater. The results indicate that up to half the exported loads (by weight) were particles greater than 1 mm and this main component to the volume of material exported.

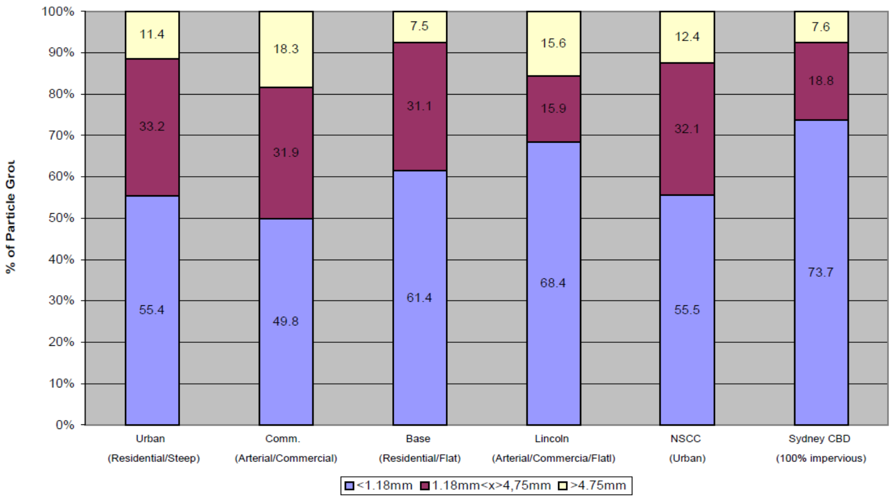


Figure 1: Particle size Characteristics of gross Pollutants

Gross pollutants are a mixture of inorganic and organic substances. Gross pollutants have variable density and large and small particles are mixed together in the runoff. Some of the coarser materials, road chip and metals, settle easily in sumps or basins. However the litter and organics, and in particular plastic typically has a low density and will float therefore requiring screening to remove it. The study in Melbourne revealed that approximately 20% of gross pollutants were floating. There is also a large amount of gross pollutants that travel in the water column i.e. they are neutrally buoyant. Another study in Sydney (Davies) found that between 50% and 90% of the volume retained material in screening gross pollutant trap were either organic or litter

Another important characteristic of gross pollutants is that they can decay when held in water, transforming the contaminants and leading to more environmental effects and a greater difficulty in removing them.

Photograph 1: Enviropod Gross Pollutants separated into litter, Organics and sediment Sydney Australia Source Davies

3 DESIGN ASPECTS OF A CATCHPIT INSERT / LITTER TRAP

3.1 STORAGE VOLUME

One of the first considerations in designing a BMP is where are the contaminants stored? Contaminants need to be stored in a stormwater device so that they are not re-suspended or allow transformation or release of the contaminants. Pitt and Field recommended that water should not be forced through stored contaminants. Further research by Abood and Riley reported that gross pollutants had a deleterious effect on water quality, and the decomposition of the gross pollutants increased with time when ever the gross pollutants were kept within a wet anaerobic environment. The same study found cigarette butts increased phosphorus, suspended sediment, conductivity and COD loads within about 10 days of being immersed.

When we are considering the storage volume of a device it is also important to consider what the anticipated capture is and what effect storing the contaminants may have on the hydraulics and performance of the system. When designing a litter trap gross pollutant load should be considered. The CRC of catchment hydrology in Australia estimated that 0.4 m3/ha/yr of particles over 5 mm where being discharged down the stormwater system in Melbourne. Hannah estimated a loading rate of 1.6 m3 of particles over 1 mm per hectare where entering the stormwater drain in urban areas.

Catchment areas for roadside catchment vary to be between 500 m^2 and 2000 m^2. Considering the loading rates from Hannah, a catchpit trap for 1000 m^2 of catchment would require a minimum storage volume of 180 litres for annual maintenance or 60 litters if cleaned 3 times a year.

3.2 SCREENING AREA AND HEAD LOSS

There are two types of screening employed in stormwater management: direct and indirect. Direct screening is a process that involves solids being removed from a screen place in the direction of the flow. Indirect screening has the screen parallel to main direction of the flow. Indirect screens are less likely to blind and clog as the main direction of flow removes screened material from the screen.

