GETTING THE WATER AWAY – A DETAILED LOOK AT CATCHPIT CAPACITY

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ABSTRACT

Local Authorities spend significant amounts of money developing stormwater models to assess network capacity and identify flood hazards. This work invariably assumes that all the runoff is able to enter the stormwater system via the inlets.

The reality is, however, that inlets and drainage systems are often not well designed or maintained, and therefore, significantly more overland flow occurs than is predicted by the models. Similarly, this can mean that pipe networks are potentially significantly under-utilised.

This project looked at local and international research into catchpit inlet design, and focused on developing a recommended design approach for use by Auckland City for road stormwater networks.

A number of different approaches were investigated; the most widely used being a method developed by the US Federal Highway Administration (HEC-22).

Using the HEC-22 approach, a data set of capacities was developed for a number of catchpits used within the Auckland area (incl standard catchpit, splay pit, max pits etc). The capacity data was then used in conjunction with road cross section data and catchment runoff to determine flow rate and flow width within the road cross-section.

Based on a specified maximum allowable flow width, and the accurate HEC-22 catchpit capacities, a design approach (spreadsheet) was developed which enabled spacing of catchpits at intervals to ensure flow widths remained within the acceptable limits, and all flow was captured at low (sag) points.

It is envisaged that adoption of this design approach for inlets could feed into stormwater models to improve overall accuracy of model outputs and lead to significantly more robust designs.

Further accuracy could be gained by undertaking detailed lab testing and it was recommended that this be considered.

KEYWORDS

Catch pit, gully pit, cess pit, capacity, spacing, HEC-22, road runoff

PRESENTER PROFILE

Xeno Captain – Xeno Captain started his career in 1979 at Auckland City in the Drainage Design Office and when Metrowater was formed in 1997, Xeno took over the management of the drainage networks across the city. He is presently involved with management of City-wide Flood Hazard Mapping efforts and flood mitigation studies.

Shaun Jones – Shaun has 8 years diverse engineering experience in the Auckland region including environmental, geotechnical and civil engineering. His career to date has involved design and construction management of stormwater management systems, hydrological assessments, and co-ordination of construction projects.

1 INTRODUCTION & BACKGROUND

Until recent years catchpits in Auckland City have been standard 675x450mm square pits with a cast iron grate and a small back entry. The hydraulic capacity of these catchpits has often been over estimated during design and consequently a large number of these catchpits quickly reach capacity during a medium storm event, resulting in bypass. The cumulative effect of catchpit bypass results in excessive accumulation of stormwater at sag points in roads and consequently surface flooding. In addition, excessive flows within the kerb and channel results in wide flows encroaching the carriageway causing a hazard to vehicles and pedestrians.

In recent years, higher capacity catchpits have been developed – which include combinations of grates and back-entry openings. Only one of these (Max Pit) is understood to have been tested in a controlled environment, and detailed capacity curves produced. Similarly, there is little detail on agreed design approaches for the sizing and spacing of catchpits along a road corridor – which leads to inconsistency in designs and performance.

Thus, it became evident that a concise, central reference containing catchpit capacities (charts) is required for commonly used catchpits along with a standard approach to spacing catchpits, based on catchment flows and road characteristics.

This project set out to investigate theoretical approaches to calculating catchpit capacity and then develop a robust methodology for catchpit sizing and spacing.

2 PROJECT SCOPE

The scope of this project was to:

- Undertaken a literature review of the range of local and international catchpit types
- Understand the issues associated with catchpit design, maintenance and construction
- Identify international methods for estimation of theoretical catchpit capacity
- Develop theoretical capacities for a range of catchpits and compare
- Develop a revised design approach for sizing and locating catchpits.

3 CATCHPITS IN AUCKLAND

The following is a summary of the various types of catchpits commonly used around the Auckland Region:

3.1 SPLAYPITS

Developed by and currently used in North Shore City, the splay pit consists of a kerb opening and an adjusted channel to direct the run off into the unit. Splay pits are manufactured and distributed by Hynds Limited. These devices can be installed as a single splay (2.4m) or double splay (3.6m) and are accessed by a manhole located within the berm behind the opening. The capture rate is anecdotally considered to be good (predicted capacity in excess of 70l/s), however no detailed testing has been undertaken.

