Australian Building Codes Board

Sanitary Plumbing and Drainage Pipe Sizing

Sanitary Plumbing and Drainage Pipe Sizing Report – Phase 2

Reference:

02 | 5 July 2023

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Executive Summary

This report considers the research conducted previously on the current methods for sizing sanitary plumbing and drainage systems used within Australia and takes into account industry observations to propose improvements to these methods. The goal of this report is to draw on the work done within the industry to date and further progress the Verification Method modifications proposed for the National Construction Code (NCC) Volume Three (Vol 3), Plumbing Code of Australia (PCA) due to be released in 2025. The modifications would allow for a more seamless and robust adoption of the previously proposed methods that have a proven scientific backing and could be modified to suit different building types, fixtures and system configurations, with the current day Australian Standard (AS) design guidance.

A continuation into the previous work conducted on fixture frequency usage factors, or K-Factors, was conducted to provide further research evidence to support the initial hypothesis relating time between fixture uses and the K-Factor. Further investigation into the modification of the equation constants were conducted to determine the effects of fixtures with vastly different time intervals between uses. It was determined that the original K-Factor equation is heavily dependent and varied significantly based on the time intervals between fixture uses in an intermittent, frequent and congested environment. The consideration into the latest fixture research data was restricted due to the limited data available at the time of writing however, the methods for analysing this data as well as documentation for requesting this data has been developed. This provides the opportunity for further investigation into developing a more bespoke K-Factor equation more suited to the fixture usage profiles of the modern day, built environment.

Previous work identified the common industry concerns that has developed over the recent decades regarding 'over-sizing' of drainage systems resulting in solid stranding and blockage issues due to technical advancements in sanitary ware, fixtures and appliances, in conjunction with the environmental desire to reduce water consumption. A more refined K-Factor equation could result in the opportunity to rationalise sizing outcomes, allowing a reduction in material usage and an overall positive impact on the environment, whether it be through saving space within a building or reducing the actual material that is manufactured, transported, installed and ultimately disposed of, or recycled.

With the introduction of additional guidance to developing a performance based sanitary plumbing and drainage design through the verification methods in the NCC 2022 Vol 3 PCA, designers now have a reliable pathway to adapt the European Standard *BS EN 12056.2:2000*. *BS EN 12056.2:2000 Gravity Drainage Systems Inside Buildings,* which is adopted by both the Institute of Plumbing (IOP) *Plumbing Engineering Services Design Guide* and *CIBSE Guide G Public Health and Plumbing*, provides a fixture discharge rate for each common fixture type with a probability usage factor developed by considering time between use and time of operation applied to the square root of the total calculated flow rate. This allows final flow rates to be adjusted to suit different building use, resulting in a more accurate and considered method for sizing the sanitary plumbing and drainage system. This circumvents the limitations within *AS/NZS 3500.2:2021 Sanitary Plumbing and Drainage* where a common Fixture Unit (FU) is applied for each fixture across all type of buildings without further consideration of usage probability or a rationalisation factor applied outside the FU itself.

Although the use of the European Standard as a standalone verification method certainly has its merits and has been tried and tested over a number of years, it has its limitations, particularly around sizing of vent pipework and sanitary plumbing in high rise buildings. Conversely, the AS provides significantly more guidance when it comes to sizing sanitary plumbing and ventilation pipework, particularly for fully vented and fully vented modified systems whereby the sizing of relief vents considers the effect of cross-sectional area and developed lengths on stack loads.

In continuation of the *ABCB Sanitary Plumbing and Drainage Pipe Sizing* Phase 1 Report, this report supports the position of adopting a more robust performance based method for sizing sanitary plumbing and drainage in the NCC 2025 Vol 3 PCA. Based on the additional research and comparisons conducted within this report, and the commentary provided on any potential points of system failure in sanitary plumbing design, we support removing British Standard elements of the VM to allow for application of additional AS elements. Whilst fundamentally the same, we concluded that adopting select, modified methods of the British Standard *BS EN 12056.2:2000* in an otherwise primarily AS 3500.2:2021 method, is a sensible means for limiting risk and increasing confidence to hydraulic practitioners seeking to adopt an alternative method for pipe sizing.

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1. Introduction

Arup has been engaged by the Australian Building Codes Board (ABCB) to continue the next phase of the research work on Sanitary Plumbing and Drainage Pipe Sizing. This project commissioned by the ABCB centres around the development, or adoption, of an industry accepted performance-based method for calculating sanitary drainage and plumbing pipe sizes within the future *National Construction Code, Volume 3 Plumbing Code of Australia 2025*.

As discussed within the previous Arup Phase 1 report, it is widely accepted in the Hydraulic and Plumbing Engineering Industry that the current methodology for calculating domestic water supply pipework and sanitary plumbing and drainage pipework under *PCA Volume 3* and *AS/NZS 3500* is outdated and does not reflect the real-world operating conditions of plumbing systems of today.

The previous research project phase conducted by Arup, and indeed previous work within the industry, assessed current Sanitary Plumbing and Drainage Pipe sizing methods with a view to optimise and enhance a common method for the hydraulic industry to more accurately size plumbing and drainage pipework through a performance-based approach which respects the advancements in plumbing technology and building occupancy use.

A short term and long term solution was recommended, with the former largely involving the adoption of the sanitary plumbing and drainage design standards from the British standard *BS EN 12056.2:2000*. Further testing using multiple different building types within the NCC was recommended to provide a greater understanding of the differences between a BS Verification Method system design and a AS DTS system design.

This report builds upon the Phase 1 work of this project and provides further development and guidance around the use of the proposed Verification Methods through the collection of additional research and data, and further review of *BS EN 12056.2:2000* for adaption to the Australian industry. The report also intends to provide further guidance for any parties interested in participating in the development of this Verification Method through an RFI explanatory note and schedule.

1.1 Terms and Abbreviations

Term	Description
Australian Building Codes Board (ABCB)	The organisation responsible for preparing the National Construction Code and Plumbing Code of Australia, and the end client of this report.
Australian Standard (AS)	See reference list for Australian Standards referenced in this report
Australian / New Zealand Standard (AS/NZS)	See reference list for Australian / New Zealand Standards referenced in this report
Average flush volume	Average volume of water used in a flushing appliance calculated by taking one full flush discharge volume and four reduced flush discharge volumes
Arrestor	Apparatus designed to intercept and retain silt, sand, oil, grease, sludge or other substances that are prohibited to charge to the sewer or drainage system
Backflow	Flow in a direction contrary to the normal or intended direction of flow
Basin (WHB)	Fixture for holding water for ablutionary purposes

Term	Description
Bath (B)	Fixture for containing water in which the human body may be immersed for ablutionary or treatment purposes
Branch Drain	Section of drain the is intended to receive the discharge of fixture discharge pipe which has a lower fixture unit loading and which may be of a smaller nominal size than the main drainage at its point of connection,
British Standard (BS)	See reference list for British Standards referenced in this report
British / European Standard (BS/EN)	See reference list for British / European Standards referenced in this report
Capacity	Volume calculated of effective water level or wetted area of pipework
Channel	Open graded passage for the conveyance of liquids
Designer	The plumbing or hydraulic practitioner designing the sanitary plumbing and drainage system
Deemed to Satisfy (DTS)	Compliant with the prescriptive requirements of the referenced standard I.e., Plumbing Code of Australia, BS 12056.2 or AS/NZS 3500.2
Discharge capacity	Volume of water discharged from a fixture appliance
Discharge Unit (DU)	Typically used in British Standard BS EN 12056.2 - Unit of measure based on the rate of discharge, timer of operation and frequency of use of a fixture that express the hydraulic load imposed by that fixture on the sanitary plumbing installation
Drain	Pipework installed above or below ground including all fittings, intended to convey sewer, waste water or trade waste water under gravity conditions
Fitting	Item placed in a pipeline for jointing, connecting or changing the direction or internal diameter of the pipeline
Fixture Unit (FU)	Typically used in Australian Standards AS3500 - Unit of measure based on the rate of discharge, timer of operation and frequency of use of a fixture that express the hydraulic load imposed by that fixture on the sanitary plumbing installation
Frequency factor	Coefficient based on probability of fixture use applied to calculated drainage flow rate to adjust final sum to consider likelihood of probable use
Fully vented system	Sanitary plumbing system with provision for separate ventilation of every fixture trap connected other than trap of each floor waste gully
Fully vented modified system	Sanitary plumbing system where traps of any group of two or more fixtures of floor waste gully discharging to the same branch pipe are vented in a common by one or more group vents
Loading Unit (LU)	Typically used in Australian Standards AS/NZS3500 - Weighted factor applied to a fixture or appliance, used for the estimation of simultaneous water usage rates
Main Drain	Main conduit of a drainage system to which branches are connected
National Construction Code (NCC)	The primary set of technical design and construction provisions for buildings in Australia.
Plumbing Code of Australia (PCA)	The third volume of the three published volumes within the NCC.

Term	Description
Sanitary drainage system	Horizontal in-ground or elevated drainage which is not an offset part of a sanitary plumbing system.
Sanitary plumbing system	A network of vertical pipes using the stack principals of either single stack, single stack modified, fully vented, or fully vented modified, including any horizontal offsets as part of the stack.
Sink (SK)	Waste water fixture containing one or more bowls to temporarily retain water for cleaning purposes and for receiving domestic, culinary, laboratory or industrial waste water
Water Closet (WC)	Sanitary fixture consisting of water closet cistern and water closet pan.
Water closet cistern	Flushing cistern to be installed with a water closet pan which incorporate and control valve to control water level and a flushing valve to discharge water into the water closet pan
Water closet pan	Accepting bowl to be installed with a water closet cistern or flush valve which incorporate a trap seal for accepting discharge from water closet cistern
Water seal depth	Vertical distance measured between the dip and crown weir of a trap
Waste water	Waste water discharged from waste water fixtures
Waste water fixture	Sanitary appliance for acceptance of waste water typically shower, wash hand basin, kitchen sink, laundry sink
Soil water	Soiled waste water discharged from water closet or urinal
Soil fixture	Sanitary fixture for use in soil applications typically water closet or urinal
Stack	Vertical pipe included offset that extends through more than one floor level using
Vent / Vent pipe	Pipe used for carrying air within sanitary plumbing and drainage systems
Verification Method (VM)	Performance based compliance pathway under the Plumbing Code of Australia

1.2 Symbols

Symbols	Definitions
°	degree(s)
°C	degree(s) Celsius
µm	micrometre
kg	kilogram(s)
kg/m	kilogram(s) per metre
Km	Kilometre(s)
kPa	Kilopascal(s)
L	Litre(s)
L/min	Litre(s) per minute
L/sec	Litre(s) per second
M	Metre(s)
m/s2	Metre(s) per second
m2	Square metre(s)
min	Minute(s)
mm	Millimetre(s)
Pa	Pascal(s)
Pa/m	Pascal(s) per metre
Q	Flow volume
%	Percentage
>	Greater than
<	Less than
≤	Less than or equal to
≥	Equal to or more than

Further symbols used within specific calculations are referenced as part of a calculation explanation throughout the body of this report.

1.3 Project Stakeholders

1.3.1 ABCB Team

The Australian Building Codes Board Team who leads the collaboration of this research project is as follows.

Role	Name	Phone	Email
Project Manager	Neil Rech	02 6243 7980	neil.rech@abcb.gov.au
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1.3.2 Arup Research Team

The research conducted by Arup as part of this project was led by the following members of the Arup Public Health, Hydraulic and Plumbing team.

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2. Scope and Limitations

2.1 History of ABCB research

Previous research commissioned by the Australian Building Codes Board as part of the Sanitary Plumbing and Drainage Pipe Sizing project is summarised in the following reports:

- Fixture Unit Rating Systems – Discussion Paper (GHD, 2015)
- Sanitary Plumbing and Drainage Pipe Sizing – British and European Standards Review (Lucid Consulting Australia, 2019)
- Sanitary Plumbing and Drainage Pipe Sizing Verification Methods (Lucid Consulting Australia, 2020)
- Draft National Construction Code Volume 3 – Plumbing Code of Australia 2022 (Australian Building Codes Board, 2022)

We have reviewed these reports, our opinion and commentary on their findings can be found in the Phase 1 Report (Arup, 2022).

2.2 Scope of this paper

2.2.1 Objectives

The ultimate objective of the Sanitary Plumbing and Drainage Pipe Sizing project as set out by the Australian Building Codes Board is to update the *National Construction Code, Volume Three, the Plumbing Code of Australia*.

To help achieve this goal this current phase consists of two primary stages each defined by the Australian Building Codes Board with a set of key objectives outlined below.

2.2.2 Stage 1

1. Review of the previous work conducted by the ABCB for sanitary drainage pipe sizing (see above).
2. Review and replace the discharge units with the appropriate flow rates (L/s) from each plumbing fixture based on the information provided by the ABCB upon engagement.
3. Note: It is assumed that the difference between the discharge units and the observed flow rates is a result of changes in fixture use and efficiency since the inception of the discharge unit. There may also have been a safety factor built into the discharge unit resulting in an overestimation.
4. Review and update the frequency factors (the probability of fixture use) for all appropriate classes of buildings. This is a key feature of this pipe sizing methodology. Consideration should be given to the number of fixtures provided in correlation with the number of bedrooms where appropriate (such as multiunit residential buildings). Where possible, Verification Methods in Section C of NCC Volume Three 2022 – Preview (Australian Building Codes Board, 2023) should be expanded where the frequency of use data provides for an accurate estimation of the different use of fixtures in different building types. Data on frequency of fixture use may be available from the ABCB Office to assist in this investigation. Consideration should be given to the *Peak Water Demand Study* (Buchberger, et al., 2017).
5. Review the sizing methodology and calculations in the Verification Methods of Section C of NCC Volume Three 2022 – Preview (Australian Building Codes Board, 2023).
6. Consider the appropriateness of the filling capacities of different system types.

7. Consider the grades of pipes for each appropriate size as outlined in *AS/NZS 3500.2:2021* (Standards Australia, 2021), noting that the Verification Method utilised for pipe sizing should limit any changes to current installation practices where possible.

8. Produce staging plan to address the objectives of Phase 2.

2.2.3 Stage 2

1. Develop an overview of the appropriate hydraulic capacities of different sanitary pipe sizes that can be utilised. An outline of the appropriate hydraulic capacity for each pipe size is required to ensure that the pipe size selected is appropriate for the hydraulic capacity determined by the Verification Method.

2. Note: Hydraulic capacities of different pipe sizes, grades and materials are provided in Australian Standards such *as AS/NZS 3500.2:2021* (Standards Australia, 2021) and *AS 2200:2006* (Standards Australia, 2006).

3. Provide recommendations of any required safety factors which should be considered or investigated further to ensure that the risk of system failure is appropriately addressed.

4. Provide recommendations on ventilation requirements to ensure that use of the revised sanitary plumbing and drainage pipe sizing methodology does not create a hydraulic imbalance in the system.

5. Identify any consequential changes required to the design and installation practices to facilitate the use of this alternative pipe sizing methodology.

2.2.4 Outcomes

The research conducted by Arup as part of the Phase 1 Report and Phase 2 report took place between June 2022 and August 2022, and May 2023 and June 2023 respectively. The above Stage 1 and Stage 2 objectives have evolved through the undertaking of this report, an expanded and modified set of Stage 2 objectives is outlined in the Stage 2 Plan within the appendix of this report.

2.2.5 Clarifications

This report is subject to the following disclaimers.

- As part of the research conducted to inform this report, we have sourced literature which was freely available on the subject matter at the time of writing. We do not claim to have reviewed all resources relevant to the subject matter.

- No physical installation, physical performance testing, mock ups or surveying has been completed by Arup as part of this report.

- Our research and analysis is largely based on available information and known mathematical equations. We have used excel based spreadsheets as part of our testing and comparison of different methods using the formulas outlined in this report. No complex computer simulations or modelling have been completed by Arup as part of this report.

- This report intends to review existing information and provide opinion on performance-based sizing methods for sanitary plumbing and drainage flow rates and pipe sizing only, and intends to inform scope for future testing, analysis and further development of sanitary plumbing and drainage pipe sizing methods.

- This report is intended to be reviewed by the Australian Building Codes Board and Hydraulic Industry working group which includes other qualified and reputable hydraulic consultants, external industry experts and licensed plumbing contractors prior to incorporation into any future codes or standards as a performance-based design framework. We accept no responsibility for any outcomes as a result of using this method.

2.3 Disclaimers

This report is subject to the following disclaimers:

- This report contains work completed by Arup as part of Phase 2 of the Sanitary Plumbing and Drainage Pipe Sizing Project. All information contained within this report has been prepared by Arup in accordance with instructions from the Australian Building Codes Board and taking into account our client's particular instructions and requirements and addresses their priorities at the time. This report is not intended for, and Arup has no liability for, any third-party use or reliance on this report. Arup is not responsible for updating this report should any information, opinions and recommendation no longer be valid in the future.

- In preparing this Sanitary Plumbing and Drainage Pipe Sizing research report we are relying on information contained in reports supplied by GHD and Lucid Consulting Australia who have been appointed directly by the Australian Building Codes Board. We have relied in particular on the accuracy and completeness of those reports and accept no liability for any error or omission in those reports which has resulted in an error or omission within this report.

- Arup is not responsible for the accurateness of any 3rd party material, technical data or information referenced within this report including design standards, guidelines, research papers and testing data.

- The work undertaken by Arup in connection with preparing this report is subject to the terms of the agreement between Arup and the Australian Building Codes Board including scope limitations set out in this report.

- This report is designed to provide information in regard to the subject matter covered. The views expressed in this publication are those of the author(s). The publisher / editor / author does not accept any responsibility for the contents or any loss or damage which might occur as a result of following or using data or advice given in this report.

- The sizing methods and formulas recommended in this report are for guidance only. It is the responsibility of the engineer / designer applying these formulas to satisfy themselves of the accurateness and appropriateness of using these methods and formulas. Arup is not responsible for the use of these methods and formulas by others.

3. K-Factor Development Continuation

3.1 Expansion on Phase 1 Research

Research conducted as part of the first phase of this project were able to speculate a mathematical means to derive K-Factors using only durations between fixture intervals. As per Section 4.1 of Phase 1 Report (Arup, 2022), a relationship between successive fixture use intervals provided by the *Plumbing Engineering Services Guide* (IOP) (Whitehead, 2002) and *CIBSE Guide G* (CIBSE, 2014), and K-Factors found in *BS EN 12056-2:2000* (B.S. Institute, 2000) and the IOP (Whitehead, 2002), was derived to be:

$$K = \left(\frac{300}{T}\right)^{0.5} = \sqrt{\frac{300}{T}}$$

The derivation of this formula assumes a correlation between the 1200, 600 and 300 second time interval between successive supply uses for the respective K factors 0.5, 0.7 and 1, as demonstrated in Table 1. From this assumption, a table of expanded K-Factors were developed to accommodate a range of time intervals shown in Table 2.