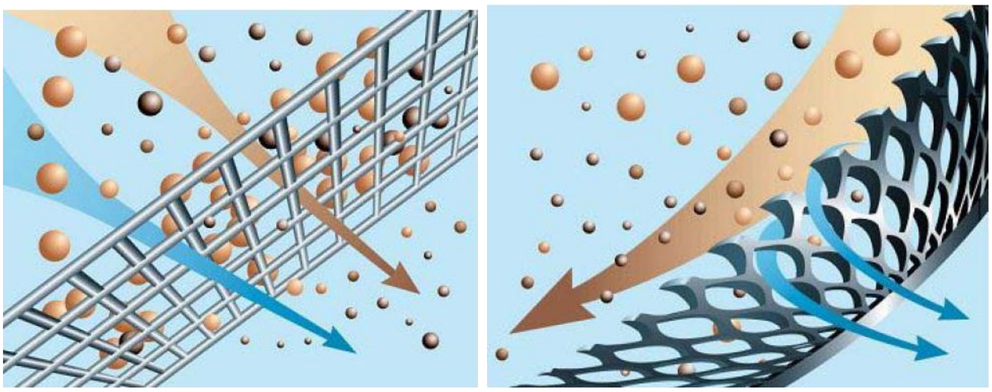


Figure 2: Illustration of direct (left) and indirect (right) screening: source CDS technologies

3.2.1 SPECIFIC FLOW RATE

Hydraulic loading or specific flow is a common concept is wastewater treatment. When considering specific flow rate for a screening device the flow rate over the surface area is determined. The higher the specific flow rate the higher the force on the screen and potential for blinding. Specific flow rate is lowered by increasing the screen area or by lowering the flow rate.

3.2.2 HEAD LOSS

Head loss for a screen is the amount of driving head required to push water through a screen. The figure below illustrates the concept. When designing a litter trap with a screen it is important to consider head loss to ensure that the required head of water to pass the desired flow rate doesn't put the system into bypass.

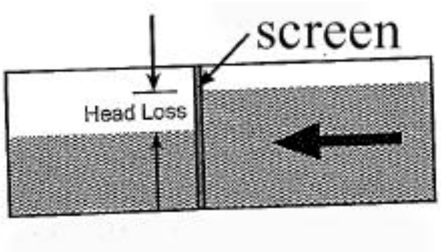
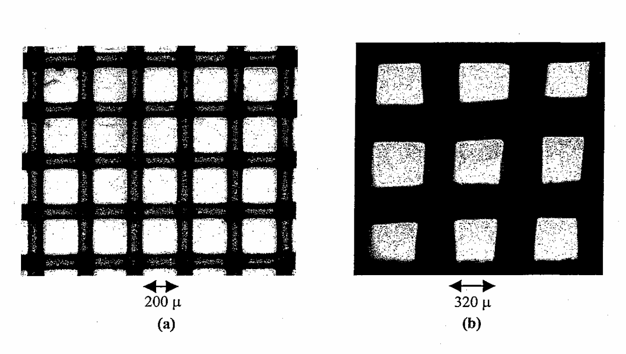


Figure 3: Head loss illustration: source: Butler K et all

Many factors effect head loss in a screen such as: open area, screen aperture size, screen aperture shape and or materials. Often the head loss through a screen is a little counter intuitive for example the two fabric screens below. One would think the screen with the bigger holes (screen B) would have less head loss and be able to pass more flow however the graph below show the screen with the bigger holes has a greater head loss.