Photograph 1: Splaypit

3.2 MAXPITS

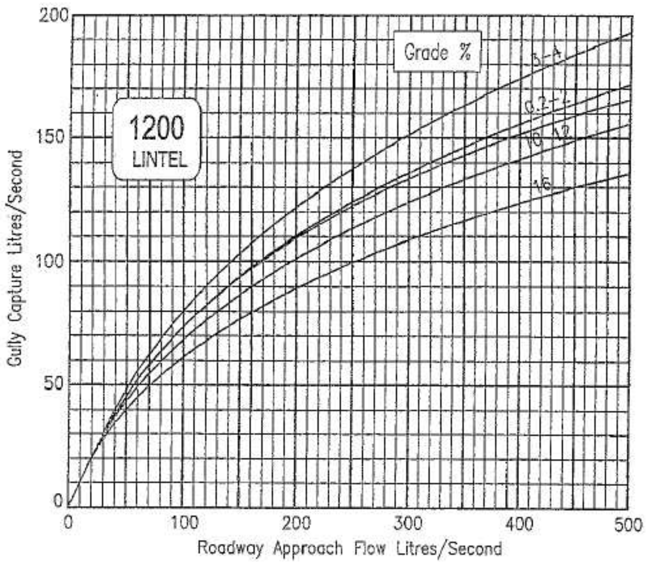
Max pits have been developed by Max Q Limited in Australia and are distributed in New Zealand by Humes Limited. They consist of a precast lintel (back entry) and Max Q grate. Lintel size can either be 1200mm or 2400mm. The Max Pits are currently used throughout New Zealand. Max Q supply two grates, either the Tasman or Mannings grates. The Mannings grate is recommended by Max Q and is more widely used throughout Australia and New Zealand, however it is understood that Auckland City Council's preferred lid is the Tasman due to it being perceived as more cycle friendly. It is noted that both grates are considered safe for cyclists as per Australian standard AS 3996:2006.

Photograph 2: Maxpit

Capacity: Extensive testing has been undertaken at the University of South Australia during the development of this product (Urban Water Resources Centre, 1994). The capacity chart below (Figure 1) gives the capture rates from different approach flows and road grades.

Note that the capacity is also limited by the outlet which is specified in Auckland City standard details as being a 225mm dia half siphon with a capacity of 50l/s. This can be upgraded to a 300mm diameter pipe which would provide improved overall capacity.

Figure 1: Max Pit Capacity Chart for 1200 lintel (Source: Max Q)



3.3 SUPERPITS

The Superpit was designed by Auckland City engineers (circa 1996) to solve a discrete flooding problem at the underground Civic Car Park entry ramp. The design was intended as a "one off solution", and not for general use as a high capacity inlet device. However, the moulds were acquired by Hynds who manufacture Superpits to this day.

Capacity: No field testing is understood to have been done. According to Hynds technical staff the capacity is assumed to be approximately 50-60l/s (personal communication).

Photograph 3: Superpit

3.4 MEGAPIT

The Megapit has been developed by Hynds as a high capacity catchpit. The product has a grate the full length of the kerb opening which substantially increases the side capture rate of the grate.

The device has been installed at a number of locations in Auckland City, including monitoring sites at the bottom of School Road, Western Springs and at the corner of Kitiwara/Benson Road, Remuera. Both these devices were the subject of a monitoring programme by Interclean (May 2008). The devices appeared to be performing relatively well and provide good capture of stormwater.

Typically, the Megapit is suited to sites where significant capacity issues exist as the units are large, costly and quite obtrusive.

Capacity: The Hynds Megapit brochure specifies capacities up to 800l/s for the catchpit located in a sag location. The capacity of this device would therefore likely be determined by the outlet pipe.

Photograph 4: Megapit

4 CATCHPIT CAPACITY

4.1 CATCHPITS ON GRADE

The hydraulic inlet capacity of a catchpit on grade is dependent on:

- the geometry of the grate and kerb opening,
- the grade and crossfall of the road and,
- the flow in the channel (approach flow).

From these parameters the efficiency of the catchpit under any given flow conditions can be determined. The efficiency (E) of a catchpit is defined as the ratio of the discharge intercepted by the inlet (Q_{int}) to the total discharge approaching the inlet (Q):

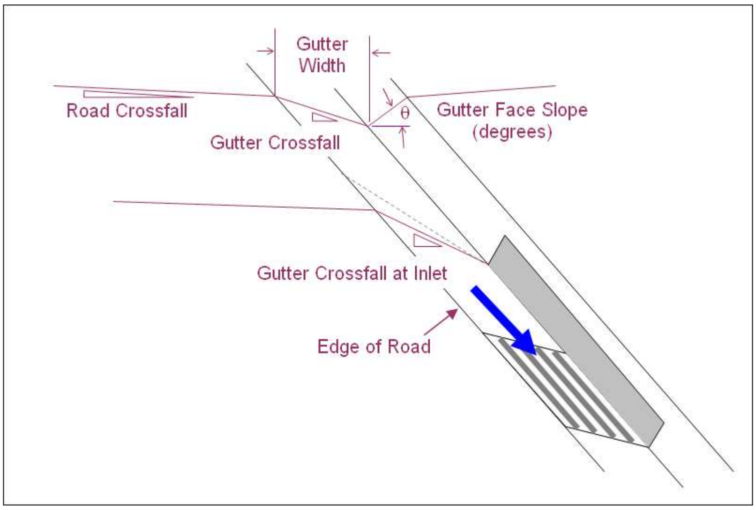
$$E = Q_{int} / Q$$

The remaining flow is considered bypass flow and will contribute to the approach flow of the next catchpit. The variables that affect the efficiency of a catchpit are as follows:

- Approach Flow
- Longitudinal Grade
- Road Cross-fall
- Kerb & Channel Geometry
- Road Surface
- Catchpit Grate Geometry
- Catchpit Lintel Opening
- Blockage

Refer Section 6 for further detail.