As identified in the Phase 1 Report (Arup, 2022), whilst the curve fitting exercise supported our assumption, with only three data points to extract a trendline, it is not possible to state with certainty that this is the actual relationship between K-Factors and time between fixture uses. Extrapolating so far beyond the existing data points can also lead to significant errors as it assumes the trend continues indefinitely. Furthermore, the Phase 1 Report (Arup, 2022) identified the resemblance of the term within the square root $\left(\frac{300}{T}\right)$ to the fixture discharge probability referenced in (Wise & Swaffield, 2002):

$$p = \frac{t}{T} = \frac{Average\ duration\ of\ a\ fixture\ discharge\ (s)}{Average\ time\ interval\ between\ consecutive\ discharges\ (s)}$$

Whilst the above form of $\left(\frac{300}{T}\right)$ is similar to that of the probability of fixture discharge, it does not make sense for a typical fixture to be in operation for 300 seconds (5 minutes).

Table 1: Potential fixture usage interval and K-Factor relationship (Arup, 2022)

Time Between Fixture Use (second)	K-Factor
1200	0.5
600	0.7
300	1.0

Table 2: Table of Expanded K-Factors with Data Points Used to Extrapolate Other Values in Green (Arup, 2022)

Time Between Fixture Use (second)	K-Factor
3400	0.3
1900	0.4
1200	0.5
800	0.6
600	0.7
450	0.8
300	1.0

Time Between Fixture Use (second)	K-Factor
200	1.2

Although the *Plumbing Engineering Services Guide* (Whitehead, 2002) and *CIBSE Guide G* (CIBSE, 2014) both reference low, medium and high frequencies of use as 1200, 600 and 300 seconds respectively, the design guide also provides different frequency of use ranges for various fixtures (see Figure 1 below). For example, the time duration between a bath being used is 4800, 2400 and 1200 seconds for low, medium, and high use cases respectively.

Type of appliance	Capacity (litres)	Flow rate (litres/sec)	Demand (seconds)	Frequency (seconds)	Usage ratio	Prop of base appl. ratio	Prop of base appl. flow rate	Demand figure	Demand unit
Basin , 15mm sep. taps	5	0.15	33	1200	0.282	1.00	1.00	1.000	1
	5	0.15	33	600	0.055	2.00	1.00	2.000	2
	5	0.15	33	300	0.110	4.00	1.00	4.000	4
Basin, 2 × 8mm mix tap	5	0.08	33	1200	0.028	1.00	0.53	0.533	1
	5	0.08	33	600	0.055	2.00	0.53	1.067	1
	5	0.08	33	300	0.110	4.00	0.53	2.133	3
Sink, 15mm sep./mix tap	12	0.2	60	1200	0.050	1.82	1.33	2.424	2
	12	0.2	60	600	0.100	3.64	1.33	4.848	5
	12	0.2	60	300	0.200	7.27	1.33	9.697	10
Sink, 20mm sep./mix tap	18	0.3	60	600	0.100	3.64	2.00	7.273	7
Bath, 15mm sep./mix tap	80	0.3	266	4800	0.055	2.02	2.00	4.030	4
	80	0.3	266	2400	0.111	4.03	2.00	8.061	8
	80	0.3	266	1200	0.222	8.06	2.00	16.121	16
Bath, 20mm sep./mix tap	80	0.5	266	3000	0.089	3.22	3.33	10.747	11
WC Suite, 6 litre cistern	4.5	0.1	60	1200	0.050	1.82	0.67	1.212	1
	4.5	0.1	60	600	0.100	3.64	0.67	2.424	2
	4.5	0.1	60	300	0.200	7.27	0.67	4.848	5
Shower, 15mm head	6	0.08	300	2700	0.111	4.04	0.53	2.155	2
	6	0.08	300	1800	0.167	6.06	0.53	3.232	3
	6	0.08	300	900	0.333	12.12	0.53	6.465	6
Urinal, single bowl/stall	0	0.003	1500	1500	1.000	36.36	0.02	0.727	1
Bidet, 15mm mix tap	0	0.08	33	1200	0.028	1.00	0.53	0.533	1
	0	0.08	33	600	0.055	2.00	0.53	1.067	1
Hand spray, 15mm	0	0.08	75	1200	0.067	2.27	0.53	1.212	1
Bucket sink, 15mm taps	0	0.15	60	3600	0.017	0.61	1.00	0.606	1
Slop hopper, cistenr only	7.5	0.1	75	600	0.125	4.55	0.67	3.030	3
Slop hopper, cistern/taps	7.5	0.2	60	600	0.100	3.64	1.33	4.848	5
Clothes washing m/c, dom.	5	0.2	25	600	0.042	1.52	1.33	2.020	2

Figure 1: Simultaneous demand base data for various fixtures (Whitehead, 2002)

By conducting a similar curve fitting exercise, two additional equations describing the relationship between K-Factor and duration between fixture uses were obtained, as shown below in Table 3, and have been plotted below in Figure 2.

Table 3: Alternative K-Factor equations using different durations between fixture uses

Item	Low Use Case (K = 0.5)	Medium Use Case (K = 0.7)	High Use Case (K = 1.0)	K-Factor Equation
Duration Between Fixture Use (s) (Basin, Sink, WC, Bidet)	1200	600	300	$K = \left(\frac{300}{T}\right)^{0.5}$
Duration Between Fixture Use (s) (Shower)	2700	1800	900	$K = \left(\frac{932.8}{T}\right)^{0.618}$
Duration Between Fixture Use (s) (Bath)	4800	2400	1200	$K = \left(\frac{1192}{T}\right)^{0.5}$

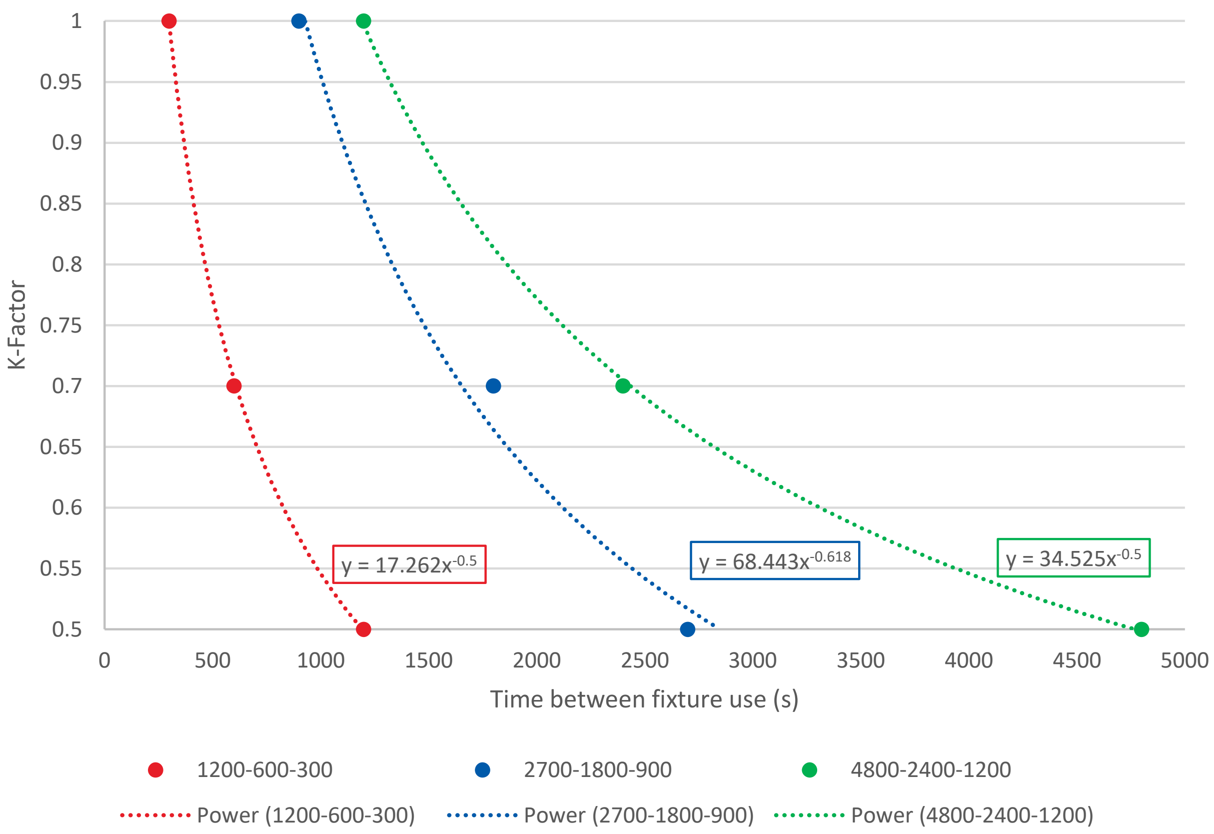

Figure 2: Graphical representation and curve fitting of alternative K-Factor equations using different durations between fixture uses

The comparison above showcases the variability and dependence of the original K-Factor equation on the range of time intervals between fixture uses proposed within the Phase 1 researched and thus, any further expansion or development of these factors should be conducted with careful consideration of the trends observed within the latest fixture research data.

3.2 RFI, Explanatory Note and Schedule

A Request for Information (RFI) package has been developed detailing the data required to improve the granularity of the K-Factors respective to the NCC Building Classes and obtain more modernised data to validate or amend our assumptions derived from the IOP technical guide. Accompanying water usage monitoring explanatory notes have also been documented for Enware and GWA. Refer to Appendix A for RFI documents.

3.3 Appraisal of Data from Literature and Influence of K-Factor on Sanitary Plumbing Sizing

In the absence of monitoring data for the NCC Building classes, a review of residential fixture usage data from literature and a comparison of resultant sizing recommendations of sanitary plumbing components using varied K-Factors was conducted to make interim recommendations of suitable K-Factor values for NCC Building classes.

3.3.1 Overview of Analysis of Literature Data and K-Factor Study

A K-Factor assessment of a residential building was conducted using data of peak hourly usage of each fixture from (Wise & Swaffield, 2002) and the fixture discharge times to determine the average time interval between fixture discharge events and a resultant K-Factor. Refer to Appendix C, Appendix AAppendix D and Appendix E for collected data, data analysis methodology and data analysis of a residential building.

A comparison of wastewater flow rates for a model residential tower and office building calculated using the Fixture unit method in *AS/NZS 3500.2:2021* (Standards Australia, 2021) (and using the formula specified in Table 7 to convert fixture units to a flow rate) and the DU and K-Factor method in *BS EN 12056.2:2000* (B.S. Institute, 2000) was conducted in Appendix B.18.

An assessment of the influence of a K-Factor of 0.3 versus 0.5 on the sizing results of sanitary plumbing components using a proposed 'integrated method' that will be adopted for the Verification Method (refer to Section 4.4 for definition), was conducted in Appendix B.19. A residential tower model was developed for various building heights (3-, 5-, 7-, 10-, 15-, 20-, 30- and 50-floors) and with 1 or 2 appliance groups connected to the stack per floor level. The implementation of System I, II and III discharge unit values were also assessed. Stack sizing, relief vent sizing and cross-vent locations was assessed for Single stack, single stack modified and fully vented (and modified) system configurations.

3.3.2 Results and Key Findings

Our analysis of literature from (Wise & Swaffield, 2002) demonstrates that it is likely a residential building will have an average time interval between fixture discharge events in the order of 3000 seconds. Using the formula proposed in Section 3.1 to convert time interval between fixture usage to a K-Factor, this would result in a K-Factor of approximately 0.3.

From testing of the residential tower model, it was evident that a K-Factor of 0.7 was most similar to the resultant flow rate derived from *AS/NZS 3500.2:2021* (Standards Australia, 2021), with flow rates calculated using a K-Factor of 0.5 and 1 being significantly lower and higher than *AS/NZS 3500.2:2021* (Standards Australia, 2021). Similar results were achieved for the office building model tested, however the *AS/NZS 3500.2:2021* (Standards Australia, 2021) was almost as close to a K-factor of 0.5 as it was to 0.7 (refer to Table 47 in B.18.3). Hence, it appears that a *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rate calculated with a:

- K-Factor of 0.5, is smaller than that of *AS/NZS 3500.2:2021* (Standards Australia, 2021)
- K-Factor of 0.7, is approximately equal to that of *AS/NZS 3500.2:2021* (Standards Australia, 2021)
- K-Factor of 1, is larger than that of *AS/NZS 3500.2:2021* (Standards Australia, 2021)

From testing of a residential tower model, the implementation of a K-Factor of 0.3 as opposed to 0.5, introduces substantial reductions to stack and relief vent sizing, primarily for the fully vented (and modified) system, when considering the use of the proposed integrated method. This could potentially result in an under sized system for buildings with minimal fixtures connected to a stack. Hence, we recommend against setting any NCC Building class to have a frequency factor less than 0.5 without further analysis and testing around outcomes of a frequency factor less than 0.5.

3.4 K-Factor Expansion

Based on the findings detailed in Section 3.3, the proposed K-Facor expansion for NCC Building Classes 1-9c will range from a K-Factor of 0.5 to 1.2. The proposed K-Factor expansion is summarised below in Table 4.

Table 4: K-Factor Expansion Based on Appraisal of Data from Literature and a comparison of resultant wastewater flow rates utilising different K-Factors

NCC Building Class	NCC Building Class Example	Frequency Factor (K)	Time interval between Fixture Use averaged over Peak Period (s)
Class 1	Residential dwelling, duplexes, or townhouses	0.5	1200
Class 2	Apartment or unit	0.5 – 0.8	450 – 1200
Class 3	Hotel, hostel, dormitory	0.6 – 0.8	450 - 800
Class 4	Caretaker's residence within storage facility	0.5	1200
Class 5	Office or commercial building	0.6 - 0.8	450 - 800
Class 6	Retail, shop, restaurant, café	0.6 - 0.8	450 - 800
Class 7	Carpark, warehouse, storage building	0.6 - 0.8	450 - 800
Class 8	Factory, workshop, laboratory	0.6 - 0.8	450 - 800
Class 9a	Healthcare building, hospital, and GP clinics	0.6 - 0.8	450 - 800
Class 9b	Public event buildings, stadiums, theatres, schools, universities, and churches	1.0 - 1.2	200 - 300
Class 9c	Aged care facilities	0.6 - 0.8	450 - 800

3.5 Recommendations and Next Steps

In the absence of monitoring data for the NCC Building classes, the formula relating K-Factors and time intervals between fixture usage (see Section 3.1), based on the data points summarised in Table 1 will be implemented.

If data in the interim becomes available for a specific NCC building class, the resultant average time between fixture usage determined over the peak period of use can be substituted into $K = \left(\frac{300}{T}\right)^{0.5}$, and the resultant K-Factor used, if it is within the range of 0.5 to 1.2.

When a comprehensive fixture usage monitoring dataset for all NCC Building classes becomes available, and provides a quantity of data to ensure sufficient reliability and accuracy, it may be warranted that the equation presented in Section 3.1 relating K-Factors to time between fixture usage, is recalibrated against time intervals between fixture usage that have been informed by the data to allow for more accurate K-Factor recommendations within the limits of 0.5 to 1.2.

We recommend maintaining K-Factors within the range of 0.5 to 1.2, since they have been implemented by the *BS EN 12056.2:2000* (B.S. Institute, 2000) and their implementation into design has validated the safety of their usage. However, K-Factors less than 0.5 or greater than 1.2 may be considered if physical testing of systems designed to K-Factors outside of this range demonstrate system compliance to performance specifications within the NCC.

4. Effect of Tall Buildings on Stack Height and System Configurations for Proposed Verification Method

4.1 Expansion on Phase 1 Research

The research conducted as part of the Phase 1 investigation on stack and vent sizing concluded that the *BS EN 12056.2:2000* (B.S. Institute, 2000) branch, stack and vent sizing methodology in general, can be implemented into the *NCC 2025 Plumbing Code of Australia* albeit with some limitations. Although a high level comparison between the *BS EN 12056.2:2000* (B.S. Institute, 2000) and *AS3500.2:2021* (Standards Australia, 2021) standards were conducted in Phase 1 of the report (see Appendix A.8), a further in-depth comparative assessment was recommended. This would allow a better understanding of the implications with adopting this method for the Australian Plumbing Industry and determine how feasible it is to adopt the *BS EN 2056.2:2000* (B.S. Institute, 2000) to calculate flow rate and pipe size in an otherwise *AS3500.2:2021* (Standards Australia, 2021) designed sanitary plumbing and drainage system.

With this research into Sanitary Plumbing and Pipe Sizing, a select number of recommendations proposed within the Phase 1 report specifically relating to stack height and system configurations for tall buildings will be considered. These include:

- Impacts of using *AS3500.2:2021* (Standards Australia, 2021) relief vent sizing based on developed lengths and stack loading in a system with flow rates and pipe sizes obtained using *BS EN 12056.2:2000* (B.S. Institute, 2000) [System I and II].

- Impacts of using *AS3500.2:2021* (Standards Australia, 2021) clearance zones at base of stacks and stack entry points in a system with flow rates and pipe sizes obtained using *BS EN 12056.2:2000* (B.S. Institute, 2000) [System I and II].

- Impacts of using *AS3500.2:2021* (Standards Australia, 2021) header vent sizing guidance in a system with flow rates and pipe sizes obtained using *BS EN 12056.2:2000* (B.S. Institute, 2000) [System I and II], noting lack of guidance in the latter standard.

Additional considerations outside the scope of this Phase of work are documented within Section 6.7 of the Phase 1 Report (Arup, 2022).

4.2 Comparison of AS/NZS 3500.2:2021 and BS EN 12056.2:2000 Standards

An in-depth comparison between *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) has been conducted and documented within Appendix B. A summary of the key findings, calculations, and considerations with reference to their relevant appendix sections are as follows:

- The system configurations within *AS/NZS 3500.2:2021* (Standards Australia, 2006) and *BS EN 12056.2:2000* (B.S. Institute, 2000) cannot be substituted for one another as the overall method for design and installation are too dissimilar. Based on the definitions obtained within each respective standard, the systems configurations can however be related in the following manner. Definitions of these systems and further clarifications for these relationships are detailed in Appendix B.1.

Table 5: Table Extracted from Appendix B - *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* Stack Configuration Comparison

***AS/NZS 3500.2:2021* Stack Configuration**		**Similar or Equivalent *BS EN 12056.2:2000* Stack Configuration**	
System	**Sizing Reference**	**System**	**Sizing Reference**
Single Stack	Table 9.7.1(A) & (B) of *AS/NZS 3500.2:2021*	Primary Ventilated	Table 11 of *BS EN 12056.2:2000*
Single Stack Modified	Table 9.7.2(A) & (B) of *AS/NZS 3500.2:2021*	Secondary Ventilated	Table 12 of *BS EN 12056.2:2000*
Fully Vented	Table 8.2.2(B) of *AS/NZS 3500.2:2021*		
Fully Vented Modified			

Table 6: Table Extracted from Appendix B - *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* Branch Configuration Comparison

***AS/NZS 3500.2:2021* Branch Configuration**		**Similar or Equivalent *BS EN 12056.2:2000* Branch Configuration**	
System	**Sizing Reference**	**System**	**Sizing Reference**
Single Stack	Table 6.3(A) of *AS/NZS 3500.2:2021*	Unventilated Discharge Branche (System III)	Table 6 of *BS EN 12056.2:2000*
Single Stack Modified			
Fully Vented	Table 8.2.2(A) of *AS/NZS 3500.2:2021*	Ventilated Discharge Branche (System I and II)	Table 7 of *BS EN 12056.2:2000*
Fully Vented Modified			
NA		Ventilated Discharge Branche (System III)	Table 9 of *BS EN 12056.2:2000*
NA		Unventilated Discharge Branche (System I and II)	Table 4 of *BS EN 12056.2:2000*

- Where *BS EN 12056.2:2000* (B.S. Institute, 2000) calculates a probable simultaneous wastewater flow rate Q_{ww} (L/s) based off a summation of discharge units ($\sum DU$) and a Frequency Factor (K), a similar equivalent equation can be used for *AS/NZS 3500.2:2021* (Standards Australia, 2021), despite the standard method using the sum of the fixture unit ratings ($\sum FU$) based off a weighting factor from a reference fixture. The justification for the use of the FU to flowrate conversion equation is discussed in Appendix B.2.