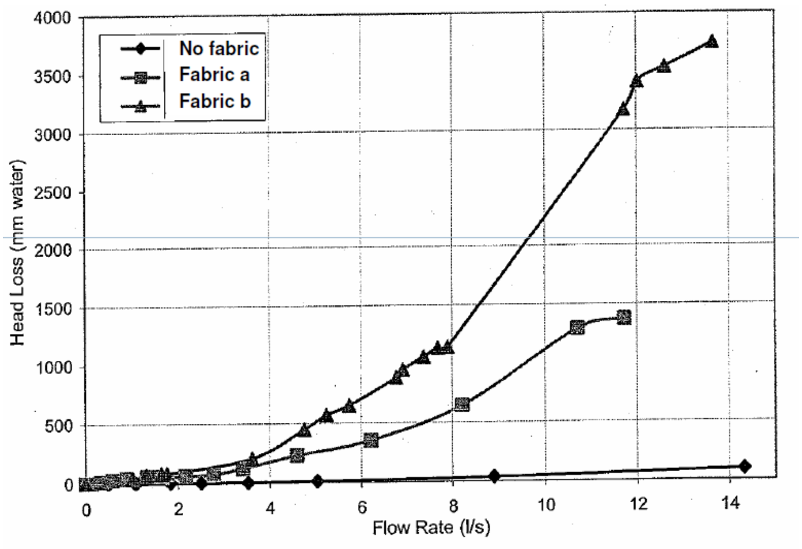


Figure 4: Difference in head loss between two screens with different aperture size source: Butler K et all

3.3 PEAK TREATABLE FLOW RATE & BYPASS CAPACITY

Stormwater treatment devices are typically sized to treat the 80 – 90% storm event. TP10 suggests a rainfall intensity of 15 mm/hr treats 93% of annual runoff. Adopting this as a water quality design storm would give a design flow rate of 8 l/sec of a 2000m2 catchment. The use of a 93% storm is appropriate as gross pollutants to not tend to exhibit first flush phenomena because of their size. Larger storms with greater intensity are required to move large particles. A catchpit trap needs to be able convey this treatment flow through the device without by pass, i.e. the system needs to have enough free screen area above the stored contaminants and low enough head loss to convey this flow through the screen

It is essential that any online BMP's such as a catchpit trap has a suitably sized bypass. It is important to size this for the full flow of the system including some sort of partial blockage safety factor.

3.4 MAINTENANCE

If a BMP is designed to remove contaminants it will require maintenance. The following factors effect maintenance costs:

- Frequency / Storage Volume /efficiency
- Removal/reinstall
- Replacement and repair cost
- Easy Access
- Cleaning/ Replacements of Filters
- Method – Hand/Truck

4 DEVELOPMENT OF AN EFFECTIVE LITTER TRAPING TECHNOLOGY

4.1 BACKGROUND

The standard Australian EnviroPod was tested at the University of South Australia. The Australian EnviroPod utilizes a burn resistant fabric with nomial aperture of 3.5 mm. The design incorporates approximately 1.0 m^2 of screen area. The unit is made from a galvanized mild steel filter box and cage, plastic seal. The Australian EnviroPod is free hanging, supported on struts.

Australian gullies are designed to capture high flows up to 350 l/sec. Testing of the Australian Enviropod design showed high gross pollutant removal at very high flow rates. During this evaluation it was noted that low flows would wash screening particles from the screen, as it was parallel to the incoming water i.e. indirect screening.

Grade	Flow Rate l/sec	Capture
1%	100	100%
	200	85%
	320	65%
4%	100	100%
	320	55%

Table 1: University South Australia Enviropod Testing

The same fabric was trialed in the New Zealand configuration of the Enviropod. A test unit was installed in Berrisford street in Auckland's CBD. The standard Auckland catchpit is smaller in cross sectional area than the standard Australian gully; however it is much deeper with a sump. The size of bag installed in the NZ configuration of the EnviroPod has the same surface area as the Australian EnviroPod bag. The figures below show the capture rates over the initial trial period.