Figure 2: Parameters affecting catchpit capacity



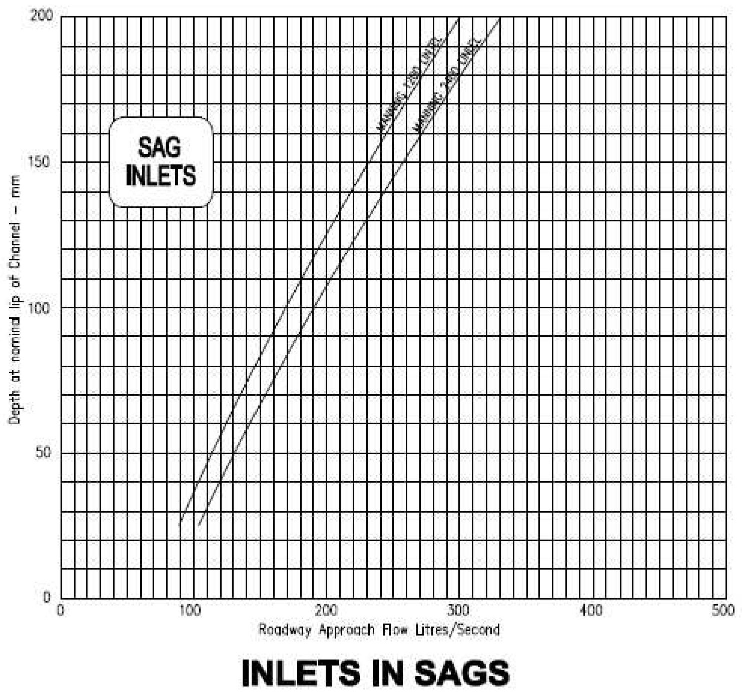
Charts have been developed based on lab testing and theoretical modelling for a number of catchpit types and road characteristics. Refer to Figure 1 and 3 for an example developed for the MaxQ pits.

4.2 CATCHPITS IN SAG LOCATIONS

Inlets in sag locations initially operate as weirs in low head conditions and then transition to orifices at greater head depths. Orifice flows begin at depths dependant on the grate size or the kerb opening height. At depths between those at which weir flow prevails and those at which orifice flows prevail, the flow is in a transitional stage. At these depths control is not fully defined and flows can fluctuate between orifice and weir control.

The following chart shows the capacity of the Max-Pit (‘Max Q’) catchpit in a sag position.

Figure 3: Max Pit Capacity Chart for 1200 lintel (Source: Max Q)



5 DESIGN APPROACHES

5.1 DESIGN APPROACH USED IN NEW ZEALAND

A robust design approach has not yet been implemented in the majority of New Zealand Territorial Authorities (TA). In general, a TA’s Engineering Standards detail a typical catchpit along with generic guidelines including maximum spacing, minimum catchpit lead diameter etc.

5.2 AUSTRALIAN DESIGN APPROACH

Authorities in Australia typically have a more robust design approach. The capacity of catchpits are usually based around either laboratory testing or theoretical approaches such as HEC-22 and accompanied by detailed design guidelines for locating and spacing catchpits.

6 FACTORS AFFECTING CATCHPIT CAPACITY

Numerous factors affect the capture efficiency of catchpits. Details of each and their effect on capture efficiency is detailed below:

Table 1: Factors Affecting Catchpit Capacity

Approach Flow	Approach flow is directly related to the contributing catchment upstream of the catchpit. In addition to the contributing road catchment, a private property component is often present. An accurate assessment of the contributing catchment is necessary at the early stages of catchpit spacing to ensure flow widths are within specified limits.
Longitudinal Grade	The longitudinal grade affects the velocity expected within the road channel. An increase in longitudinal grade will result in increased velocity resulting in increased likelihood of bypass occurring.
Road Cross-fall	Road cross-fall is one of the more significant contributors to flow width. Steeper cross-fall causes the flow to tend more toward the kerb resulting in a narrower flow width. Conversely, where the road cross fall is shallow the flow spreads out, meaning even if the flow is not significant, the surface water can still cause a hazard to motorists and requires control.
Kerb & Channel Geometry	During the majority of storm events the flow is maintained within the kerb and channel. The geometry of the kerb and channel needs to be such that moderate flows will be contained.
Road Surface	The depth of flow is often very shallow, and as a result the surface roughness is critical in determining the width of flow. Typically the only differentiation made is between a smooth hot mixed surface and a rough chip seal surface.
Catchpit Grate Geometry	As noted above, geometry of the grate i.e. higher void area, longer grate and longitudinal bars all increase the efficiency.
Catchpit Lintel Opening	As flow widths increase, chance of bypass are more likely. Longer lintels provide more opportunity for flows to turn and enter the catchpit (ie change in flow direction). Lintels range in size up to 2.4m in New Zealand, however, in Brisbane where high intensity storms occur, lintels can be up to 4.8m long (Brisbane 1 in 10yr ARI intensity is 167mm/hr compared with Auckland intensity of 96mm/hr).
Blockage	It is important to consider and apply blockage factors when designing catchpit inlets. The blockage factor will vary depending on the catchment characteristics, inlet type, location etc. This is generally left to the discretion of the designer, however, different blockage factors often applied are: • Catchpit grates for pits on grade (eg 50% blockage) • Catchpit grates for pits in sags (eg 50% blockage) • Catchpit back entries on grade (eg 10% blockage) • Catchpit back entries in sags (eg 20% blockage)