Table 7: *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* Sanitary Plumbing and Drainage Flowrate Equations

***AS/NZS 3500.2:2021* Sanitary Plumbing and Drainage Flowrate Equation**	***BS EN 12056.2:2000* Sanitary Plumbing and Drainage Flowrate Equation**
$Q_{ww,AS} = \sqrt{\frac{\sum FU}{6.75}}$	$Q_{ww,BS} = K\sqrt{\sum DU}$

- *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack design versus *BS EN 12056.2:2000* (B.S. Institute, 2000) primary ventilated design is summarised in Table 8 below: (Detailed discussion in Appendix B.3)

Table 8: Stack Sizing Requirements *AS/NZS 3500.2:2021* single stack versus *BS EN 12056.2:2000* primary ventilated system

Design Item	*AS/NZS 3500.2:2021* Single Stack	*BS EN 12056.2:2000* Primary Ventilated System
Ventilation of Branches	Branches are unventilated.	Branches can be ventilated or unventilated and can be designed to System I to III requirements.
Influence of branch configurations on Stack Sizing	Except for some provisions for fixture pairs and fixture ranges, "*Each fixture is to be connected to the stack by a separate unvented fixture discharge pipe of a prescribed length, size and grade*."	• Fixtures in a System I and II design are to be connected similar to that of a *AS/NZS 3500.2:2021* Fully vented and modified system. • Fixtures in a System III design are to be connected similar to that of a *AS/NZS 3500.2:2021* Single Stack.
Floor level limitations	Specified[1] • DN100: – Domestic/Residential: 10 consecutive floors – Commercial: 4 consecutive floors • DN125: – Domestic/Residential: 15 consecutive floors – Commercial: 6 consecutive floors • DN150: – Domestic/Residential: 30 consecutive floors – Commercial: 8 consecutive floors	Not specified
Influence of Commercial versus Residential building type on Stack Sizing Influence of branch connections on stack sizing	Specified • Limitations to number & type of fixtures connected to a stack on each level specified for commercial and residential building types. • Provision for fixture ranges connected to a common discharge pipe. • Separate sizing tables provided for residential and commercial. • Difference in equivalent flow rates	Not specified. • Variation in building type is accounted for by the K-Factor, which influences the loading of stack. However, this accounts only for the expected frequency of use of appliances, not the connection of fixtures.
Provisions for smaller stack sizes (DN40-100)	Specified. Requirement that: • the stack has no offsets, and • not more than 25% of the maximum loading of a stack may discharge into each floor level (with exceptions for stacks ≤ DN50).	Not specified

[1] Not specified for sizing of DN40-100 using Table 9.5.2 of AS/NZS 3500.2:2021.

Table 9: Table Extracted from Appendix B - Comparison of Maximum Hydraulic Loading on Stacks specified in *AS/NZS 3500.2:2021* Single Stack System and *BS EN 12056.2:2000* Primary Ventilated System

Stack Nominal Diameter (DN)	Table 11 of BS EN 12056.2 (Square or 88° junction)	Table 11 of BS EN 12056.2 (Sweep or 45° junction)	Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Domestic)	Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Commercial)	Table 9.5.2 of *AS/NZS 3500.2:2021*
40					0.5
50					0.9
60 / 65	0.5	0.7			1.5
70	1.5	2			
80	2	2.6			2.1
90	2.7	3.5			
100	4	5.2	6.2	3.0	4.2
125	5.8	7.6	7.6	3.8	
150	9.5	12.4	10.7	5.4	
200	16	21			

Table 10: Table Extracted from Appendix B - Percentage Difference between Maximum Stack Capacities derived from *AS/NZS 3500.2:2021* for Single Stack Systems and those provided in *BS EN 12056.2:2000* for Primary Ventilated Systems

Stack Nominal Diameter (DN)	Percentage Difference between *AS/NZS 3500.2:2021* and Table 11 of *BS EN 12056.2:2000*					
	Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Domestic)		Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Commercial)		Table 9.5.2 of *AS/NZS 3500.2:2021*	
	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)
60 / 65					200.0%	114.3%
80					5.0%	-19.2%
100	55.0%	19.2%	-25.0%	-42.3%	5.0%	-19.2%
125	31.0%	0.0%	-34.5%	-50.0%		
150	12.6%	-13.7%	-43.2%	-56.5%		

- *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented, and fully vented modified design and *AS/NZS 3500.2:2021* single stack modified versus *BS EN 12056.2:2000* (B.S. Institute, 2000) secondary ventilated stack design is summarised in Table 11 and Table 12 below: (Detailed discussion in Appendix B.4)

Table 11: Stack Sizing Requirements for *AS/NZS 3500.2:2021* Fully Vented, and Fully Vented Modified versus *BS EN 12056.2:2000* Secondary Ventilated system

Design Item	**Comments**
Secondary Ventilated versus Fully Vented (and Modified)	• *BS EN 12056.2:2000* stack capacities are similar to the *AS/NZS 3500.2:2021* stack capacities calculated using the maximum fixture unit loading of the fully vented (and modified) system for stacks serving 4 or more floors and 3 or less floors. • DN65 is an exception where *BS EN 12056.2:2000* reports a significantly smaller value.
Secondary Ventilated versus Single Stack Modified	• Cross venting requirements are largely different. • *BS EN 12056.2:2000* specifies a DN50 secondary vent for a DN100 stack and cross-venting on every floor, whereas *AS/NZS 3500.2:2021* provides the option of cross-venting alternative floors depending on size of the relief vent and number of consecutive floor levels for domestic and residential buildings. • Similarly, to *BS EN 12056.2:2000* cross-vents are required on every floor for all other types of buildings in *AS/NZS 3500.2:2021.* • *AS/NZS 3500.2:2021* provides the option for stack sizes depending on required stack capacity and number of consecutive floor levels. • *BS EN 12056.2:2000* stack capacities are largely dissimilar to the *AS/NZS 3500.2:2021* stack capacities with some exceptions.

Table 12: Table Extracted from Appendix B - Percentage Difference between Maximum Stack Capacities derived from Table 8.2.2(B) of AS/NZS 3500.2:2021 Fully Vented (& Modified) and those provided in BS EN 12056.2:2000 for Secondary Ventilated Systems

Stack Nominal Diameter (DN)	**Percentage Difference between Table 8.2.2(B) of AS/NZS 3500.2:2021 and Table 12 of *BS EN 12056.2:2000***			
	Table 8.2.2(B) of AS/NZS 3500.2:2021 (≥ 4 Floors)		**Table 8.2.2(B) of AS/NZS 3500.2:2021 (≤ 3 Floors)**	
	AS and BS (Square or 88° junction)	**AS and BS (Sweep or 45° junction)**	**AS and BS (Square or 88° junction)**	**AS and BS (Sweep or 45° junction)**
60 / 65	311.5%	220.0%	133.3%	81.4%
80	32.4%	1.3%	-6.4%	-28.4%
100	53.7%	17.9%	-4.0%	-26.4%
125	60.2%	21.7%	7.4%	-18.4%
150	52.1%	3.0%	-15.0%	-42.4%

- A summary regarding the presence or absence of design guidance for various sanitary plumbing system components between *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* is provided in Table 13 below:

Table 13: Summary on the presence of guidance clauses for various design items within AS/NZS 3500.2:2021 and BS EN 12056.2:2000

Design Item	AS/NZS 3500.2:2021	BS EN 12056.2:2000	Detailed Discussion
Clearance zones near base of stacks	Guidance provided.	No guidance for drains or graded pipes. Guidance for connections above base of stack.	Appendix B.5
Stack height limits	Guidance on maximum consecutive floors for single stack (and modified) systems. Guidance on maximum developed lengths of vents for fully vented (and modified) systems.	No guidance.	Appendix B.6
Venting requirements of steep and graded offsets	Guidance provided.	Guidance provided for graded offsets only.	Appendix B.7
Minimum centre-line radius of swept and straight bends	Guidance provided for swept and straight pipe (2 x 45º bends)	Guidance provided for swept bends only.	Appendix B.8
Stack capacities for swept and square junctions	No guidance. Capacities of swept and square junctions not delineated.	Guidance provided.	Appendix B.9
Restricted entry zones of junctions	Guidance provided.	Guidance provided.	Appendix B.9
Header vents	Guidance provided.	No guidance.	Appendix B.13
Minimum airflow rates for air admittance valves	Guidance provided for branches and discharge stacks.	Guidance provided for branches and discharge stacks.	Appendix B.14
Pressure attenuators	Guidance provided.	No guidance.	Appendix B.15

- *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) largely agree that stack vents should be sized equal to the stack for all system configurations with a provision in each standard that the stack vent may be downsized given certain criteria. Unlike *BS EN 12056.2:2000* (B.S. Institute, 2000) however, this criterion is much more clearly defined in *AS/NZS 3500.2:2021* (Standards Australia, 2021). Detailed discussion in Appendix B.10.
- *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) agree that cross vents/cross-connections are to be sized equal to that of the relief vent/ventilation stack. Detailed discussion in Appendix B.11.
- Relief vent sizing recommendations are similar for *AS/NZS 3500.2:2021* single stack modified systems and *BS EN 12056.2:2000* secondary ventilated systems. Relief vent sizing guidance between *AS/NZS 3500.2:2021* fully vented (and modified) systems and *BS EN 12056.2:2000* secondary ventilated & ventilated branch systems vary quite significantly; with *BS EN 12056.2:2000* (B.S. Institute, 2000) stating that a "*ventilating stack of DN 30 is usually sufficient*". We believe the method of relief vent sizing in Table 8.5.3.5 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) is much more robust and accurate. Detailed discussion in Appendix B.12.

Table 14: Table Extracted from Appendix B - Comparison of Relief vent Sizing Guidelines of *AS/NZS 3500.2:2021* Single Stack Modified System and *BS EN 12056.2:2000* Secondary Ventilated System

Stack Nominal Diameter (DN)	Relief Vent Size (DN)		
	AS/NZS 3500.2:2021 Single Stack Modified System		*BS EN 12056.2:2000* Secondary Ventilated System
	Domestic/Residential	'Other than residential' type building	
65	-	-	50
80	-	-	50
100	50/65: Size depending on required stack capacity and location cross-vents (each/alternate floor).	50	50
125	-	65	80
150	-	80	80

- *AS/NZS 3500.2:2021* (Standards Australia, 2021) provides fixture unit ratings for a much broader range of fixture types than the fixtures provided discharge units in *BS EN 12056.2:2000* (B.S. Institute, 2000). Detailed discussion in Appendix B.16.

- Branch pipe and branch vent sizing recommendations are similar between *AS/NZS 3500.2:2021* fully vented (and modified) and *BS EN 12056.2:2000* System I and II ventilated discharge branches, however *BS EN 12056.2:2000* specifies limitations to maximum pipe length, bends and drop height, which are not required of branches in *AS/NZS 3500.2:2021* fully vented (and modified) systems. Fixture discharge pipe sizing recommendations are similar between *AS/NZS 3500.2:2021* single stack (and modified) and *BS EN 12056.2:2000* System III unventilated branches, however the limitations of the branches are typically more conservative in *AS/NZS 3500.2:2021*. Detailed discussion in Appendix B.17.

Table 15: Extracted from Appendix B - Branch pipe and branch vent sizing requirements for *BS EN 12056.2:2000* System I and II Ventilated discharge branches and *AS/NZS 3500.2:2021* Fully Vented (and modified)

Branch Size (DN)	*BS EN 12056.2:2000*				*AS/NZS 3500.2:2021* Fully Vented (and modified)			
	Ventilated Branches Flow Rate (l/s)		Branch Vent Size (DN)					
System	I	II	I	II	Min Flow Rate (L/s)	Max Flow Rate (L/s)	Branch Vent (DN)	Group Vent (DN)
30		0.6		30				
40		0.75		30	0.77	0.94	32	32
50	0.75	1.5	40	30	1.09	1.49	40	40
60	1.5	2.25	40	30				
65					1.76	2.75	40	40
70[2]	2.25	3	50	40				
80[3]	3	3.4	50	40	1.54	3.10	50	50

[2] For DN70 ventilated and unventilated discharge branches in System II, no WC's connected to branch.

[3] For DN80 ventilated and unventilated discharge branches, no WC's connected to branch in System I, or a maximum of 1 WC connected in System II.

Branch Size (DN)	*BS EN 12056.2:2000*				*AS/NZS 3500.2:2021* Fully Vented (and modified)			
	Ventilated Branches Flow Rate (l/s)		Branch Vent Size (DN)					
System	I	II	I	II	Min Flow Rate (L/s)	Max Flow Rate (L/s)	Branch Vent (DN)	Group Vent (DN)
90[4]	3.4	3.75	60	50				
100	3.75		60		4.13	7.46	50	50
125					6.13	11.88		
150					8.68	17.04		
225					18.35	32.43		

- *AS/NZS 3500.2:2021* wastewater flow rates are most similar to *BS EN 12056.2:2000* System I (K=0.5) and System II (K=0.7) designs for the residential and office building model tested respectively. With regards to resultant *BS EN 12056.2:2000* wastewater flow rates, the frequency factor (K) has a greater influence than the system selected (System I to System III). Detailed discussion in Appendix B.18.

4.3 Key Findings from AS/NZS 3500.2:2021 and BS EN 12056.2:2000 Comparison

From the summary above and the discussion in Appendix B, it is evident that:

- The sizing methodology provided in *AS/NZS 3500.2:2021* (Standards Australia, 2021) is significantly more extensive and comprehensive in comparison to *BS EN 12056.2:2000.* (B.S. Institute, 2000)

- The sizing methodology provided in *AS/NZS 3500.2:2021* (Standards Australia, 2021) already accounts for the design of tall buildings, providing clear guidance on maximum stack heights in single stack (and modified) systems and maximum developed stack vent and relief vent lengths in fully vented (and modified) systems; guidance which is not provided by *BS EN 12056.2:2000.* (B.S. Institute, 2000)

- A formula for converting fixture units into an equivalent wastewater flow rate has been sourced from within *AS/NZS 3500.2:2021* (Standards Australia, 2021) and provides comparable results to that of *BS EN 12056.2:2000* (B.S. Institute, 2000) recommendations.

4.4 Proposed 'Integrated Method'

4.4.1 Integrated Method

Given that the DU and K-Factor approach detailed in BS EN 12056-2:2000 (B.S. Institute, 2000) for calculating the expected wastewater flow rate is deemed most viable for adoption into the NCC 2025 Plumbing Code of Australia VM, and the AS/NZS 3500.2:2021 (Standards Australia, 2021) methodology of sizing sanitary plumbing systems is significantly more extensive and comprehensive in comparison to BS EN 12056.2:2000, an 'Integrated Method' is proposed. This method consists of implementing:

1. The *BS EN 12056.2:2000* (B.S. Institute, 2000) DU and K-Factor method of estimating the probable simultaneous wastewater flowrate to size the loading on the sanitary plumbing system, and
2. The *AS/NZS 3500.2:2021* (Standards Australia, 2021) method of designing and sizing sanitary plumbing systems.

[4] For DN90 ventilated and unventilated discharge branches in a System I, a maximum of 2 WC's connected and a maximum of 1 x 90-degree bend.

To achieve (2) the designer may either:

a) Convert the probable simultaneous wastewater flowrate (Q_{Total}) derived by the *BS EN 12056.2:2000* (B.S. Institute, 2000) DU and K-Factor method into an equivalent AS/NZS 3500.2 (Standards Australia, 2021) FU using the following:

$$FU_{Total} = 6.75Q_{Total}^2$$

Where:

- Q_{Total} = the wastewater flowrate (l/s); and
- FU_{Total} = the equivalent fixture units converted from a flowrate (dimensionless)

b) Or convert all relevant sizing tables and design guidance referencing FU in AS/NZS 3500.2 (Standards Australia, 2021) to an equivalent flow rate using the following:

$$Q = \sqrt{\frac{\sum FU}{6.75}}$$

Where $\sum FU$ = the sum of fixture units to be converted (dimensionless)

Note the following:

- Fixture units calculated using (2) must be rounded up to the next integer.
- The use of the approach identified in (2) results in all relevant sizing tables and design guidance in AS/NZS 3500.2 (Standards Australia, 2021), for the purpose of (1), to be used directly.

Refer to Appendix B.19 for a study on a residential tower model and a comparative assessment of the sizing results of this method.

4.4.2 Key Findings

A summary of the key findings is provided below in Table 16. As evident from the findings, the use of the proposed 'integrated method' facilitates some rationalisation in the sizing of sanitary plumbing components compared to that of the *AS/NZS 3500.2:2021* (Standards Australia, 2021) alone.

Table 16: Summary of Sizing Recommendations of Residential Tower Model for the Proposed 'Integrated' Method compared to AS/NZS 3500.2:2021 alone and BS EN 12056.2:2000

System	Proposed 'Integrated' Method compared to AS/NZS 3500.2:2021 and BS EN 12056.2:2000 Key Findings
Single Stack System	• Potentially facilitates a reduction in stack sizing of one or two pipe size for short (≤ 15 floor) residential buildings implementing a single stack system. • Potentially facilitates the design of single stack systems for tall buildings (≥15 floors) that would otherwise exceed the maximum capacity when designed to the *AZ/NZS 3500.2:2021* method alone. • Provisions for stacks to be sized larger than they would otherwise be in *BS EN 12056.2:2000*, for tall buildings (≥15 floors) implementing a primary ventilated system, noting that the maximum height of a single stack system is limited to 30 floors.
Single Stack Modified System	• Single stack modified systems only provide designs with a DN100 stack size, so no variation in recommended stack size is possible. • Provisions for relief vents to typically be sized equal to that determined by the *AZ/NZS 3500.2:2021* method. • Potentially facilitates a reduction in the required intervals of cross-venting (cross-venting on alternate floors instead of every floor).