Photograph 2: New Zealand EnviroPod GPT bag Prototype

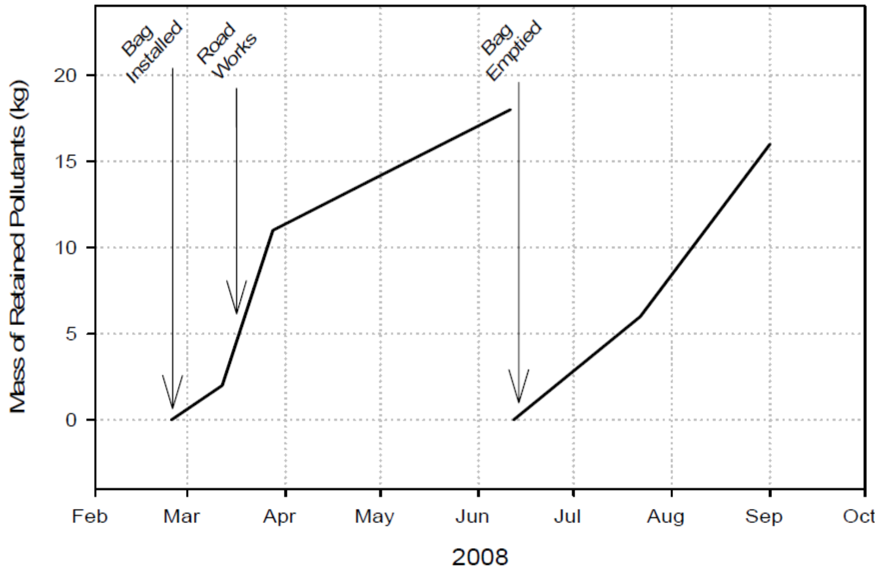


Figure 5: Gross Pollutant capture Berrisford St trail Auckland CBD

18 kg of gross pollutants were retained in the first four month period. This comprised of sediment, gravel, organic material litter and cigarette butts. This equates to a loading of 1800 kg/ha/yr. NIWA estimates the TSS load for the CBD to be 1100 kg/ha/yr. The retained material occupied 15% of the bag volume leaving a large amount of free screen area to convey flows.

Photograph 3: New Zealand EnviroPod GPT bag Prototype

Photograph 4: Retained Gross Pollutants Berrisford St Trail

4.2 AN EFFICIENT DESIGN

Confident that effective gross pollutant capture could be obtained with the design and the selection of screen, Stormwater360 looked to optimism the design of the system for mass production.

In 2010 Stormwater360 successfully applied to the Ministry of Science and Innovation for a technology development grant to redevelop the EnviroPod filter. The MSI grant enabled extensive lab and field-testing, engineering materials design, modeling and industrial design

One of the important features of the old EnviroPod design was the cage. The cage prevents the "bag bulge" and blocking the flow part around the bag. A large amount of force is generated as water and solids flow through the screen (estimated up to 2.5 kpa). This force required the cage to be constructed in a strong material such as steel.

The design of the Enviropod LT is based around a self-supporting bag, removing the need for a cage. As the system sets loaded with gross pollutants the bag gets heavier causing the sidewalls of the original bag to get stiffer. This feature allows the removal of the frame, which was a costly yet essential element to the original design.

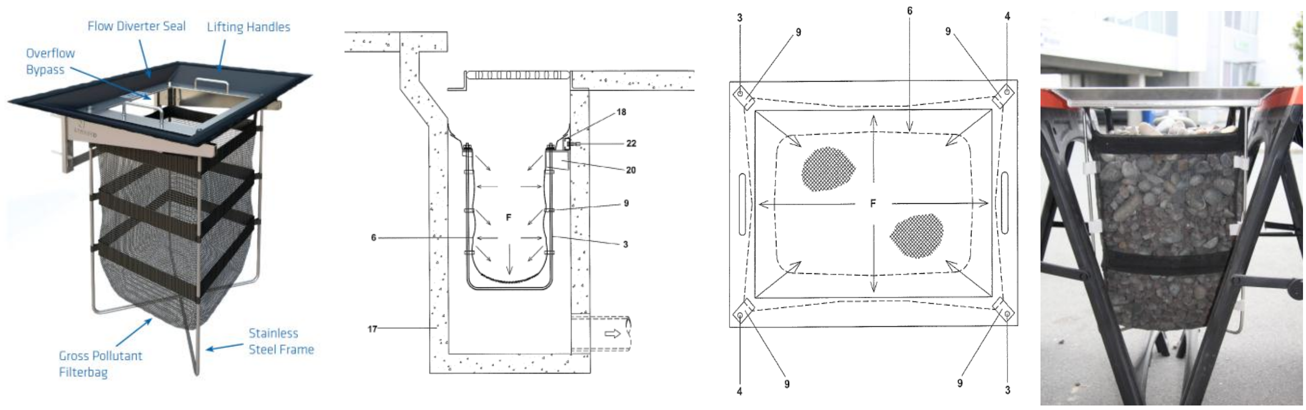


Figure 6: Enviropod LT Intelligent Design

The effective bag design enables a large surface area bag to be constructed. The large surface area allows the device to convey a high amount of flow through the screen with low head loss.