7 EXISTING EMPERICAL METHODS

Although the number of available studies covering theoretical capacities and lab testing of catchpits are limited, the details contained within them are extensive. A summary of the studies reviewed are as follows:

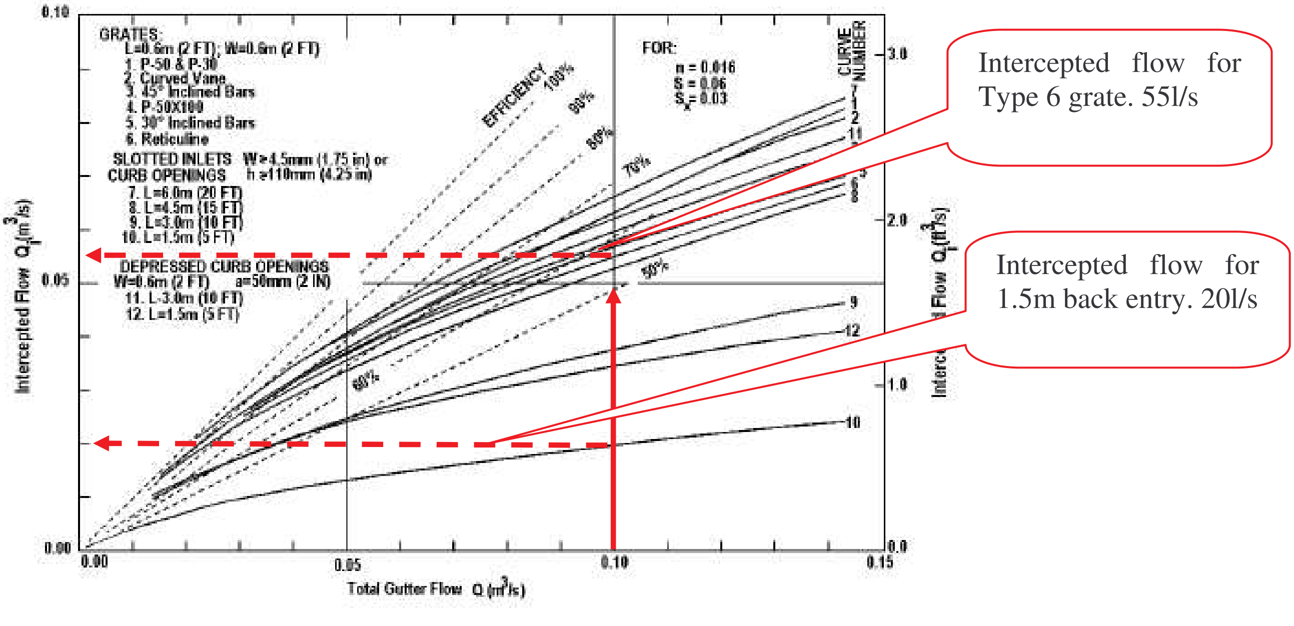
7.1 HEC-22: URBAN DRAINAGE DESIGN MANUAL

HEC-22: Urban Drainage Design Manual (FHWA, 2001), developed by the US Federal Highway Administration, is considered one of the most important design references that allows the estimation of inlet hydraulic capacities. Detailed testing was involved in developing the design procedure and the result is a series of charts and formulae that apply to a variety of catchpit types. The design process is robust and is used in a number of USA State County design manuals.

Essentially, the procedure allows for separate capacity calculations of the inlet grating and also the kerb back entry. This can be done for a variety of gratings, back entry openings/lengths and road geometry. The bypass for the catchpit is simply the approach flow minus the captured flow.

Figure 4 below gives an example of the capacity of a range of inlets with varying approach flow rates for a specified road configuration. For example, for an approximate flow of 100l/s, a type 6 grate combined with a 1.5m long kerb opening could achieve a total intercepted flow of approximately 75l/s.

Figure 4: HEC 22 Comparison of Inlet Interception Capacity (Longitudinal Grade of 6%, Crossfall of 3%)



7.2 MAX Q AUSTRALIA TESTS

Max Q Australia engaged the University of South Australia to undertake lab tests on their proprietary product. The test results have been developed by Max Q engineers for use under New Zealand conditions. The Max Q product is available in NZ as the 'Humes Max Pit' product, currently being used in Auckland City.

7.3 BRISBANE CITY COUNCIL

Brisbane City Council (BCC) undertook a testing regime for the same grate and kerb inlet configuration as the MaxQ tests. The results of these tests were used to produce the Council's capacity charts for the approved catchpit designs (Urban Water Resources Centre, 1994). These test results were also used by MaxQ to assist in developing the capacity charts for the Max Pit for New Zealand conditions.

7.4 DRAINS SOFTWARE (AUSTRALIA)

Watercom Pty Ltd is a Consulting Engineering and software development company based in Sydney, Australia specialising in water supply, distribution and drainage. They have developed a software program called 'DRAINS' which is used for designing and modelling piped networks.