System	Proposed 'Integrated' Method compared to AS/NZS 3500.2:2021 and BS EN 12056.2:2000 Key Findings
	• Potentially facilitates the design of single stack modified systems for tall buildings (≥15 floors) that would otherwise exceed the maximum capacity when designed to the *AZ/NZS 3500.2:2021* method alone, noting that the maximum height of a single stack system is limited to 20 floors for residential building. • Provisions for stacks and relief vents to be sized equal to or larger than they would otherwise be in *BS EN 12056.2:2000* implementing a secondary ventilated system.
Fully Vented (and Modified) System [Considering the use of K=0.5 using the integrated method]	• Potentially facilitates a reduction in stack sizing of one or two pipe size for residential buildings. • Potentially facilitates a reduction in relief vent sizing of one pipe size for residential buildings. • Potentially facilitates the design of fully vented (and modified) systems for tall buildings that would otherwise exceed the maximum developed length when designed to the *AZ/NZS 3500.2:2021* method alone, noting that the maximum height of a single stack system is limited to 20 floors for residential building.

4.5 Comparison of System I, II and III Discharge Units provided in BS EN 12056.2:2000

Given the approach of the proposed 'integrated method' outlined in Section 4.4, which implements the *BS EN 12056-2:2000* (B.S. Institute, 2000) method for calculating the expected wastewater flow rate and the *AS/NZS 3500.2:2021* (Standards Australia, 2021) methodology of sizing sanitary plumbing systems, a review of design and sizing consequences of employing System I, II or III discharge units to calculate the wastewater flow rate was conducted, to determine what Systems would be appropriate for inclusion in the NCC 2025 Volume 3 VM for sanitary plumbing systems.

4.5.1 Design Intent

System I, II and III refer to the filling degree of the discharge branches:

- System I: 50% filling degree
- System II: 70% filling degree
- System III: 100% filling degree

The countries that typically employ each of the systems is summarised below in Table 17.

Table 17: Countries that use System I, II and III Design (Whitehead, 2002)

System	Typical Practice in:
I	Germany, Austria, Switzerland, Belgium
II	Scandinavia
III	United Kingdom

4.5.2 Design Implications

The use of different Systems provided in *BS EN 12056.2:2000* (B.S. Institute, 2000) is to provide varying filling degrees within discharge branches pipes. It is worth noting that the implementation of a given system specified in *BS EN 12056.2:2000* (B.S. Institute, 2000) has a twofold consequence:

1. The design guidance in *BS EN 12056.2:2000* (B.S. Institute, 2000) on the sizing of discharge branches varies depending on the systems selected. For instance, System I and II branches are sized given maximum capacities for each discharge pipe size and limitations to maximum length, number of 90-degree bends, maximum drop and minimum gradients. System III branches on the other hand, are sized in a similar manner to branches within an *AZ/NZS 3500.2:2021* (Standards Australia, 2021) single stack (and modified) system.

2) Discharge unit values for each fixture type vary depending on the system selected, as illustrated below in Figure 13.

    a) From analysis in Appendix B.18, whilst it can be said that System I have larger DU values than System II for all fixture types, the relationship between System II and III is not consistent. Hence, using System I will always result in the largest wastewater flow rate compared to system II and III.

    b) System II and III have varying comparative wastewater flow rates depending on the number and combination of fixtures connected to the plumbing system being assessed.

    c) It is also worth noting that no particular System (I, II or III) consistently aligns with the equivalent flow rate of *AS/NZS 3500.2:2021*. (refer to Appendix B.18.3)

    d) In summary, the use of different systems will result in varied total discharge unit sums and resultant flow rates, and hence, potentially different sizing recommendations of sanitary plumbing components.

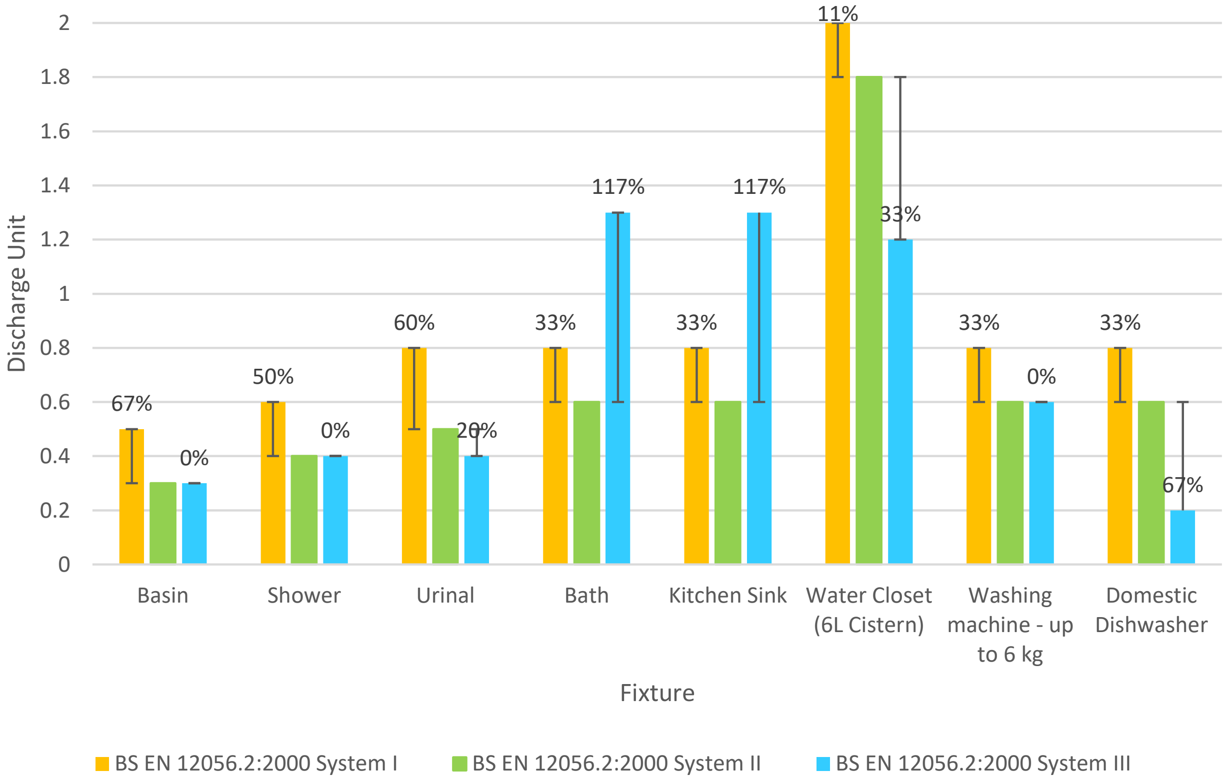

Figure 3: Figure Extracted from Appendix B - Variation in Discharge Unit of each Fixture for System I to III with Percentage Differences between System II and System I & III

4.5.3 Assessment of Implementing a System I, II and III Design on Stack and Relief Vent Sizing

Whilst resultant calculated wastewater flow rate values vary, depending on the use of System I, II or III discharge units, as discussed above in Section 4.5.2, this may or may not result in a consequent variation in the recommended size of a sanitary plumbing component, depending on how the resultant wastewater flow rate values compare to the equivalent maximum flow rates converted from FU limits specified in relevant sizing tables and design guidance of *AS/NZS 3500.2:2021*.

A residential tower model study comparing the sizing recommendations of the proposed 'integrated method' (detailed in Appendix B.19), demonstrated the following findings regarding the use of System I, II and III discharge unit values:

- For the single stack systems tested, the recommended stack size was the same across System I, II or III Discharge unit values.
- For the single stack modified systems tested, the recommended stack and relief vent size was the same across System I, II or III Discharge unit values. One difference in the recommendation of cross-vent intervals was identified for a 15-floor building (K=0.5), where System I recommended cross-venting on every floor, whilst System II and III recommended cross-venting on alternate floors.
- For fully vented (and modified) the recommended stack and relief vents sizes were consistent across System I to III, except for the instances summarised below in Table 18. It should be noted that the greater than (>) or less than (<) symbol indicates a comparative increase or decrease in pipe diameter by 1 DN increment.

Table 18: Discrepancies in Stack and Relief Vent Sizing Recommendations for System I to III Discharge Unit Values used in the Proposed 'Integrated Method' tested in Appendix B

<table>
<tr><th>Component</th><th colspan="2">1 Appliance Group</th><th colspan="2">2 Appliance Groups</th></tr>
<tr><th>K-Factor</th><th>0.3</th><th>0.5</th><th>0.3</th><th>0.5</th></tr>
<tr><td>Stack</td><td rowspan="2">• 15-floor System I DN > System II & III DN
• 50-floor System II < System I & III DN</td><td rowspan="2">NA</td><td>• 3-floor System II DN < System I & III DN
• 5-floor System I DN > System II & III DN
• 50-floor System II DN < System I & III DN</td><td rowspan="2">• 30-floor System II DN < System than I and III</td></tr>
<tr><td>Relief Vent</td><td>• 3-floor System I DN > System II and III DN
• 5-floor System I DN > System II and III DN
• 50-floor System II DN < System I and III DN</td></tr>
</table>

We note that these results are specific to the residential tower model tested in Appendix B.19 and may not be able to be extrapolated as a generalised statement to predict the behaviour of these systems for all building types and system components. However, from the specific model tested it should be noted that variation in System I to III does not result in any stack or relief vent sizing discrepancies single stack (and modified) systems, whilst it does for fully vented (and modified) systems, with a maximum change in the pipe diameter of one DN increment. Within these pipe size discrepancies for stack and relief vents, System I always results in the largest pipe size, System II always results in the smallest pipe size, and System III has no consistent behaviour, and its comparative sizing recommendation cannot be predicted unlike System I and II.

With the above analysis in mind, System I and II are more suitable than System III for the sizing of stack and relief vents within the use of the proposed 'integrated method', given that their comparative performance can be predicted.

4.5.4 Assessment of Implementing a System I, II and III Design on Branch Sizing and Configuration

We note the following impacts of implementing a System I versus System II design on branch sizing in the proposed 'integrated method':

- The sizing methodology of branches in an *AS/NZS 3500.2:2021* single stack (and modified) system is dependent on the fixture type connected to the stack, and hence is independent of the calculated wastewater flow rate. Hence, the use of System I or II discharge unit values does not influence the sizing of branches in single stack and modified systems.
- The sizing methodology of branches in an *AS/NZS 3500.2:2021* fully vented (and modified) system is dependent on the maximum fixture unit loading (or equivalent converted wastewater flow rate). Hence, the use of System I or System II discharge unit values may influence the sizing of branches in fully vented and modified systems. Whilst this has not been tested, it is predicted that similar to stack and relief vents, the influence of using a System I over and System II design may result in either no discrepancy in recommended branch size, or an increase in the recommended branch size.

We note the following impacts of implementing a System III design on branch sizing in the proposed 'integrated method':

- *BS EN 12056.2:2000* System III design requires fixtures be independently connected to the stack via separate fixture discharge pipes (with some provisions for ranges of fixtures). This is a similar design methodology to that of branches in *AS/NZS 3500.2:2021* single stack (and modified) systems, however, it should be noted that this design configuration is a requirement in *BS EN 12056.2:2000* for both vented and unvented System III branches (although the limitations of an unvented branch are less conservative comparatively).
- If we implemented a System III design, it may be warranted to follow its design guidance specified in *BS EN 12056.2:2000* (B.S. Institute, 2000), in addition to that required by *AS/NZS 3500.2:2021* (Standards Australia, 2021), which would potentially result in conflicting design guidance.

As a result, the use of System III introduces more stringent design requirements for vented branches, than the *AS/NZS 3500.2:2021* equivalent. With the above analysis in mind, System I and II are more suitable for the sizing of branch pipes within the use of the proposed 'integrated method'.

4.5.5 Recommendations of System I, II and III Implementation

From the assessments conducted in Section 4.5.3 and 4.5.3 above, we recommend that:

- System III DU values are removed from the NCC 2022 Volume 3 Verification Method, given that:
  - There is no foreseeable benefit to recommending a System III design regarding sizing recommendations, and
  - Its inclusion may introduce further design complexities.
- System I DU values are removed from the NCC 2022 Volume 3 Verification Method given that:
  - System I and System II behaves similarly with the former providing only a more conservative wastewater flow rate;
  - We deem that the less conservative baseline of System II is more appropriate for the VM, noting that the degree of conservatism can be significantly altered by the selected K-Factor;
  - K-Factors have a more significant influence over the calculated wastewater flow rates than slight variations to DU values, thus contingency should be incorporated through the selection of frequency factors; and
  - It is more effective to allow the practitioner to adjust specific fixture DU values of System II than restrict them to choose between a set of DU values based on a system.

- Providing options to select between two sets of DU values introduces unnecessary complexity into the VM;
- Providing options to select between two sets of DU values implies the use of one system over another results in consistent differences may imply consistent differences

5. National Construction Code 2022 Volume 3 Sanitary Plumbing Verification Method Review & Proposed Amendments

The objective of this section is to review the published NCC 2022 Volume 3 PCA Verification Methods for sanitary plumbing, provide commentary on any potential points of system failure, and propose amendments for the for the use of the VM. Based on the research and comparisons summarised in Section 4, the shortfalls of using the European Standard are now more widely understood.

The exact wording of the proposed amendments to the NCC 2025 Vol 3 PCA Section C VM are documented in detail within Appendix F.

5.1 NCC 2022 Volume 3 Sanitary Plumbing Verification Method Review

5.1.1 Sanitary Plumbing System Verification Method Summary

The current approach of the NCC Volume 2022 PCA Verification Method for sanitary plumbing systems can be summarised as follows:

1. Determine sanitary plumbing wastewater flowrates using the method adopted from *BS EN 12056.2:2000* (B.S. Institute, 2000) (C1V1).

2) Size common discharge pipes according to the method adopted from *BS EN 12056.2:2000* (B.S. Institute, 2000) for System I (C1V2), System II (C1V3) and System III (C1V4).

3) Size stacks based on whether or not there is a separate relief vent provided (Table C1V5a and b).

4) Size stack vents according to Clause 8.5.4 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) (C1V5(3)(b)(i)).

5) Size relief vents according to Clause 8.5.3 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) (C1V5(3)(b)(ii)).

5.1.2 Potential Points of System Failure Involving the Sizing Stacks without a Relief Vent

Within the current NCC 2022 Volume 3, the sizing of stack capacity is delineated by the presence of a relief vent, however there is no guidance within the Verification Method regarding any limitations for designing stacks without a relief vent. As highlighted in Section 4.2, *BS EN 12056.2:2000* (B.S. Institute, 2000) does not delineate between commercial and residential buildings when sizing stack height, nor does it provide commentary on stack height limits; particularly for stacks without relief vents. It was also identified that whilst drainage systems without relief vents were capable of serving up to 8 floors of appliances, hydraulic practitioners would provide an auxiliary vent stack for stacks exceeding 15m to minimise pressure transients.

The concerns involving single stack systems for use in tall buildings, and buildings of different types are addressed in *AS/NZS 3500.2:2021* (Standards Australia, 2021) through the provision of maximum flow rates for commercial and domestic buildings, and limitations to the maximum floors stacks of difference sizes can serve.

5.1.3 Potential Points of System Failure Involving the Sizing Stacks with a Relief Vent

As mentioned above in Section 5.1.2, within the current NCC 2022 Volume 3, the sizing of stack capacity is delineated by the presence of a relief vent. Similarly, to how there is no guidance within the Verification Method regarding any limitations for designing stacks without a relief vent, there is also limited guidance regarding any limitations for designing stacks with relief vents. As summarised in Section 4.2, a sanitary drainage system with a relief vent can be associated with single stack modified, fully vented, and fully vented modified systems within the Australian Standard. The differences in stack capacities between single stack and fully vented systems due to variations with venting needs to be considered within the Verification Method.

5.1.4 Potential Points of System Overdesign Involving the Venting Guide

We note that the current NCC 2022 Volume 3 directs designers to interconnect relief vents with the stack at each floor, which is indicative of cross-venting in a *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack (and modified) system. However, the current NCC 2022 Volume 3 also directs users to size stack vents and relief vents as per the method outlined in the *AS/NZS 3500.2:2021* (Standards Australia, 2021) for a fully vented (and modified) system. In an *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) system design, cross-relief vents are instead only required to be placed at intervals of not more than 10 floors levels for vertical sections of stacks of 20 floor levels or more in height. Even within the *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack (and modified) clauses, provision of cross-relief vents at every floor may not be necessary for residential and domestic buildings. Whilst the discrepancy between the cross-venting requirement of *AS/NZS 3500.2:2021* (Standards Australia, 2021) and the current NCC 2022 Volume 3 is unlikely to be a point for system failure, the application of this clause within the Verification Method will introduce potential points of system overdesign.

5.2 NCC 2022 Volume 3 Sanitary Drainage Verification Method Review

The current approach of the NCC Volume 2022 Verification Method for sanitary drainage systems can be summarised as follows:

1. Determine sanitary plumbing wastewater flowrates using the method provided in *BS EN 12056.2:2000* (B.S. Institute, 2000) (C2V3).

2. Ensure compliance with performance requirements of a sanitary drainage system (C2V1).

No further guidance is provided on the recommended method of sizing and grading sanitary drainage systems. It should be noted that the recommendation in the Phase 1 Report (Arup, 2022) was that the Colebrook-White equation present in *AS 2200:2006* (Standards Australia, 2006) is to be adopted as a Verification Method for sizing drainage capacities of sewerage pipework.

Note, due to limitations of scope and comprehensive methods for designing a sanitary drainage system through the NCC 2022 PCA VM, no further investigation into potential points of system failure or overdesign have been conducted.

5.3 Fixture Types Providing Discharge Units for Sanitary Plumbing and Drainage Wastewater Flowrates Calculation

The current NCC 2022 Volume 3 provides discharge unit ratings for System I and II for the following fixture types:

- Basin
- Shower
- Urinal
- Bath
- Kitchen sink
- Water closet
- Washing machine – up to 6 kg
- Domestic dishwasher

We note the following:

- Discharge units for a ‘floor waste gully’ are not provided. As per our findings from Appendix B.16 (summarised in Section 4.2), the guidance of *AS/NZS 3500.2:2021* (Standards Australia, 2021) is most suitable whereby the loading of the floor gully is as per the sum of fixture unit rating of the fixtures connected to it. We propose that the equivalent discharge unit of a floor gully is the sum of discharge units for fixtures connected to it.

- Discharge units for a 'Washing machine up to 12 kg' are not provided. As per our findings from Appendix B.16 (summarised in Section 4.2), whilst we cannot confirm whether this is equivalent to the fixture type 'Dishwashing machine – commercial' listed in *AS/NZS 3500.2:2021* (Standards Australia, 2021), we deem that its provision in the NCC 2022 PCA VM will provide greater flexibility for the designer.

- *AS/NZS 3500.2:2021* (Standards Australia, 2021) makes no distinction of varying cistern volumes of water closets in the fixture unit rating, whilst *BS EN 12056.2:2000* (B.S. Institute, 2000)does despite the difference between the discharge units is minimal to none. We agree with the current use of *BS EN 12056.2:2000* (B.S. Institute, 2000) discharge units for a 'WC with 6,0 l cistern' in the verification method and propose no changes.

- *BS EN 12056.2:2000* (B.S. Institute, 2000) provides varied discharge units for single urinal with cistern, urinal with flushing valve, and slab urinal, whilst *AS/NZS 3500.2:2021* (Standards Australia, 2021) makes no distinction. We deem the current use of *BS EN 12056.2:2000* (B.S. Institute, 2000) discharge units for a 'Single urinal with cistern' for a urinal is suitable, with the clarification that this refers to wall-hung (including waterless), stall, and each 600 mm length of slab.