A large amount of gross pollutants that travel in the water column i.e. they are neutrally buoyant. The only effective way to capture floating or neutrally buoyant material is by screening it. A standard catchpit has no means to stop neutrally buoyant material. Some standard catch pits are installed with half siphons; this has only a limited effect on capturing truly floating material. By screening the flow the EnviroPod LT can effectively capture and retain all gross pollutants in the flow.

The EnviroPod LT is installed into the catchpit by cantileving from one pit wall. This allows the design to fit a large number of pit configurations. The retained trash and debris are held dry in the system, preventing break down in the catchpit sump or in the receiving environment. Allowing excess water to drain from the retained material lowers the disposal costs.

The whole system has been designed to be flat packable so that the product can be mass produced in New Zealand and exported to the world.

Photograph 5: EnviroPod Flat Pack Design

The efficient design of the EnviroPod LT will approximately half the supply price of the product. This will encourage greater up-take of the product and in turn reduce the plastic load to our marine environment.

4.3 LABORATORY TRIALS

Stormwater360 commissioned the Auckland University Engineering School Fluids Laboratory to undetake a series of quantitative and qualitative experiments developing the new design. The figure below shows laboratory set up. A silicon sand mix of a representative particle size was added to give a standard influent quality and manual samples were taken from the out flow.

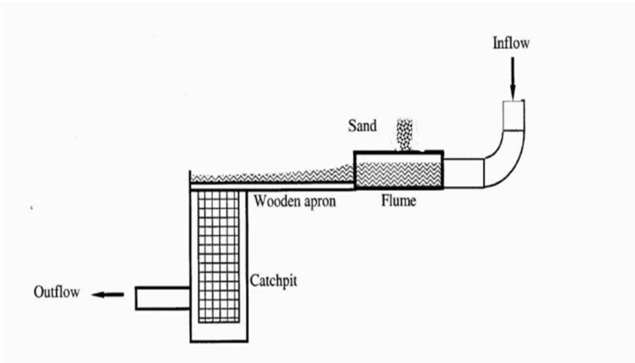


Figure 7: Laboratory Performance Testing Set up

The table below compares the results of performance testing. The old Enviropod and a catchpit were tested to add a control. As the flow rate rose, the removal of 100 – 500 micron particles in the LT and the clean standard catchpit fell. Observation showed less turbulence in the sump from the LT than the catchpit this thought to be a contributing factor to the improved performance obtained by the Enviropod LT.

		SSC (101 - 500 micron)	**SSC (501 – 1000 micron)**
Clean Catchpit Only	**1 L/s**	**69%**	**100%**
	4 L/s	**31%**	**100%**
Original EnviroPod 200	**1 L/s**	**100%**	**100%**
	4 L/s	**100%**	**100%**

Enviropod LT	**1 L/s**	**100%**	**100%**
	4 L/s	**57%**	**100%**

Table 2: Enviropod LT performance testing

The photo (below, right) shows the small amount of head loss through the system as a flow of 12 l/sec passes through the bag. The photo also shows very little turbulence in the sump under the Enviropod LT as the bag dissipated the incoming flows energy. This energy dissipation enhances sediment settling in the sump of the catchpit.

Photograph 7: Hydraulic testing

5 FIELD & SERVICEABILITY TRAILS

Having quantified the performance in the laboratory, the robustness and serviceability of the product needed to be evaluated and developed. Over 40 prototypes were manufactured and installed in various catch pits around Auckland and a few in Sydney. Trial locations where chosen specifically to test the functional aspects of the design, these included: concrete yard, steep streets and ultra urban catchments. . Removal rate was between 550 -1800 kg/ha/or 2.3 – 7.5 m3/ha/yr.

Photograph 6: Maintenance during field Trails

In field trials different types of maintenance were trialed. It was found the EnviroPod LT could easily be emptied of gross pollutants by hand in less than 30 sec at the time of cleaning the catchpit pit. The catchpit sump could easily be vacuumed with conventional equipment through the EnviroPod LT frame. Maintaining the EnviroPod LT added little time to the process of cleaning the catchpit well, allowing the catchpit to capture all floating and neutrally buoyant material.