A spreadsheet has been developed for use in DRAINS that calculates the theoretical capacity of catchpits based on HEC-22. The spreadsheet allows for the calculation of kerb openings, grate inlets or combination inlets – in both 'on grade' and 'sag' locations.

A comparison between the theoretical results (based on HEC-22) and various lab test results was undertaken for on-grade catchpits by the developer of the DRAINS software (Pezzaniti et al, 2005). The result table is shown in Figure 5. This table shows that:

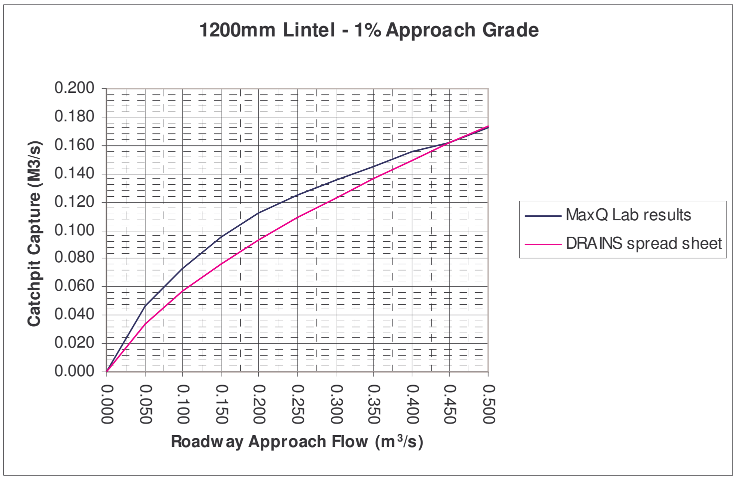
- Grate only: DRAINS gives a good approximation for flows < 0.5m3/s, and underestimates higher flows by approximately 25%.
- Kerb inlet only: generally DRAINS underestimates the lab results by between 10% and 33%
- Combined inlet: DRAINS gives a good approximation for flows < 0.5m3/s, and over-estimates by between 10% and 20% for higher flows.

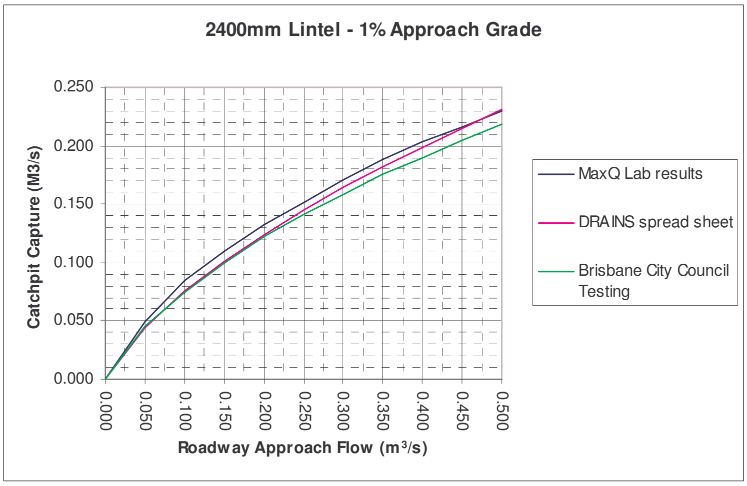
The results from this spreadsheet were compared against lab testing undertaken for both the Max Pit and the Brisbane City Council catchpit (very similar design to the Max Pit). This is shown in Figure 6. There is good alignment of results for approach flows of less than 0.5m3/s.

Figure 5: Summary of DRAINS Spreadsheet vs Lab Catchpit Capacities (Source: Pezzaniti et al, 2005)

Inlet Type	Approach Flow Range	Approximate Length of On-Grade Inlet		
		1 m or Shorter	Between 1 & 3 m	3 m and Longer
Grate Only	$< 0.15\ m^3/s$	OK	OK	-
Grate Only	0.15 to $0.5\ m^3/s$	OK	-	
Grate Only	$> 0.5\ m^3/s$	Underestimates by about 25%	-	-
Kerb Inlet Only	$< 0.15\ m^3/s$	25% over for un-depressed inlet, 50% under for depressed	25% underestimate	20% underestimate
Kerb Inlet Only	0.15 to $0.5\ m^3/s$	25% underestimate	33% underestimate	10% underestimate
Kerb Inlet Only	$> 0.5\ m^3/s$	45% underestimate	33% underestimate	OK
Combination with 1 m Grate	$< 0.15\ m^3/s$	OK	OK	OK
Combination with 1 m Grate	0.15 to $0.5\ m^3/s$	5% overestimate	OK	OK
Combination with 1 m Grate	$> 0.5\ m^3/s$	20% overestimate	20% overestimate	10% underestimate

Figure 6: Comparison between MaxQ, BCC, DRAINS for 1% Approach Grade





8 APPLYING HEC-22 TO AUCKLAND CATCHPITS

HEC-22 is one of the most widely used approaches (USA / Aus) for calculating catchpit capacities. A comparison between the various catchpits discussed above was undertaken and is shown below for a longitudinal grades of 1% and 4%. In addition to the types of catchpits found in Auckland, two larger units used in Brisbane City have been shown. These include a unit with a grate and a 3600mm long kerb opening and a unit with a 4800mm long kerb opening.