5.4 Proposed NCC 2022 Volume 3 Verification Method Amendments

Refer to Appendix F for the specific wording of the proposed amendments to the NCC 2022 Volume 3 Verification Method for Sanitary Plumbing and Drainage Systems. The proposed amendments include:

- A revised frequency factor table providing a range of K-factor values for each building class and corresponding time interval between fixture usage events.

- Minor amendments and clarifications to the Discharge Unit table, including the omission of System I and III discharge units.

- The removal of the current design strategy within C1 Sanitary plumbing systems verification method utilising the sizing recommendations provided by *BS EN 12056.2:2000* (B.S. Institute, 2000) for stack and branch sizing; specifically, the removal of C1V2 to C1V5 (inclusive).

- The addition of a new Clause C1V2 detailing a method for sizing sanitary plumbing components utilising the guidance provided by *AS/NZS 3500.2:2021* (Standards Australia, 2021).

- The addition of Clause C2V4 detailing the method of sanitary drainage design using the Colebrook-White equation present in *AS 2200:2006* (Standards Australia, 2006).

5.5 Limitations of NCC 2025 Volume 3 Verification Method

5.5.1 Sanitary Plumbing Verification Method

The limitations to the verification method of sanitary plumbing systems are:

- We believe the proposed approach for adoption into the NCC 2022 Volume 3 VM for sanitary plumbing systems is sensible, however we cannot guarantee it's accuracy.

- We have tested the equivalent flow rates resultant from using this approach versus that of *AS/NZS 3500.2:2021* (Standards Australia, 2021) for a model residential and office building (refer to Appendix B.18). Whilst this quantification is useful, we note that comparison of sizing results is more indicative of effective differences between the approaches.

- We have assessed the approach against the sizing results of *AS/NZS 3500.2:2021* (Standards Australia, 2021) for a model residential building using K=0.3 and K=0.5, tested multiple building heights, System I to III discharge units, and 1 or 2 appliance groups connected to the stack at each floor level (refer to Appendix B.19). No other building types or K-Factors have been tested.

- We have compared the proposed approach considering a resultant flow rate derived from *BS EN 12056.2:2000* (B.S. Institute, 2000) and converted all relevant sizing guidance in *AS/NZS 3500.2:2021* (Standards Australia, 2021) to an equivalent flow rate. Alternatively, we recommend an equivalent method whereby the practitioner would convert the BS flow rate into a Fixture Unit, rounded up to the next integer. Whilst we envisage this process to be equivalent, we note that rounding up of FUs may result in some sizing discrepancies between the two approaches.

- We note that a limitation of this approach, which also exists with the current NCC Volume 3 VM strategy, is that only fixture types that are provided with DUs can be accounted for; i.e., if your system has fixtures not captured in this list, the designer either (1) cannot use this method or (2) needs to conduct testing to determine what fixture type listed would be equivalent.

- Recommendations on suitable ranges of K-Factor values for all NCC building classes have been made (refer to Section 3.4), noting that no monitoring data is available to confirm this recommendation.

- Given the absence of monitoring data, it is assumed that the time intervals between fixture usage that correspond to K-Factors of 0.5, 0.7 and 1 are 1200, 600 and 300 seconds respectively (refer to Section 3.4).

5.5.2 Sanitary Drainage Verification Method

The limitations to the verification method of sanitary drainage systems are:

- Limitations around suitable K-Factors and the limited number of fixture types provided discharge unit values, as discussed for sanitary plumbing systems (refer to Section 5.5.1) is also relevant to the sanitary drainage verification method.

- No additional research or reviews have been conducted in this report on the implementation of the Colebrook White method for sizing sanitary drains provided in *AS 2200:2006* (Standards Australia, 2006).

5.6 Future Work

The following future work is recommended to further verify the proposed method specified in the NCC 2025 Volume 3 VM and better understand the implications of the proposed method over the use of *AS/NZS 3500.2:2021* alone:

- Gather fixture usage monitoring data for each of the NCC building classes to inform the average time between fixture uses during peak periods, and the comparative spread of K-Factor values across all NCC building classes. Refer to Appendix A for further detail on requirements of data.

- Conduct comparative studies using model buildings for all NCC building classes to further assess and understand the differences with sizing recommendations for sanitary plumbing components between *AS/NZS3500.2:2021* and the proposed integrated method.

- Conduct comparative studies using K-Factor values of 0.6 to 1.2 to further assess and understand the differences in sizing recommendations for sanitary plumbing components between *AS/NZS3500.2:2021* and the proposed integrated method.

- Compare both methods proposed in Clause C1V2 on utilising the design guidance provided in *AZ/NZS 3500.2* and identify and quantify any discrepancy between the resultant sizing recommendations.

- Conduct a comparison of branch sizing and group/branch vent sizing for a Fully vented (and modified) system using the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) and the integrated method proposed in CCC 2022 Volume 3 Sanitary Plumbing Amendments (Appendix F.1).

- Review comparative sizing recommendations for drains provided by *AZ/NZS 3500.2:2021* (Standards Australia, 2021) and *AS 2200:2006* (Standards Australia, 2006). As noted in Phase 1 Report (Arup, 2022), further research and reviews should be conducted to minimise any unforeseen consequences with adopting this method for sizing sanitary drains to the Australian Plumbing Industry. These are documented in detail in Appendix A.9.2 of the Phase 1 Report (Arup, 2022).

6. References

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Appendix A - RFI Documents

A.1. RFI Building Use Data

ARUP

Memorandum

To	Australian Building Codes Board
Date	17 April 2023
Copies	Tom Roberts
Reference number	288270-02
From	Arup
File reference	MEM-001 RFI Building Use Data
Subject	Request for Information – Building Use Data

Request for Information – Building Use Data

Arup request the following data to assist with our work on the Sanitary Plumbing and Drainage Pipe Sizing research project for the Australian Building Codes Board.

Requested Data

To allow us to better understand current sanitary fixture discharge rates and peak water flow conditions, and how these may be used to inform frequency factors in sanitary plumbing systems we request the following data set for each building.

We understand this data may be sensitive and do not need to know building name, address or street name unless this can be freely provided.

Data type	Units	Example
Building location (Optional)	-	Crowes Nest, NSW 2065
Building / floor level / area type	-	Office
Building / floor level / area net lettable area or usable area	m2	15,000m2
Building / floor level / area occupancy	Persons	1,875 persons
Building / floor level / area occupancy at time of data measurement	Persons	1,200 persons
Fixture type	-	Wash hand basin, cleaners sink, water closet, etc.
Fixture design flow rate	l/s or l/m	0.1 l/s or 6 l/m
Actual measured fixture flow rate	l/s or l/m	0.05 l/s or 3 l/m
Time of operation at each use	Seconds	15 seconds
Time between each operation	Seconds or minutes	1200 seconds or 20 minutes

Requested Building Types

We request the above data for the following building types where possible.

Page 1 of 2

ARUP

Building type	NCC Classification
Residential dwelling, small apartment block or townhouses	Class 1 to 4
Office or commercial building	Class 5
Retail, shop, restaurant, café	Class 6
Carpark, warehouse, storage building	Class 7
Factory, workshop, laboratory	Class 8
Healthcare building, hospital, and GP clinics	Class 9a
Public event buildings, stadiums, theatres, schools, universities, and churches	Class 9b
Aged care facilities	Class 9c

Requested File Type

As a starting point we can use CSV files. If more a readable, usable format of data is available we would like to have this also.

A.2. Data Request – Enware

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arup.com

By email
8 May 2023

Jason Hinds; Dean Martin; Jordi Skelton

9 Endeavour Road, Caringbah NSW 2229 Australia
P.O. Box 2545 Taren Point NSW 2229 Australia

Our ref 288270-02

Dear Enware Representatives,

ABCB Sanitary Plumbing and Drainage Research Project - Stage 2

Smart Flow TMV and Fixture Data Request

This letter serves to clarify our reasoning and intention with the Smart Flow TMV and fixture data requested as per our previous correspondence appended to this letter in Appendix A. As you are aware, Arup have been engaged by the Australian Building Codes Board (ABCB) to assist in further progressing the work they commissioned around the development, or adoption, of an industry accepted performance-based method for calculating sanitary drainage and plumbing pipe sizes within the future *National Construction Code, Volume 3 Plumbing Code of Australia 2025*.

It is widely accepted in the Hydraulic Industry within Australia that there are limitations within *AS/NZS 3500.2* Sanitary Plumbing and Drainage where a common Fixture Unit (FU) is applied for each fixture across all type of buildings without further consideration of usage probability or a rationalisation factor applied outside the FU itself. Additionally, there are some common industry concerns which have developed over recent decades as the result of technical advancements in sanitary ware, fixtures and appliances, largely driven by an environmental desire to reduce water consumption, resulting in 'over-sizing' of drainage systems and an inherent risk of solid stranding resulting in blockage issues.

The proposed performance-based approach presents an opportunity to rationalise sizing outcomes to potentially allow a reduction in material usage and ultimately result in a positive impact on the environment, whether it be through saving space within a building or reducing the actual material that is manufactured, transported, installed and ultimately disposed of or recycled. Further, by reducing the risk of solid stranding and trap loss, the risk of waterborne and airborne disease transmission through drainage systems will decrease.

The work was split into two stages. The report summarising Arup's work on Stage 1 of this project is available on the ABCB website here.

Arup are now in the process of undertaking Stage 2 of the research work on Sanitary Plumbing and Drainage Pipe Sizing. The work builds upon the Stage 1 work and provides further development and guidance around the use of the proposed verification methods through the collection of additional research and data.

Arup Australia Pty Ltd | ABN 76 625 912 665

Our ref 288270-02
Date 8 May 2023

Modern day data on water and fixture use is vital to the further development of the proposed verification method, particularly around granulating fixture frequency usage factors (K-Factors) to better align with the NCC building classes. Through the collaboration between Enware, ABCB and Arup, sizable progression can be made on this front through the contribution of Smart Flow data by Enware.

The explanatory note *MEM-003 RFI Explanatory Note – Enware* provides additional clarification regarding the type of data that would be requested and showcases an expected typical water usage monitoring setup for a hospital building.

In the interest of maintaining privacy towards all of Enware’s stakeholders, all provided data can be anonymised, and all identifiable building information be replaced by generalised descriptions of the buildings e.g., NLA, designed occupancy, etc. All data will strictly adhere to Arup’s Privacy Statement. Any data provided that may contain personal or sensitive information will only be retained for as long as it is necessary and will be deleted/destroyed as per the Arup procedures.

Yours sincerely

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cc Tom Roberts; James Thomson

Appendix A – MEM RFI Request for Building Use Data

ARUP

Memorandum

To	Australian Building Codes Board
Date	17 April 2023
Copies	Tom Roberts
Reference number	288270-02
From	Arup
File reference	MEM-001 RFI Building Use Data
Subject	Request for Information – Building Use Data

Request for Information – Building Use Data

Arup request the following data to assist with our work on the Sanitary Plumbing and Drainage Pipe Sizing research project for the Australian Building Codes Board.

Requested Data

To allow us to better understand current sanitary fixture discharge rates and peak water flow conditions, and how these may be used to inform frequency factors in sanitary plumbing systems we request the following data set for each building.

We understand this data may be sensitive and do not need to know building name, address or street name unless this can be freely provided.

Data type	Units	Example
Building location (Optional)	-	Crowes Nest, NSW 2065
Building / floor level / area type	-	Office
Building / floor level / area net lettable area or usable area	m2	15,000m2
Building / floor level / area occupancy	Persons	1,875 persons
Building / floor level / area occupancy at time of data measurement	Persons	1,200 persons
Fixture type	-	Wash hand basin, cleaners sink, water closet, etc.
Fixture design flow rate	l/s or l/m	0.1 l/s or 6 l/m
Actual measured fixture flow rate	l/s or l/m	0.05 l/s or 3 l/m
Time of operation at each use	Seconds	15 seconds
Time between each operation	Seconds or minutes	1200 seconds or 20 minutes

Requested Building Types

We request the above data for the following building types where possible.

Page 1 of 2

Building type	NCC Classification
Residential dwelling, small apartment block or townhouses	Class 1 to 4
Office or commercial building	Class 5
Retail, shop, restaurant, café	Class 6
Carpark, warehouse, storage building	Class 7
Factory, workshop, laboratory	Class 8
Healthcare building, hospital, and GP clinics	Class 9a
Public event buildings, stadiums, theatres, schools, universities, and churches	Class 9b
Aged care facilities	Class 9c

Requested File Type

As a starting point we can use CSV files. If more a readable, usable format of data is available we would like to have this also.

Our ref	288270-02
Date	8 May 2023

Appendix B – MEM RFI Explanatory Note Enware

ARUP

Memorandum

To	Australian Building Codes Board
Date	5 May 2023
Copies	Tom Roberts; Neil Rech
Reference number	288270-02
From	Arup
File reference	MEM-003
Subject	Request for Information - Hospital Water Usage Data Explanatory Note

1. Context

This explanatory note follows the issue of the Memorandum 'MEM-001 RFI – Building Use Data' dated 17/04/2023 and outlines a method of configuring a fixture water usage monitoring system within hospital buildings. The same monitoring configuration could be applied to other building typologies. This memo focuses on using Enware's Smart Flow Thermostatic Mixing Valve (TMV) monitoring system to obtain the data requested. An example schematic of a typical floor of a hospital building is provided to illustrate the required monitoring devices in further detail.

2. Limitations

1. We understand that Enware's Smart Flow TMV monitoring system only monitors the warm water usage of basins, showers, and baths. We note that the system cannot monitor the usage of fixtures which are not supplied from a Smart Flow TMV, which includes fixtures that require a direct hot water feed and/or a cold-water feed, such as sinks, Water Closets (WC's), etc.

2. We understand that the implementation of smart sub metering of each level and/or department within a hospital, may not accurately determine the usage of each fixture not monitored by a TMV.

3. We understand that monitored isolation valves may be commercially available in the future by Enware to assist with providing water usage data of fixtures not connected to TMV's. This technology may assist to address the foreseeable gap in fixture usage data when solely using the Smart Flow TMV Monitoring System.

4. We assume that the monitoring devices transmit data to the cloud via an ICN and the data is accessible by Enware to be provided to Arup and ABCB in a CSV or equivalent format.

3. Definitions of Monitoring Components

Definitions of the monitoring components, the data required, and their functionality for the methodology detailed in this memorandum are summarised in Table 1 below.

Table 1 Definitions of Monitoring Components

Component	Definition/Components Required	Data Required	Functionality Required
Occupancy Counter	A device that records the number of people entering and exiting a defined space within the building (e.g., a particular level of a building or a particular room).	Occupancy counter sensor ID Timestamp In/Out or Net count	Records occupancy counts at regular time intervals (e.g., every 5 minutes) Collects and uploads the data to an online platform, where data is stored and accessible. Data must be able to be exported in CSV/Excel format.
Smart Water Metering Solution	Smart water meter; or Smart water meter logger which connects into an existing mechanical water meter (mechanical water meter must be pulse enabled).	Meter ID Timestamp Meter water consumption (L or kL)	Reads meter consumption at regular time intervals (e.g., every 15 or 30 minutes). Collects and uploads the data to an online platform, where data is stored and accessible. Data must be able to be exported in CSV/Excel format.
Enware Smart Flow TMV monitoring system	Monitors warm water usage of basins, showers and baths.	TMV ID Number and type of Fixtures each TMV serves Timestamp of every fixture usage event Fixture type specified of every usage event Duration of every fixture usage event (s) Set fixture flow rate (L/s) Measured fixture warm water flow rate (l/s)	Collects and uploads the data to an online platform, where data is stored and accessible. Data must be able to be exported in CSV/Excel format.

4. Methodology

The smart metering placement strategy for a hospital class building is as follows (refer to Figure 1 below):

1) Install sub flow smart water meters or isolation valves on cold and hot (flow and return) water supply take-offs for each level and/or department undergoing monitoring.

2) Install occupancy counters to each level and/or department being monitored at:
   a) Every entry and exit of the level/department (e.g., outside the lift doors), and

   b) The entry of amenities in public areas and amenities in ward areas (i.e., dedicated ensuites do not require occupancy counting).

3) Replace existing standard TMV’s with Enware Smart Flow monitoring TMVs.

Notes:

- Where the same or equivalent monitoring component is already installed, and there are no compatibility or data extraction complications, no replacement of the component is required.
- Where possible, monitoring multiple levels of a multi-level hospital building is encouraged to improve the reliability of the data obtained.
- Prior to commencement of any installation and monitoring works, the manufacturers of the respective monitoring components should be consulted.
- It is assumed that the Enware Smart Flow TMV's can detect and identify simultaneous supply use events (for example, a basin and shower being used simultaneously).

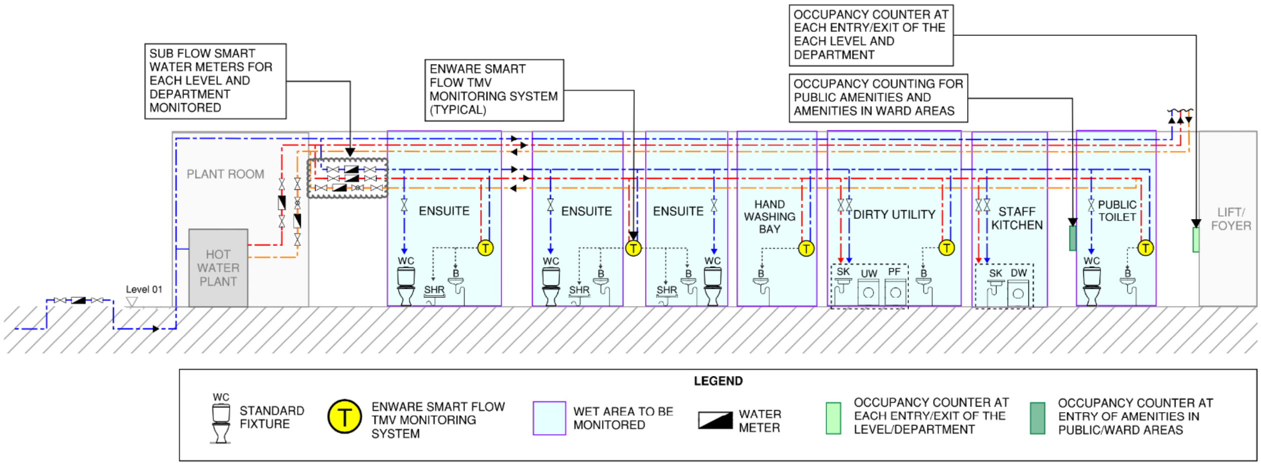

Figure 1 Monitoring Methodology of a Hospital

A.3. Data Request – GWA

By email
8 May 2023

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Bruce McIntosh

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Our ref 288270-02

Dear GWA Group Representatives

ABCB Sanitary Plumbing and Drainage Research Project - Stage 2

Caroma Smart Command Fixture Data Request

This letter serves to clarify our reasoning and intention with the Caroma Smart Command fixture data requested as per our previous correspondence. As you are aware, Arup was previously engaged by the Australian Building Codes Board (ABCB) to assist in further progressing the work they commissioned around the development, or adoption, of an industry accepted performance-based method for calculating sanitary drainage and plumbing pipe sizes within the future *National Construction Code, Volume 3 Plumbing Code of Australia 2025*.