Being able to hand maintain the EnviroPod LT allows uptake of the technology by private sites. Private catch pits are typically not maintained and require the use of vacuum trucks at $200/hr. It is envisaged corporates such as McDonalds, The Warehouse and Westfield could easily install and maintain the EnviroPod LT with unskilled labour.

400 micron, 1 mm, 3.5 mm and 5 mm screens where trialed in the prototypes of the EnviroPod LT. Field observations showed minimal signs of blinding or clogging in the larger aperture fabrics. The 400 micron fabric showed some signs of clogging when installed at the concrete yard. This was easily removed by water blasting the screen in the catchpit. The storage capacity of the prototypes was found to be adequate for a 4 monthly clean even in tree-clad streets.

Photograph 8: Prototype Field Trails

6 CONCLUSIONS AND THE FUTURE

This paper has described the process and development of a well-engineered litter trap, designed to sit in the entry of the stormwater system.

Previous research into enhancing catchpit performance has shown minimizing turbulence from the incoming water increases the sediment retention of the catchpit. Little work has been done into investigating the capture of floating gross pollutants.

Indirect screening and designing a screen to have a low specific flow rate minimize blinding. Gross pollutant loads are very high from urban areas and storage volumes in gross pollutant traps need to be adequate for the anticipated load.

The hydraulics' of stormwater treatment systems are essential to its performance. Stormwater treatment devices need to ensure the treatment flows can pass through the system full with debris without causing bypass. For larger storms bypass capacity needs to adequate to pass peak flows even with partial blockage.

Stormwater360 obtained a Ministry of Science and Innovation grant to assist in laboratory and field testing of it new EnviroPod LT Litter traps. This Laboratory and field work combined with a good understanding of the science lead to an effective and efficient design that has halved the capital cost of the product. Operation and maintenance costs of the new EnviroPod LT are minimal as the system can simply be emptied by hand. This simple operation makes the product more appealing for use in private as well as public catchpits.

The Enviropod LT is currently being industrial designed for manufacture and mass production beginning in August 2013. A trial is planned with Auckland Transport replacing some of the original Enviropods installed in Takapuna.

With existing markets for the product in Australia, Malaysia, USA and the Middle East it is hoped the product will be another great kiwi invention.

REFERENCES

Allison, R.A, Walker, T.A., Chiew, F.H.S., O'Neill, I.C., McMahon, T.A. (1998) *From Roads to Rivers: Gross Pollutant Removal from Urban Waterways*, Cooperative Research Centre for Catchment Hydrology

Hannah. M.M, (2005) *Stormwater Bed load and Gross Pollutant Export rates and their implication for treatment devices*, North American stormwater conference (Stormcon) Orlando, Florida.

Voyde, E,Fassman, Sediment *Retention Efficiencies of In-Use Catchpits*, E, Department of Civil and Environmental Engineering, Auckland University, Undergraduate Environmental Project 2006

Pratt CJ, Adams JRW(1984) *Sediment supply and transmission via road side gullypots*, science and the total environment 33

Robert Pitt, Richard Field, *AN EVALUATION OF STORM DRAINAGE INLET DEVICES FOR STORMWATER QUALITY TREATMENT,* Water Environment Federation Technical Exposition and Conference, Orlando, FL, 1998.

Butler, D. and S. H. P. G. Karunaratne (1995). "*The suspended solids trap efficiency of the road side gully pot*." Water Research 29(2): 719-729.

Butler, K., G. Ockleston, et al. (2003). *Auckland City's field and laboratory testing of stormwater catchpit filters*.

Fassman, E. A. and D. Kwan (2006). Sediment Retention Efficiency of In-Use Catchpits: Draft Final Report. Department of Civil and Environmental Engineering, Auckland University, Undergraduate Environmental Project 2006

Lager, J. A., W. G. Smith, et al. (1977). *Urban Stormwater Management and Technology: Update and Users' Guide*., U.S. Environmental Protection Agency (EPA-600/8-77-014 c.2).

Abood M. and Riley S.J. (1997); *Impact on Water Quality of Gross Pollutants*;. Research Report No. 121 Urban Water Research Association of Australia, June 1997.