Note the intercepted flows become unrealistic as the approach flow increases above 0.5m3/s. HEC-22 would predict the capacity of the catchpit to continue to increase as approach flow increases, however in reality this would reach a maximum.

It is noted also that the maximum capacity would be determined by the inlet capacity of the pipe outlet from the catchpit (i.e. 225mm diameter = 0.1m3/s, 300mm diameter = 0.18m3/s). These capacities are shown on the graphs below – based on an inlet capacity for a 1.0m headwater depth.

Figure 7: Catchpit Comparison – 1% Channel Slope

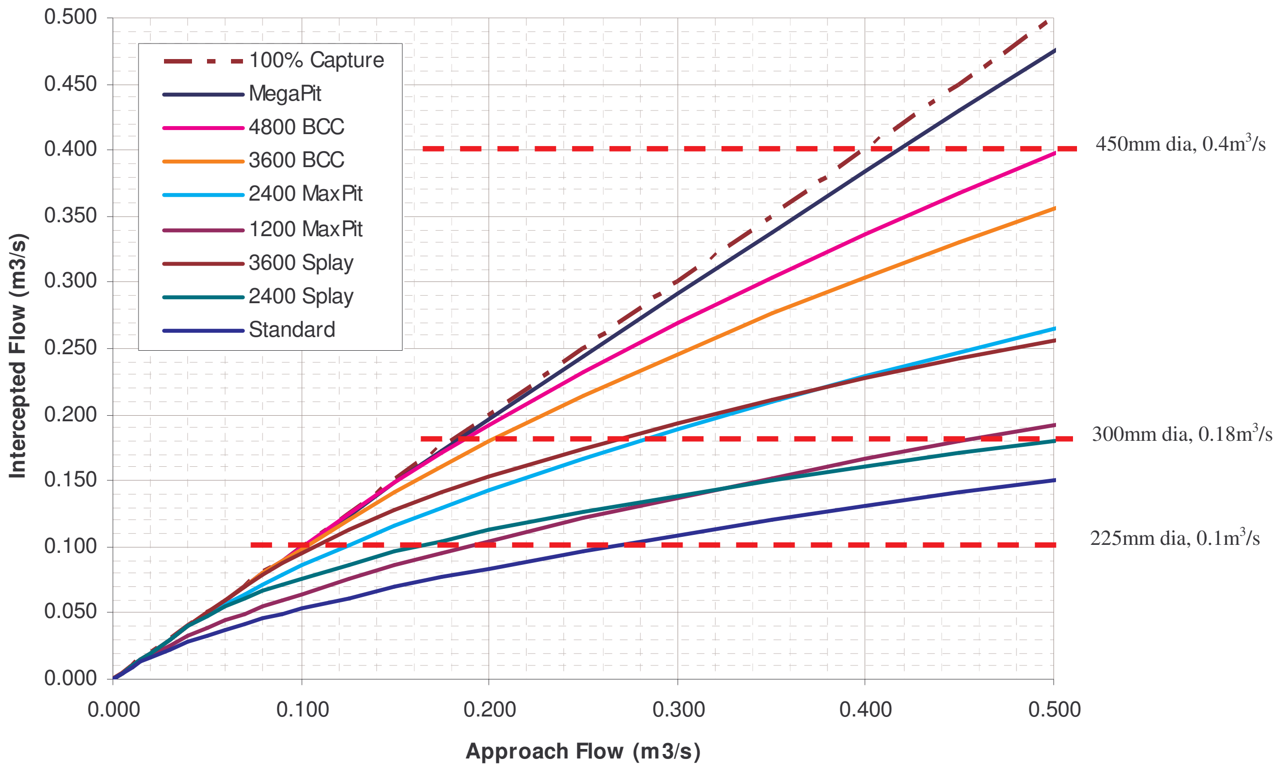
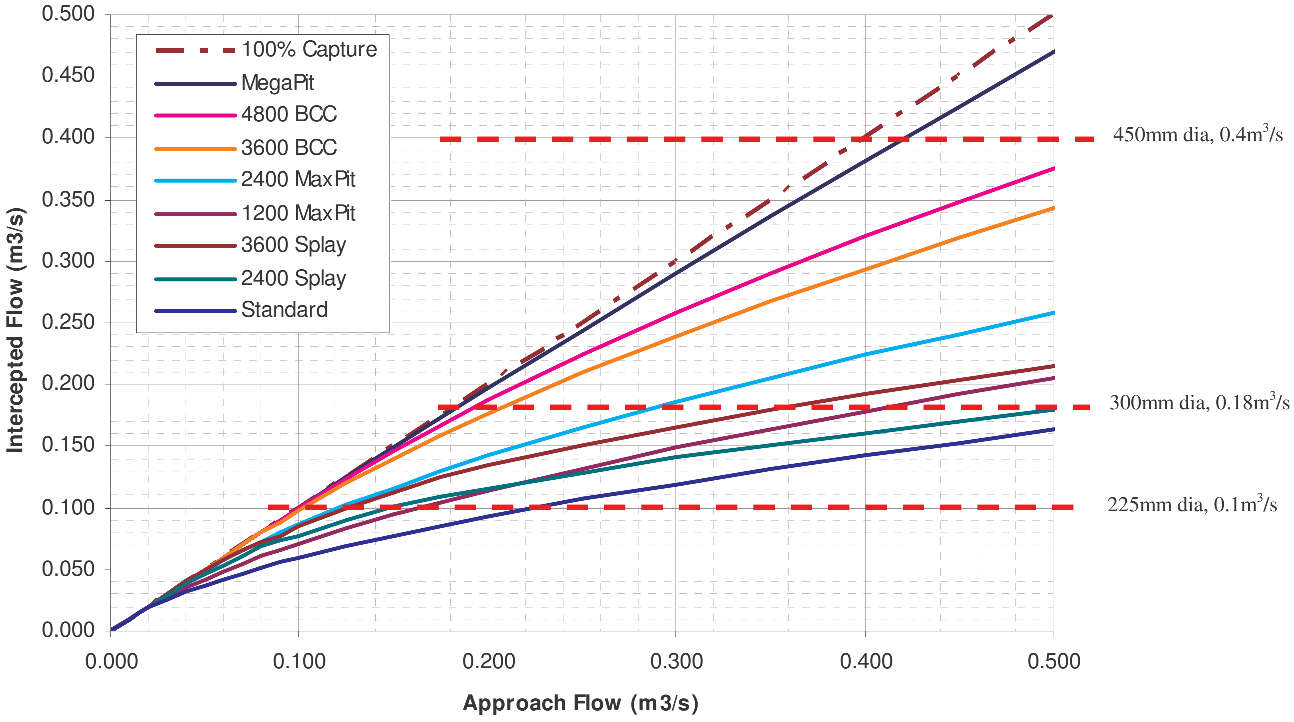