It is widely accepted in the Hydraulic Industry within Australia that there are limitations within *AS/NZS 3500.2* Sanitary Plumbing and Drainage where a common Fixture Unit (FU) is applied for each fixture across all type of buildings without further consideration of usage probability or a rationalisation factor applied outside the FU itself. Additionally, there are some common industry concerns which have developed over recent decades as the result of technical advancements in sanitary ware, fixtures and appliances, largely driven by an environmental desire to reduce water consumption, resulting in 'over-sizing' of drainage systems and an inherent risk of solid stranding resulting in blockage issues.

The proposed performance-based approach presents an opportunity to rationalise sizing outcomes to potentially allow a reduction in material usage and ultimately result in a positive impact on the environment, whether it be through saving space within a building or reducing the actual material that is manufactured, transported, installed and ultimately disposed of or recycled.

The work was split into two stages. The report summarising Arup's work on Stage 1 of this project is available on the ABCB website here.

Arup has since been reengaged by the Australian Building Codes Board (ABCB) to progress Stage 2 of the research work on Sanitary Plumbing and Drainage Pipe Sizing. The work builds upon the Stage 1 work and provides further development and guidance around the use of the proposed verification methods through the collection of additional research and data.

Our ref 288270-02

Date 8 May 2023

Modern day data on water and fixture use is vital to the further development of the proposed verification method, particularly around granulating fixture frequency usage factors (K-Factors) to better align with the NCC building classes. Through the collaboration between GWA Group and Arup, sizable progression can be made on this front through the contribution of Caroma Smart Command fixture data by GWA Group.

The explanatory note *MEM-002 RFI Explanatory Note* provides additional clarification regarding the type of data that would be requested and showcases an expected typical water usage monitoring setup for single user amenities and, multi user (group) amenities.

In the interest of maintaining privacy towards all of GWA Group's stakeholders, all provided data can be anonymised, and all identifiable building information be replaced by generalised descriptions of the buildings e.g., NLA, designed occupancy, etc. All data will strictly adhere to Arup's Privacy Statement. Any data provided that may contain personal or sensitive information will only be retained for as long as it is necessary and will be deleted/destroyed as per the Arup procedures.

Yours sincerely

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Our ref 288270-02
Date 8 May 2023

Appendix A – MEM RFI Request for Building Use Data

ARUP

Memorandum

To	Australian Building Codes Board
Date	17 April 2023
Copies	Tom Roberts
Reference number	288270-02
From	Arup
File reference	MEM-001 RFI Building Use Data
Subject	Request for Information – Building Use Data

Request for Information – Building Use Data

Arup request the following data to assist with our work on the Sanitary Plumbing and Drainage Pipe Sizing research project for the Australian Building Codes Board.

Requested Data

To allow us to better understand current sanitary fixture discharge rates and peak water flow conditions, and how these may be used to inform frequency factors in sanitary plumbing systems we request the following data set for each building.

We understand this data may be sensitive and do not need to know building name, address or street name unless this can be freely provided.

Data type	Units	Example
Building location (Optional)	-	Crowes Nest, NSW 2065
Building / floor level / area type	-	Office
Building / floor level / area net lettable area or usable area	m2	15,000m2
Building / floor level / area occupancy	Persons	1,875 persons
Building / floor level / area occupancy at time of data measurement	Persons	1,200 persons
Fixture type	-	Wash hand basin, cleaners sink, water closet, etc.
Fixture design flow rate	l/s or l/m	0.1 l/s or 6 l/m
Actual measured fixture flow rate	l/s or l/m	0.05 l/s or 3 l/m
Time of operation at each use	Seconds	15 seconds
Time between each operation	Seconds or minutes	1200 seconds or 20 minutes

Requested Building Types

We request the above data for the following building types where possible.

Building type	NCC Classification
Residential dwelling, small apartment block or townhouses	Class 1 to 4
Office or commercial building	Class 5
Retail, shop, restaurant, café	Class 6
Carpark, warehouse, storage building	Class 7
Factory, workshop, laboratory	Class 8
Healthcare building, hospital, and GP clinics	Class 9a
Public event buildings, stadiums, theatres, schools, universities, and churches	Class 9b
Aged care facilities	Class 9c

Requested File Type

As a starting point we can use CSV files. If more a readable, usable format of data is available we would like to have this also.

Appendix B – MEM RFI Explanatory Note

ARUP

Memorandum

To	Australian Building Codes Board
Date	26 April 2023
Copies	Tom Roberts; Neil Rech
Reference number	288270-02
From	Arup
File reference	MEM-002
Subject	Request for Information - Building Use Data Explanatory Note

1. Context

These explanatory notes follow the issue of the Memorandum 'MEM-001 RFI – Building Use Data' dated 17/04/2023, outlining a method of configuring a fixture water usage monitoring system within a building to obtain the data requested. This methodology is detailed for:

1. Single user amenities, i.e., fixtures within Class 1-4 buildings (residential dwelling, small apartment block or townhouses), and

2. Multiple user (group) amenities, i.e., fixtures within Class 5-9c buildings (commercial office, retail, public event building etc.)

Within single and multiple user amenity building types, the methodology for configuring a fixture water usage monitoring system is detailed for each scenario of pre-existing flow and occupancy monitoring. An example schematic of a typical floor of a (1) single user amenities building and (2) multiple user amenities building is provided to illustrate the required steps in further detail.

2. Clarifications

This memorandum is subject to the following clarifications.

1. As part of the research conducted to inform this memorandum, we have reviewed monitoring components available at the time of writing.

2. No physical installation, physical testing or mock ups has been completed by Arup as part of developing the methodology detailed within this memorandum.

3. This memorandum intends to provide guidance on configuring a fixture water usage monitoring system for both residential and commercial type buildings. Prior to engaging in any monitoring configuration works, consultation with the manufacturers of the respective monitoring components is recommended.

4. This memorandum details one such method of obtaining the data specified in 'MEM-001 RFI – Building Use Data'.

4.1. Our research of monitoring components currently on the market demonstrates that in some instances, water monitoring and shutoff systems may provide an alternative method to collecting the required data, without the requirement of sensor flow monitoring fixtures. Refer to Section 6 for further detail.

4.2. The investigation of other monitoring methodologies is accepted, providing that the data variables specified in 'MEM-001 RFI – Building Use Data' can be ascertained from analysis of the monitoring data.

5. In the example schematics provided in this memorandum:

5.1. A typical floor of a building is shown. It should be noted, however, that where possible, monitoring multiple levels of a multi-level building is encouraged to improve the reliability of the data obtained.

5.2. All amenity groups on the typical floor are shown to be monitored (e.g., for the multiple user amenities building, the male amenities, female amenities, accessible amenities, and the kitchen are all monitored; see Figure 6). Whilst this is not required, it is encouraged that as many amenity groups as is feasible are monitored to improve the reliability of the data obtained.

5.3. All fixtures except for hose taps, dishwashers and washing machines are installed as sensor monitoring flow fixtures. The usage of these fixtures may be able to be determined from analysis of sub metering data.

3. Definitions of Monitoring Components

Definitions of the monitoring components in terms of required data output and their functionality for the methodology detailed in this memorandum are summarised below in Table 1.

Table 1 Definitions of Monitoring Components

Component	Definition/Components Required	Data Required	Functionality Required
Occupancy Counter	A device that records the number of people entering and exiting a defined space within the building (e.g., a particular level of a building or a particular room).	Occupancy counter sensor ID Timestamp 'in' count and 'out' count, or net count (in minus out)	Records occupancy counts at regular time intervals (e.g., every 5 minutes) Collects and uploads the data to an online platform, where data is stored and accessible. Data must be able to be exported in CSV/Excel format. Note: only offline reporting of occupancy is required (i.e., a live occupancy display is not required).

Component	Definition/Components Required	Data Required	Functionality Required
Smart Water Metering Solution[1]	A smart water metering solution could either consist of a: Smart water meter, or Smart water meter logger which connects into an existing mechanical water meter (mechanical water meter must be pulse enabled).	Meter ID Timestamp Meter water consumption (L or kL)	Reads meter consumption at regular time intervals (e.g., every 15 or 30 minutes). Collects and uploads the data to an online platform, where data is stored and accessible. Data must be able to be exported in CSV/Excel format.
Sensor flow monitoring fixtures	A Sensor flow monitoring fixture is a smart fixture (e.g., toilet, shower, tapware, urinals etc.), whereby water usage data is collected from each fixture.	Fixture ID Timestamp of every fixture usage event Duration of every fixture usage event (s) Measured fixture flow rate (l/s)	Collects and uploads the data to an online platform, where data is stored and accessible. Data must be able to be exported in CSV/Excel format.

4. Single User Amenities

4.1 Continuous Monitoring Scenarios

The methodology for configuring a fixture water usage monitoring system within a single user amenities building will be provided for buildings with the following existing monitoring equipment:

1. Buildings with only utilities meter
2. Buildings with tenancy sub flow smart water metering solutions
3. Buildings with tenancy sub flow smart water metering solutions and sensor monitoring flow fixtures.

4.2 Preliminary Investigation & Testing Area Definition

For the following preliminary steps, refer to the schematic in Figure 1 as an example.

1. Identify the whether the building to be monitored has any of the following existing components:
   - Tenancy sub flow smart water metering solutions
   - Sensor monitoring flow fixtures.
2. From the above assessment, determine which scenario (1 to 3) is applicable to the building under consideration (refer to Section 4.1 for scenarios). Refer to the respective procedure of the building outlined in the following sections (4.3 to 4.5).
3. Considering the location of any existing monitoring components, identify amenity groups within the building that will be subject to water supply monitoring.

[1] https://www.unitywater.com/about-us/projects-in-your-area/major-projects/smart-meter-network

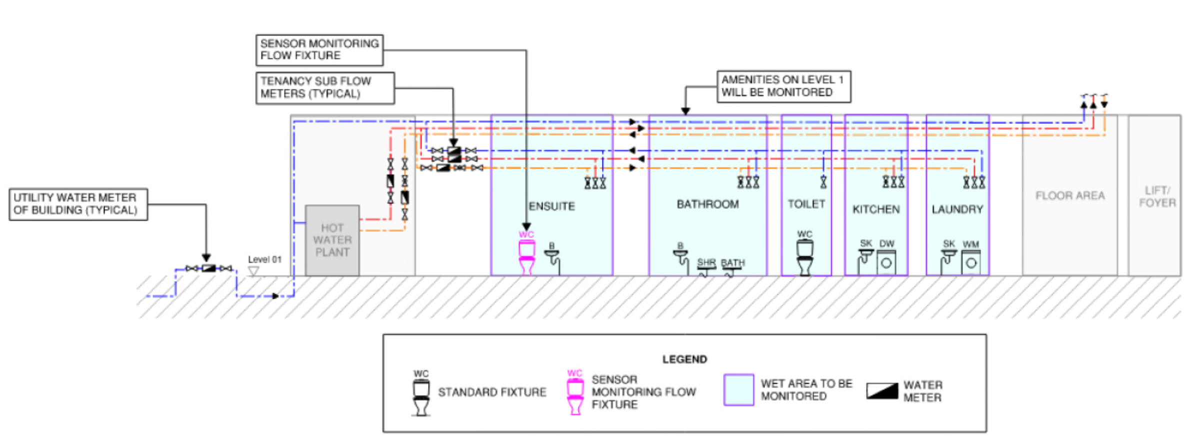


Figure 1 Single user amenities building schematic illustrating potential monitoring components to be identified during the Preliminary Investigation Stage

4.3 Buildings with only utilities meter

The steps to facilitate monitoring are as follows, and are illustrated in Figure 2 below:

1. Install tenancy sub flow meters and any associated valving on cold and hot (flow and return) water supply take-offs for each level and/or department undergoing monitoring.
2. Replace existing standard fixtures with sensor monitoring flow fixtures for fixtures within wet areas to be monitored.

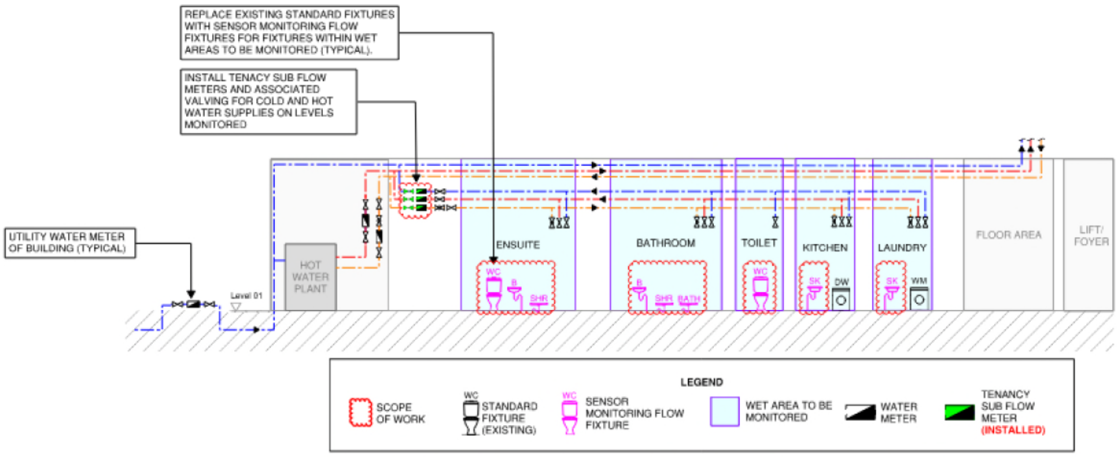


Figure 2 Single user amenities building schematic for Scenario 1 – Existing Configuration noting Required Works to Facilitate Monitoring

4.4 Buildings with tenancy sub flow meters

The steps to facilitate monitoring are as follows, and are illustrated in Figure 3 below:

1. Replace existing standard fixtures with sensor monitoring flow fixtures for fixtures within wet areas to be monitored.

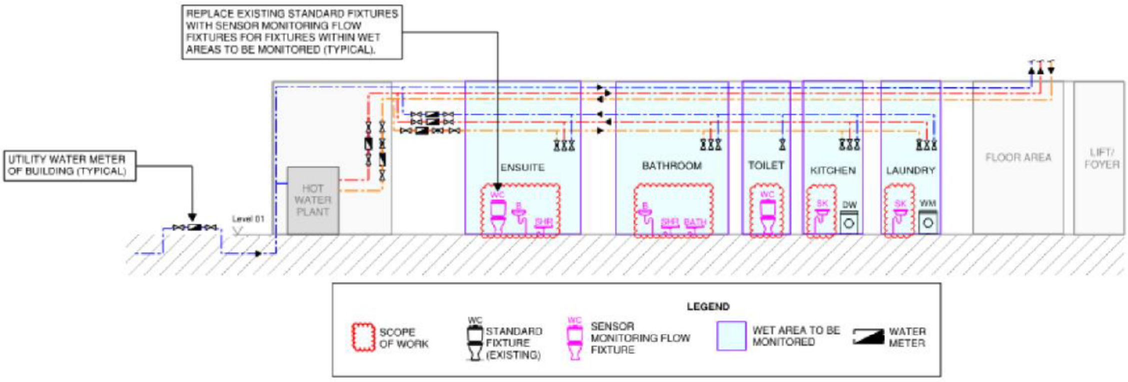


Figure 3 Single user amenities building schematic for Scenario 2 – Existing Configuration Noting Required Works to Facilitate Monitoring

4.5 Buildings with tenancy sub flow meters and sensor monitoring flow fixtures

A building in this configuration is already suitable to commence monitoring and does not require any works to facilitate monitoring. Refer to Figure 4 for an example of this configuration.

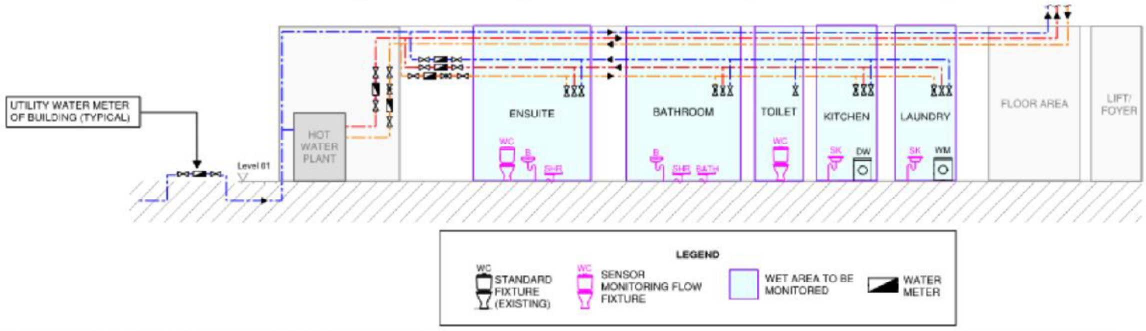


Figure 4 Single user amenities building schematic for Scenario 3 – Existing Configuration Suitable for Monitoring

5. Multiple User (Group) Amenities

5.1 Continuous Monitoring Scenarios

The methodology for configuring a fixture water usage monitoring system within a multiple user amenities building will be provided for buildings with the following existing monitoring equipment:

1. Buildings without sub flow smart water metering solutions,
2. Buildings with sub flow smart water metering solutions[2] and no occupancy counting,
3. Buildings with sub flow smart water metering solutions[2] and occupancy counting[3], and
4. Buildings with sensor monitoring flow fixtures, sub flow smart water metering solutions[2] and occupancy counting[3].

5.2 Preliminary Investigation & Testing Area Definition

For the following preliminary steps, refer to the schematic in Figure 5 as an example.

1. Identify the whether the building to be monitored has any of the following existing components:

[2] Note that a building having 'sub flow smart water metering solutions' is defined as (1) meeting requirements specified in Section 2 and (2) be installed on cold and hot (flow and return) supplies.

[3] Note that a building having 'occupancy counting' in these scenarios is considered to mean that the floor level(s) considered for water usage monitoring have occupancy counting at every entry and exit of the floor level. Occupancy counting will still be required to be installed at every entry and exit of each amenity.

- Sub flow smart water metering solutions[2] (smart water metering on each level/department of the building),
- Occupancy counting functionality[3], and
- Sensor monitoring flow fixtures.

2. From the above assessment, determine which scenario (1 to 4) is applicable to the building under consideration (refer to Section 5.1 for scenarios). Refer to the respective procedure of the building outlined in the following sections (5.3 to 5.6).
3. Considering the location of any existing monitoring components, identify amenity groups within the building that will be subject to water supply monitoring.

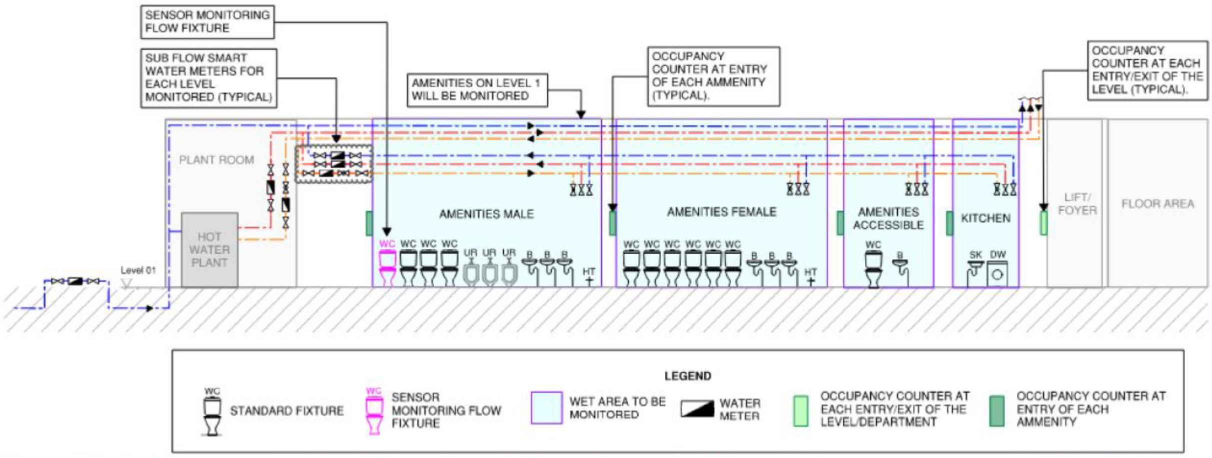


Figure 5 Multiple user amenities building schematic illustrating potential monitoring components to be identified during the Preliminary Investigation Stage

5.3 Buildings without sub flow smart water meters and no occupancy counting

The steps to facilitate monitoring are as follows, and are illustrated in Figure 6 below:

1. Install sub flow smart water meters and associated valving on cold and hot (flow and return) water supply take-offs for each level and/or department undergoing monitoring.
2. Install occupancy counters to each level and/or department being monitored at:
   2.1. Every entry and exit of the level/department (e.g., outside the lift doors), and
   2.2. The door entry of each amenity.
3. Replace existing standard fixtures with sensor monitoring flow fixtures for fixtures within wet areas to be monitored.

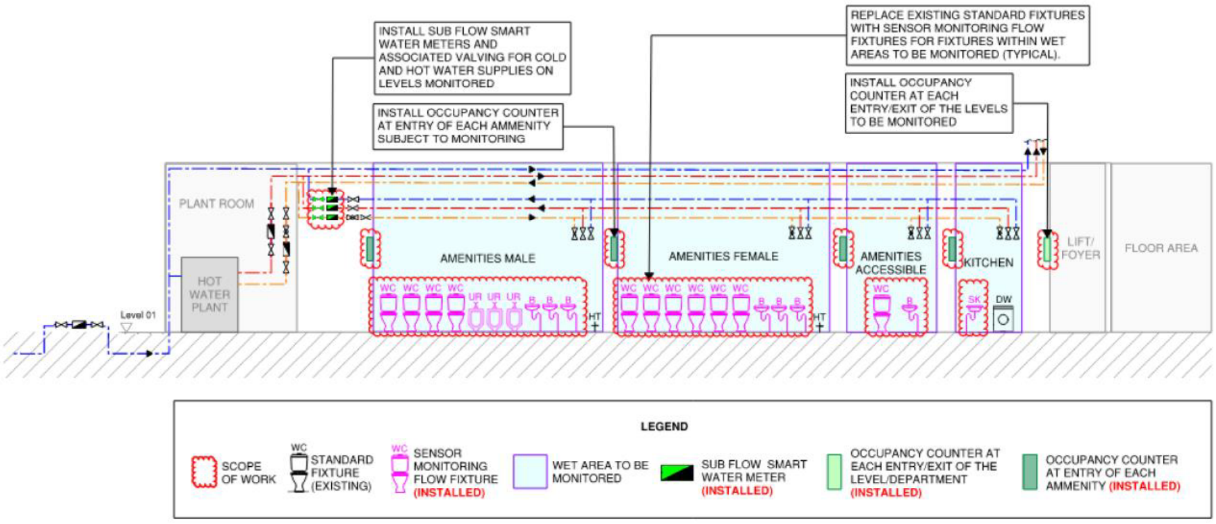


Figure 6 Multiple user amenities building schematic for Scenario 1 – Existing Configuration noting Required Works to Facilitate Monitoring

5.4 Buildings with sub flow smart water meters and no occupancy counting

The steps to facilitate monitoring are as follows, and are illustrated in Figure 7 below:

1. Install occupancy counters to each level and/or department being monitored at:
   3.1. Every entry and exit of the level/department (e.g., outside the lift doors), and
   3.2. The door entry of each amenity.
4. Replace existing standard fixtures with sensor monitoring flow fixtures for fixtures within wet areas to be monitored.

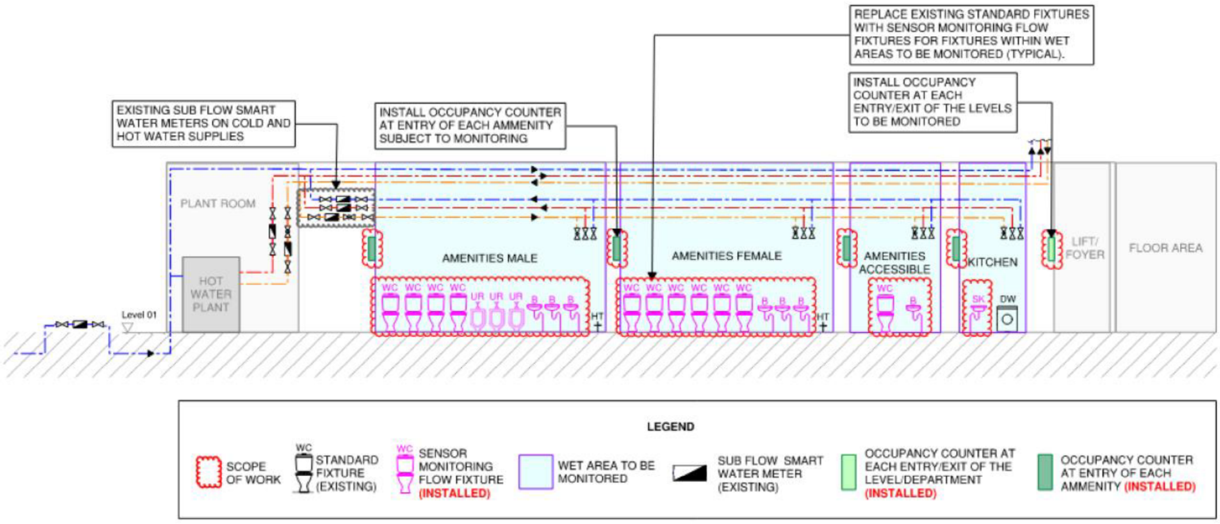


Figure 7 Multiple user amenities building schematic for Scenario 2 – Existing Configuration noting Required Works to Facilitate Monitoring

5.5 Buildings with sub flow smart water meters and occupancy counting

An example of a building configured in this scenario is shown below in Figure 8. The steps to facilitate monitoring are as follows, and are noted in Figure 8:

1. Replace existing standard fixtures with sensor monitoring flow fixtures for fixtures within wet areas to be monitored.

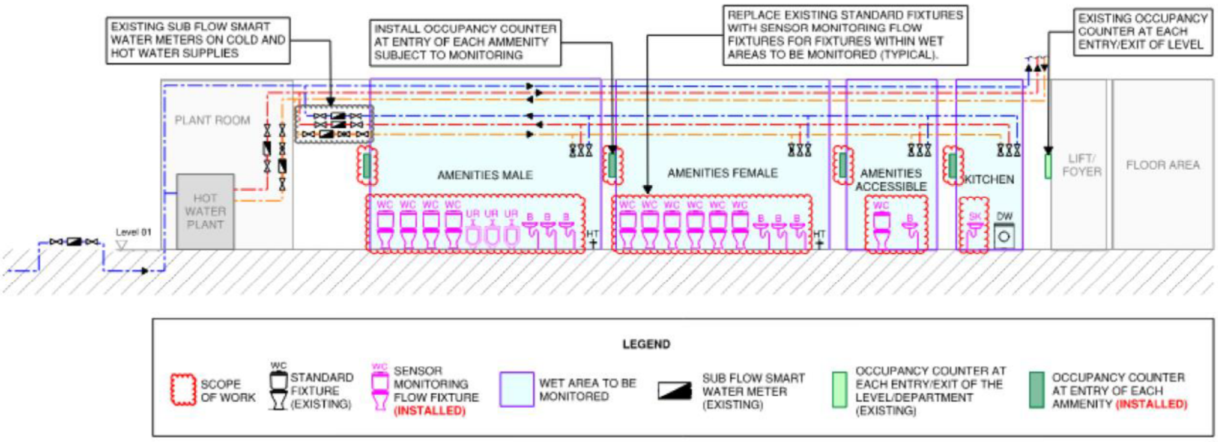


Figure 8 Multiple user amenities building schematic for Scenario 3 – Existing Configuration noting Required Works to Facilitate Monitoring

5.6 Buildings with sensor monitoring flow fixtures, sub flow smart water meters and occupancy counting

A building in this configuration is already suitable to commence monitoring and does not require any works to facilitate monitoring. Refer to Figure 9 for an example of this configuration.

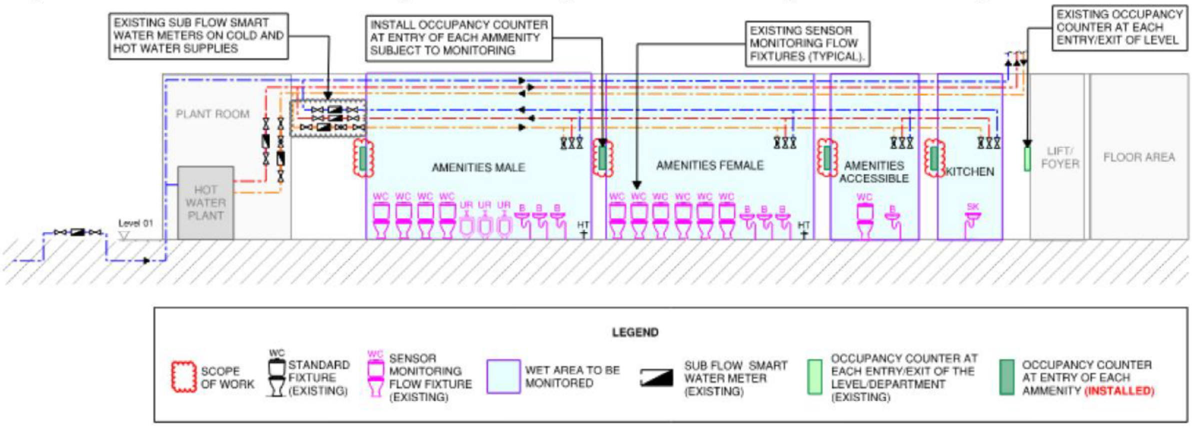


Figure 9 Multiple user amenities building schematic for Scenario 4 – Existing Configuration noting Required Works to Facilitate Monitoring

6. Recording Results

Refer to the excel schedule for a template of how to record the results of the water supply monitoring. Note that the exact format of the raw data from metering, occupancy counting and sensor monitoring flow fixtures may vary depending on the manufacturer of the equipment and is intended as a guide.

Appendix B - AS/NZS 3500.2:2021 and BS EN 12056.2:2000 Comparison

B.1. Definitions of Key System Configuration

To ensure the comparisons of sanitary plumbing and drainage systems are valid, and conducted as accurately as possible, the definitions of each type of configuration will be obtained from the respective standard. This will form the basis of all further comparisons in this section. The definitions are summarised below in Table 19.

Table 19: Sanitary Plumbing and Drainage Configuration Definitions

Configuration	Definition Origin	Definition
Single Stack	*AS/NZS 3500.2:2021*	System of sanitary plumbing in which the stack and discharge pipes also serve as vent pipes.
Single Stack Modified	*AS/NZS 3500.2:2021*	System of sanitary plumbing where additional venting is provided by relief vents, connected to the stack at intervals by cross vents.
Fully Vented	*AS/NZS 3500.2:2021*	System of sanitary plumbing with provision for the separate ventilation of every fixture trap connected (other than fixtures discharging to a floor waste) and of the trap of every floor waste gully.
Fully Vented Modified	*AS/NZS 3500.2:2021*	System of sanitary plumbing where the traps of any group of two or more fixtures or floor waste gullies, discharging to the same branch pipe, are vented in common by one or more group vents.
Primary Ventilated	*BS EN 12056.2:2000*	Control of pressure in the discharge stack is achieved by air flow in the discharge stack and the stack vent. Alternatively, air admittance valves may be used.
Secondary Ventilated	*BS EN 12056.2:2000*	Control of pressure in the discharge stack is achieved by use of separate ventilating stacks and/or secondary branch ventilating pipes in connection with stack vents. Alternatively, air admittance valves may be used.
Unventilated Discharge Branch	*BS EN 12056.2:2000*	Control of pressure in the discharge branch is achieved by air flow in the discharge branch.
Ventilated Discharge Branch	*BS EN 12056.2:2000*	Control of pressure in the discharge branch is achieved by ventilation of the discharge branch.

Based on the definitions above, not any one configuration of one standard can be substituted for the other due to their inherent differences. The system configurations that are most similar to one another are grouped below in Table 20 and Table 21 with their most relevant stack sizing or branch sizing clauses identified in the adjacent cells. Further delineation between Systems I through III was also provided where relevant.

Table 20: Similar or Equivalent Stack Configuration in *BS EN 12056.2:2000* and *AS/NZS 3500.2:2021*

***AS/NZS 3500.2:2021* Stack Configuration**		**Similar or Equivalent *BS EN 12056.2:2000* Stack Configuration**	
System	**Sizing Reference**	**System**	**Sizing Reference**
Single Stack	Table 9.7.1(A) & (B) of *AS/NZS 3500.2:2021*	Primary Ventilated	Table 11 of *BS EN 12056.2:2000*
Single Stack Modified	Table 9.7.2(A) & (B) of *AS/NZS 3500.2:2021*	Secondary Ventilated	Table 12 of *BS EN 12056.2:2000*
Fully Vented	Table 8.2.2(B) of *AS/NZS 3500.2:2021*		
Fully Vented Modified			

As demonstrated above in Table 20 above, for instances where *BS EN 12056.2:2000* (B.S. Institute, 2000) references a secondary ventilated system design, the similar *AS/NZS 3500.2:2021* (Standards Australia, 2021) methods include single stack modified, full vented, and fully vented modified systems. The limited ability to separate single stack modified and all variations of fully vented design from a secondary ventilated system design within *BS EN 12056.2:2000* (B.S. Institute, 2000) will need to be taken to account in further comparisons of both standards.

Table 21: Similar or Equivalent Branch Configuration in *BS EN 12056.2:2000* and *AS/NZS 3500.2:2021*

***AS/NZS 3500.2:2021* Branch Configuration**		**Similar or Equivalent *BS EN 12056.2:2000* Branch Configuration**	
System	**Sizing Reference**	**System**	**Sizing Reference**
Single Stack	Table 6.3(A) of *AS/NZS 3500.2:2021*	Unventilated Discharge Branches (System III)	Table 6 of *BS EN 12056.2:2000*
Single Stack Modified			
Fully Vented	Table 8.2.2(A) of *AS/NZS 3500.2:2021*	Ventilated Discharge Branches (System I and II)	Table 7 of *BS EN 12056.2:2000*
Fully Vented Modified			
NA		Ventilated Discharge Branches (System III)	Table 9 of *BS EN 12056.2:2000*
NA		Unventilated Discharge Branches (System I and II)	Table 4 of *BS EN 12056.2:2000*

As documented in Table 21 above, investigations into the Standards revealed that *BS EN 12056.2:2000* (B.S. Institute, 2000) System III Unventilated Discharge Branches appears to align best with the *AS/NZS 3500.2:2021* (Standards Australia, 2021) method of branch sizing for single stack and single stack modified systems, due to (1) branches within both systems being unventilated and (2) the sizing methodology recommended by both standards being similar (both requiring that apart from some exceptions, each fixture is to be connected to a stack by a separate discharge pipe, and specifying branch sizing and limitations according to the fixture connected).

Furthermore, the *BS EN 12056.2:2000* (B.S. Institute, 2000) System I and II Ventilated Discharge Branches appears to better align with the *AS/NZS 3500.2:2021* (Standards Australia, 2021) method of branch sizing for fully vented (and modified) systems, due to (1) branches within both systems being ventilated and (2) the sizing methodology recommended by both standards being similar (both specifying maximum hydraulic load for each branch size).

It is apparent that the *BS EN 12056.2:2000* (B.S. Institute, 2000) System III Ventilated Discharge branches, and, System I and II Unventilated Discharge Branches do not have equivalent *AS/NZS 3500.2:2021* (Standards Australia, 2021) systems with similar sizing methods:

- *BS EN 12056.2:2000* (B.S. Institute, 2000) System III Ventilated Discharge branches are ventilated branches like those in *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) systems, however due to being sized to System III (100% filling degree of the branch) requirements, they are sized similar to that of a single stack (or modified) system (each fixture independently connected to the stack, except for some provisions for fixture ranges connected to a common discharge branch).

- System I and II Unventilated Discharge Branches are unventilated branches (without trap or branch vents), which is similar to branches in a single stack (or modified) system, however, due to the 50% (System I) or 70% filling capacity (System II), *BS EN 12056.2:2000* (B.S. Institute, 2000) provides branch sizing which is similar to that of a fully vented (or modified) system, where multiple appliances can be connected to a common fixture branch, and is only limited by the maximum hydraulic load specified for each branch size.

B.2. Calculation of Hydraulic Loads Between AS/NZS 3500.2:2021 and BS EN 12056.2:2000

As discussed in the Phase 1 Report, the unit of quantifying the hydraulic load on sanitary plumbing and drainage pipework differs quite significantly between *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000). Where *AS/NZS 3500.2:2021* (Standards Australia, 2021) uses the sum of the fixture unit ratings ($\sum FU$) based off a weighting factor from a reference fixture to determine the fixture unit loading, *BS EN 12056.2:2000* (B.S. Institute, 2000) calculates a probable simultaneous wastewater flow rate Q_{ww} (L/s) based off a summation of discharge units ($\sum DU$) and a Frequency Factor (K):

$$Q_{ww} = K\sqrt{\sum DU}$$

The *AS/NZS 3500.2:2021* (Standards Australia, 2021) standard however, does not explicitly provide an equation for the conversion of fixture units (FU) into a flow rate. A semblance of a FU to flow rate conversion equation is present in the air admittance valve (AAV) design guidance section of the standard; specifically, regarding minimum airflow rates of AAVs in branches and stacks. These equations also appear to share a relationship with the minimum airflow rate of AAVs dictated in *BS EN 12056.2:2000* (B.S. Institute, 2000). A comparison has been conducted in Table 22 below.