Figure 8: Catchpit Comparison – 4% Channel Slope



A number of comments are made on the results of the above comparison:

- Note that the Splaypit data contains some adjustment factors as per Figure 5.
- There is no data within HEC-22 for standard Auckland catchpit grates which may result in inaccurate results for the standard catchpits. There is also some uncertainty over the capacity generated by HEC-22 for kerb-only inlets. Refer Figure 5.
- Max pits (1200mm and 2400mm lintels) generally give reasonably constant results for different road grades.
- Splay pits (2400mm and 2600mm) appear to marginally decrease in capacity as road grade increases.
- Of the catchpits available in Auckland, the 2400mm Maxpit gives the highest inlet capacity at all grades. At flat grades it is comparable to the 3600 Splaypit, but at steeper grades, the Splaypit capacity drops off.
- No allowance is made for blockage

9 RECOMMENDED DESIGN APPROACH

A design approach was developed for specifying and spacing catchpits on a section of road, based on HEC 22. The approach is outlined below:

1. Determine fixed inlet locations. These should include:

   - in the low points of all sags.
   - at the tangent point of intersection kerb returns such that the width of gutter flow around the kerb return in the 10 year storm does not exceed requirements.
   - immediately upstream of pedestrian crossings, intersections, access ramps, taxi or bus stops.
   - immediately upstream of any reverse crossfall road pavement, where flow would be directed across the pavement.

2. Calculate approach flow at first inlet based on contributing catchments.

3. Calculate capacity and bypass of desired catchpit (either from manufacturers charts or from DRAINS spreadsheet) based on approach flow.

4. Ensure capacity of catchpit lead (inlet control) is sufficient to cope with intercepted flow.

5. Determine catchpit spacing to:

   a. Achieve no bypass at the lowest catchpit on grade for 1 in 10 year storm.

   b. Not exceed the maximum allowable flow width for the roadway.

6. Ensure catchpits in sag locations are designed to restrict flow width to allowable limits. Manufacturer’s tables or DRAINS spreadsheet can be used for this calculation.

Note – a draft design tool has been developed which references detailed capacity data tables and allows accurate spacing of catchpits based on road alignment information. Refer Figure 9 below.

Figure 9: Example of Draft Design Tool

ROAD GEOMETRY INPUT		TP108 Input	p24	143
or Side Slope (%) **Sx**	0.03		q*	0.16
Gutter Width (m) (low point to edge) **W**	0.3			
Half Road Width (incl. Gutter) (m)	8			
Manning's n	0.015			
Maximum Allowable Flow Width **T**	1.2			

Type 1	2400 Splaypit
Type 2	3600 Splaypit

NOTES	Use interpolate to the right for RL's at 1m intervals from 10m chainages				approximate value entered manually (nearest 0.5%)	From 'Half Rd Width' above, referencing TP108 Approach Flow sheet	Calculate per meter and input here				Input type 1 or 2 at compustary locations 1st then where flow width exceeds maximum allowable		
Chainage	RL	Longitudinal Grade	Road Width m	Road Area m2	Road crossfall	Runoff From Road (m^3/s)	Additional flow from off site (m^3/s)	Total Gutter Flow (m^3/s)	Flow width indexed	Flow Width (m)	Insert Catchpit Type 1-2	Captured flow	Bypass
0	80.000												
5	79.950	1.0%	10.00	50.00	3.0%	0.001156		0.0012	0.1057				
10	79.900	1.0%	10.00	50.00	3.0%	0.001156		0.0023	0.2115	0.6539		0.0000	0.0023
15	79.850	1.0%	10.00	50.00	3.0%	0.001156		0.0035	0.3172	0.7612		0.0000	0.0035
20	79.800	1.0%	10.00	50.00	3.0%	0.001156		0.0046	0.4229	0.8480		0.0000	0.0046
25	79.750	1.0%	10.00	50.00	3.0%	0.001156		0.0058	0.5287	0.9220		0.0000	0.0058
30	79.700	1.0%	10.00	50.00	3.0%	0.001156		0.0069	0.6064	0.9872		0.0000	0.0069
35	79.650	1.0%	10.00	50.00	3.0%	0.001156		0.0081	0.7618	1.0460		0.0000	0.0081
40	79.600	1.0%	10.00	50.00	3.0%	0.001156		0.0092	0.8396	1.0997		0.0000	0.0092
45	79.550	1.0%	10.00	50.00	3.0%	0.001156		0.0104	0.9173	1.1493		0.0000	0.0104
50	79.500	1.0%	10.00	50.00	3.0%	0.001156		0.0116	0.9674	1.1957		0.0000	0.0116
55	79.450	1.0%	10.00	50.00	3.0%	0.001156		0.0127	1.0175	1.2392	1	0.0120	0.0007
60	79.400	1.0%	10.00	50.00	3.0%	0.001156		0.0019	0.1057	0.6037		0.0000	0.0019
65	79.350	1.0%	10.00	50.00	3.0%	0.001156		0.0030	0.3172	0.7232		0.0000	0.0030
70	79.300	1.0%	10.00	50.00	3.0%	0.001156		0.0042	0.4229	0.8165		0.0000	0.0042
75	79.250	1.0%	10.00	50.00	3.0%	0.001156		0.0053	0.5287	0.8948		0.0000	0.0053
80	79.200	1.0%	10.00	50.00	3.0%	0.001156		0.0065	0.6064	0.9631		0.0000	0.0065
85	79.150	1.0%	10.00	50.00	3.0%	0.001156		0.0076	0.6841	1.0241		0.0000	0.0076
90	79.100	1.0%	10.00	50.00	3.0%	0.001156		0.0088	0.7618	1.0796		0.0000	0.0088
95	79.050	1.0%	10.00	50.00	3.0%	0.001156		0.0100	0.8396	1.1307		0.0000	0.0100
100	79.000	1.0%	10.00	50.00	3.0%	0.001156		0.0111	0.9674	1.1783		0.0000	0.0111
105	78.950	1.0%	10.00	50.00	3.0%	0.001156		0.0123	1.0175	1.2228	1	0.0120	0.0003
110	78.900	1.0%	10.00	50.00	3.0%	0.001156		0.0014	0.1057	0.5454		0.0000	0.0014

SUMMARY & CONCLUSIONS

This background review has resulted in a number of findings:

- HEC-22 (US Federal Highway Administration) is considered to be one of the most appropriate design procedure for estimating stormwater catchpit capacity

- This method has been applied throughout the US and also Australia (by Mainroads, the State Roading Authority).

- A spreadsheet and software application entitled 'DRAINS' has been developed by Watercom Pty (Sydney) which utilises the HEC-22 method.

- Comparisons of the HEC-22 results and lab testing have been done for a variety of catchpit types (different grates and kerb back entry lengths). The results showed good approximation to a number of catchpit types and also some discrepancy:

    - Grate only: HEC-22 gives a good approximation for flows < 0.5m3/s, and underestimates higher flows by approximately 25%.
    - Kerb inlet only: generally HEC-22 underestimates the lab results by between 10% and 33%
    - Combined inlet: HEC-22 gives a good approximation for flows < 0.5m3/s, and over estimates by between 10% and 20% for higher flows.
- A comparison of a range of Auckland and Australian catchpits (at different road grades) using HEC-22 showed that:

    - Of the catchpits available in Auckland, the Megapit has the greatest capacity and efficiency. The Megapit shows virtually no bypass for flows up to 500l/s.

    - The 2400mm Max-Pit gives the second highest inlet capacity. At flat grades it is comparable to the 3600mm Splay-pit, but at steeper grades, the Splay-pit capacity drops off.

    - Max pits (1200mm and 2400mm lintels) generally give reasonably constant results for different road grades

    - Splay pits (2400 and 3600mm) appear to decrease in efficiency as road grade increases.

    - It is noted that for kerb inlets only (eg Splay-pit), HEC-22 is expected to underestimate capacity by up to 33%. Adjustment factors were therefore used as recommended by relevant studies

- Blockage: no allowance is given in the HEC-22 method for blockage either of the grates or of the back entry. It is recommended that a blockage factor be applied when used in design.

- Catchpit Testing: It is recommended that, in order to reduce areas of discrepancy, lab testing be undertaken for the splay-pit in order to develop a definitive set of capacity curves for use in design. A similar testing regime to that used for the Max Pits is recommended (University of South Australia).

ACKNOWLEDGEMENTS

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