It should be noted that there are two equations for minimum airflow of air admittance valves in *BS EN 12056.2:2000* (B.S. Institute, 2000) for System II/III and System I, with the equation for System II/III being identical to that provided in *AS/NZS 3500.2:2021*. Hence, it is assumed that *AS/NZS 3500.2:2021* (Standards Australia, 2021) is designed equivalent to that of *BS EN 12056.2:2000* (B.S. Institute, 2000) System II or III in regard to required airflow.

Table 22: Comparison of Guidance in *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* on minimum airflow rates of air admittance valves in branches and stacks

System Component	*AS/NZS 3500.2:2021*[5]	*BS EN 12056.2:2000*[6]	Deduction of Fixture Unit to Flow Rate Formula
Stacks	For stacks, airflow capacity of the valve Q in L/s is given as: $$Q = 8\sqrt{\frac{FU}{6.75}}$$	For stacks, minimum airflow rate of the valve (Q_a) in L/s is given as: $$Q_a = 8 \times Q_{tot}$$ Where Q_{tot} is the total wastewater flow rate in L/s.	Equating both equations: $$Q_a = 8\sqrt{\frac{FU}{6.75}} = 8 \times Q_{tot}$$ $$Q_{tot} = \sqrt{\frac{FU}{6.75}}$$
Branches	For discharge pipes airflow capacity of the valve Q in L/s is given as: $$Q = 2\sqrt{\frac{FU}{6.75}}$$	For branches, minimum airflow rate of the valve (Q_a) in L/s is given as: $$Q_a = 2 \times Q_{tot}$$ For System II and III, and: $$Q_a = 1 \times Q_{tot}$$ For System I.	Equating both equations: $$Q_a = 2\sqrt{\frac{FU}{6.75}} = 2 \times Q_{tot}$$ $$Q_{tot} = \sqrt{\frac{FU}{6.75}}$$

Whilst *AS/NZS 3500.2:2021* (Standards Australia, 2021) does not explicitly reference the expression $\sqrt{\frac{FU}{6.75}}$ as the wastewater flow rate, comparison of the formula provided in *BS EN 12056.2:2000* (Standards Australia, 2021) which references airflow rate as a multiple of wastewater flow rate provides evidence for this assumption. Further support for the use of the above expression for conversion of FU into a flow rate is mentioned briefly in a comparison of different mathematical methods within Appendix 1 of the Phase 1 Report (Arup, 2022) whereby (Swaffield, 2015) utilised the following formula to convert fixture units to a total wastewater flow rate.

$$Q_{ww,AS} = \sqrt{\frac{\sum FU}{6.75}}$$

As identified in the Phase 1 Report (Arup, 2022), this formula produces results similar to those reported in Table 6.3(B) of *AS/NZS 3500.2:2021* (Standards Australia, 2021). A comparison of the results provided by both methods is summarised below in Table 23. These results have also been plotted below in Figure 4. It is evident that the flow rate values provided in Table 6.3(B) of *AS/NZS 3500.2:2021* (Standards Australia, 2021) are in close agreement with that resultant from the formula, except for 6 Fixture Units (FU), where the formula overestimates the equivalent flow rate by 88.6% compared to Table 6.3(B) of *AS/NZS 3500.2:2021* (Standards Australia, 2021).

Utilising the comparison above and the reference from (Swaffield, 2015), a reasonably safe assumption can be made that the FU to flowrate conversion formula is a viable means of calculating maximum flow rate capacities of sanitary plumbing components specified in *AS/NZS 3500.2:2021* (Standards Australia, 2021). This formula will be used to compare the recommendations provided by *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000).

[5] Section 6.10.2 of *AS/NZS 3500.2:2021*

[6] Section 6.5.3 and 6.4.3 of *BS EN 12056.2:2000*

Table 23: Comparison of Flow rates provided in Table 6.3(B) of *AS/NZS 3500.2:2021* and calculated flow rate using 'Fixture Unit to Flow Rate' Formula

Fixture Unit (FU)	Flow (L/s) – Table 6.3(B) of *AS/NZS 3500.2:2021*	Calculated Flow using 'Fixture Unit to Flow Rate' Formula (L/s)	Percentage Difference (%)
6	0.5	0.94	88.6
8	1	1.09	8.9
15	1.5	1.49	-0.6
25	2	1.92	-3.8
40	2.5	2.43	-2.6
60	3	2.98	-0.6
85	3.5	3.55	1.4
115	4	4.13	3.2

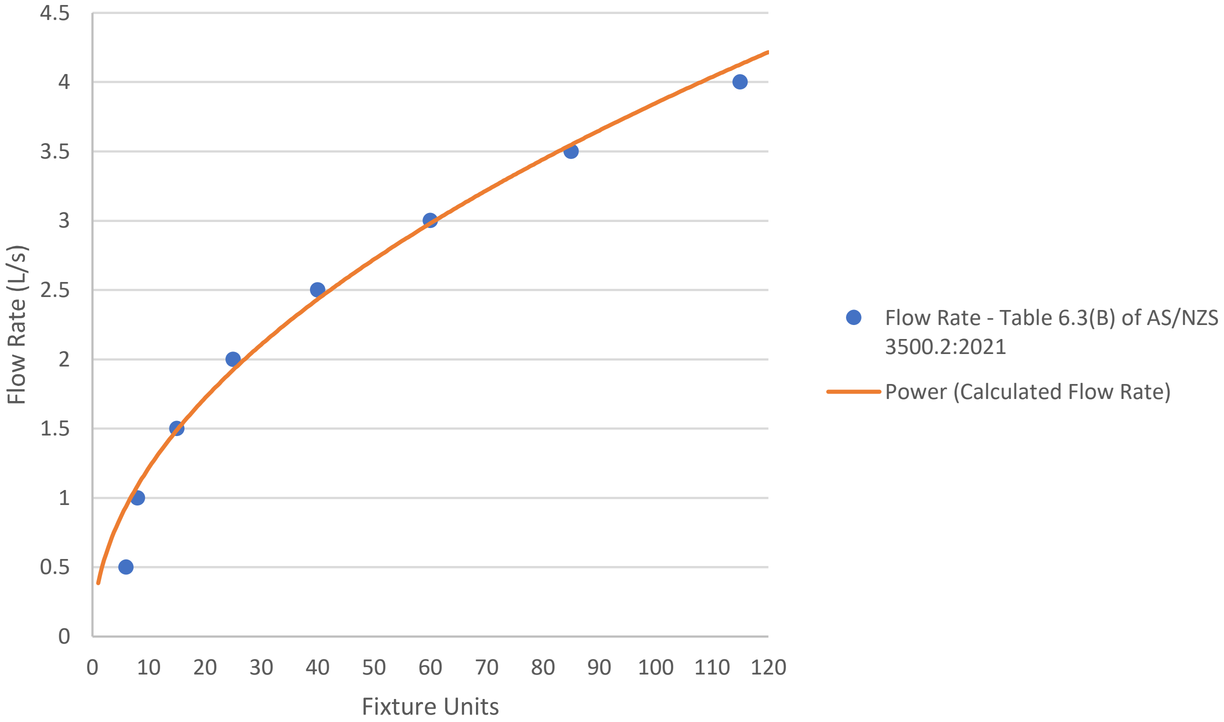


Figure 4: Fixture Units versus Flow rate for data provided in Table 6.3(B) of *AS/NZS 3500.2:2021* and calculated flow rate using 'Fixture Unit to Flow Rate' Formula

B.3. Stack Sizing Comparison of AS/NZS 3500.2:2021 Single Stack and BS EN 12056.2:2000 Primary Ventilated Systems

B.3.1. Influence of Branch Connections

AS/NZS 3500.2:2021 (Standards Australia, 2021) clearly specifies the requirements for branch connections for each stack sizing alternative provided for the single stack system. These requirements include:

- "*Each fixture is to be connected to the stack by a separate unvented fixture discharge pipe of a prescribed length, size and grade*." (Table 9.5.1 of *AS/NZS 3500.2:2021* (Standards Australia, 2021)), with the exception that:
  - DN100-150 stacks in commercial-type buildings can have ranges of fixtures connected to a common discharge pipe (Section 9.5.2(g) of *AS/NZS 3500.2:2021* (Standards Australia, 2021)), and
  - DN65-100 stacks can have fixture pairs jointly discharging to a common fixture trap and fixture discharge pipe (Section 9.5.2(f) of *AS/NZS 3500.2:2021* (Standards Australia, 2021)).
- Limitations to number and type of fixtures connected to a given floor level of a single stack for domestic/residential and commercial/industrial buildings (see Section 9.4.1 and 9.4.2 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) respectively).
- DN40-100 stacks may be sized according to Table 9.5.2 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) if (Section 9.5.2 of *AS/NZS 3500.2:2021* (Standards Australia, 2021)):
  - the stack has no offsets, and
  - not more than 25% of the maximum loading of a stack may discharge into each floor level (with exceptions for stacks ≤ DN50).

  Note that no maximum stack height appears to be specified for this sizing, although the 25% loading per floor requirements suggests that the sizing could be suitable for ≥ 4 floor levels.
- Note that there are other variations to the sizing of single stack systems presented in Section 9.8 of *AS/NZS 3500.2:2021* (Standards Australia, 2021), which are based on "*actual installations that have been subjected to performance testing.*"

In comparison, *BS EN 12056.2:2000* (B.S. Institute, 2000) does not provide alternative sizing of stacks for different branch configurations. Whilst it specifies limitations to maximum length, drop and bends, and minimum grade of unventilated and ventilated branch connections to a stack, it:

- Does not specify limitations to number and type of fixtures connected to a given floor level of a single stack, and
- Does not clearly specify configurations allowable (e.g., range of basins, fixture pairs), except to clarify configurations where WC's are either excluded or limited to 1 or 2 for a given system (I, II, III or IV) and branch size.

B.3.2. Sizing Tables

The sizing of stacks ≥DN100 for *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack systems details stack sizing for both residential and commercial buildings, accounting for the fact that in commercial buildings, ranges of fixtures may be connected to stacks and the varied number and type of appliances allowable for connection at each floor level.

Hence, *AS/NZS 3500.2:2021* (Standards Australia, 2021) accounts for the influence of branch connections on stack sizing, which is reflected in the significantly lower maximum fixture unit loading of commercial buildings compared to the loading specified for residential buildings. It should also be noted that the stack and the type of building (residential or commercial) influences the maximum consecutive floor levels of a stack.

In comparison, whilst *BS EN 12056.2:2000* (B.S. Institute, 2000) considers the impact of junction configuration (square or swept) on the maximum fixture loading of a stack, it does not account for the influence of varied branch connections on stack sizing.

B.3.3. Quantitative Comparison of *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* Stack Sizing

A comparison of the maximum stack capacities specified by *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) is summarised below in Table 24 and plotted in Figure 5. The maximum fixture unit loading provided in *AS/NZS 3500.2:2021* (Standards Australia, 2021) has been converted to an equivalent flow rate using the 'Fixture Unit to Flow Rate' Formula specified in Appendix B.2. Percentage differences between the maximum stack capacities provided in Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Standards Australia, 2021) (Domestic), Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Standards Australia, 2021) (Commercial) and Table 9.5.2 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) and those of Table 11 of *BS EN 12056.2:2000* (B.S. Institute, 2000), are tabulated and plotted below in Table 25 and Figure 6 to Figure 8 respectively. Table 25 distinguishes percentage differences between 0 and $\pm$ 20% in green, between $\pm$ 20% and $\pm$ 100% are provided in orange and $\geq \pm$ 100% provided in red.

In general, the following trends are observed in relation to reported stack capacity values:

- Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Standards Australia, 2021) (Domestic) stack capacity values are similar to those provided by Table 11 of *BS EN 12056.2:2000* (B.S. Institute, 2000),
- Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Standards Australia, 2021) (Commercial) stack capacity values are significantly lower (25-56%) than those provided by Table 11 of *BS EN 12056.2:2000* (B.S. Institute, 2000), and
- Table 9.5.2 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) stack capacity values are similar to those provided by Table 11 of *BS EN 12056.2:2000* (B.S. Institute, 2000) for DN80 and DN100 (5 to 19%), except for DN60/65 where the stack capacity provided in Table 9.5.2 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) is significantly larger than that of *BS EN 12056.2:2000* (B.S. Institute, 2000).

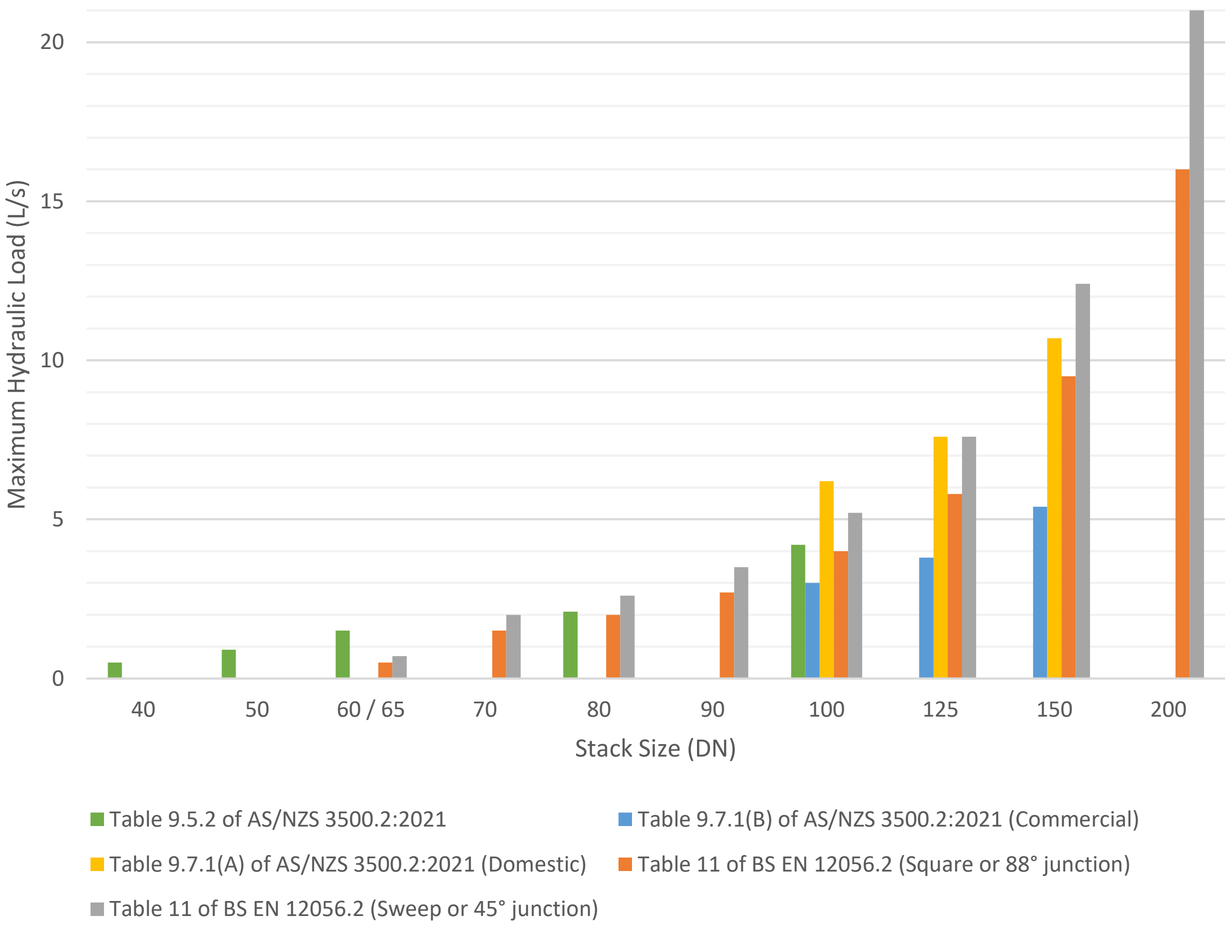
We are unable to validate the discrepancy between the values for DN60/65, however, expect that it may be due to the additional requirements specified by *AS/NZS 3500.2:2021* (Standards Australia, 2021) that stacks sized using Table 9.5.2 must have no offsets and not more than 25% of the maximum stack loading may discharge into a stack at a given floor level, hence allowing a greater capacity. However, if this were the case, this discrepancy should be present for both DN65 and 80. It should also be noted that *AS/NZS 3500.2:2021* considers a DN65 stack, whilst the *BS EN 12056.2:2000* (B.S. Institute, 2000) is only a DN60 stack; the difference in size potentially contributing for some of the capacity discrepancy.

Generally, a comparison of values demonstrates that stack capacities provided in *BS EN 12056.2:2000* (B.S. Institute, 2000) is comparable to that of the maximum flow rates for domestic buildings in *AS/NZS 3500.2:2021* (Standards Australia, 2021). It should be noted that the maximum loading of stacks in commercial buildings (Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Standards Australia, 2021)) is approximately half that of residential buildings (Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Standards Australia, 2021)).

Table 24: Comparison of Maximum Hydraulic Loading on Stacks specified in *AS/NZS 3500.2:2021* Single Stack System and *BS EN 12056.2:2000* Primary Ventilated System

Stack Nominal Diameter (DN)	Maximum Loading on Stacks (L/s)				
	Table 11 of BS EN 12056.2 (Square or 88° junction)	Table 11 of BS EN 12056.2 (Sweep or 45° junction)	Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Domestic)	Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Commercial)	Table 9.5.2 of *AS/NZS 3500.2:2021*
40					0.5

Stack Nominal Diameter (DN)	Maximum Loading on Stacks (L/s)				
	Table 11 of BS EN 12056.2 (Square or 88° junction)	Table 11 of BS EN 12056.2 (Sweep or 45° junction)	Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Domestic)	Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Commercial)	Table 9.5.2 of *AS/NZS 3500.2:2021*
50					0.9
60 / 65[7]	0.5	0.7			1.5
70	1.5	2			
80	2	2.6			2.1
90	2.7	3.5			
100	4	5.2	6.2	3.0	4.2
125	5.8	7.6	7.6	3.8	
150	9.5	12.4	10.7	5.4	
200	16	21			



[7] *BS EN 12056.2:2000* provides maximum capacity for a DN60 stack and AS/NZS 3500.2:2021 provides maximum capacity for a DN65 stack.

Figure 5: Plot of Maximum Hydraulic Loading on Stacks specified in *AS/NZS 3500.2:2021* Single Stack System and *BS EN 12056.2:2000* Primary Ventilated System

Table 25: Percentage Difference between Maximum Stack Capacities derived from *AS/NZS 3500.2:2021* for Single Stack Systems and those provided in *BS EN 12056.2:2000* for Primary Ventilated Systems

Stack Nominal Diameter (DN)	Percentage Difference between *AS/NZS 3500.2:2021* and Table 11 of *BS EN 12056.2:2000*					
	Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Domestic)		Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Commercial)		Table 9.5.2 of *AS/NZS 3500.2:2021*	
	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)
60 / 65					200.0%	114.3%
80					5.0%	-19.2%
100	55.0%	19.2%	-25.0%	-42.3%	5.0%	-19.2%
125	31.0%	0.0%	-34.5%	-50.0%		
150	12.6%	-13.7%	-43.2%	-56.5%		

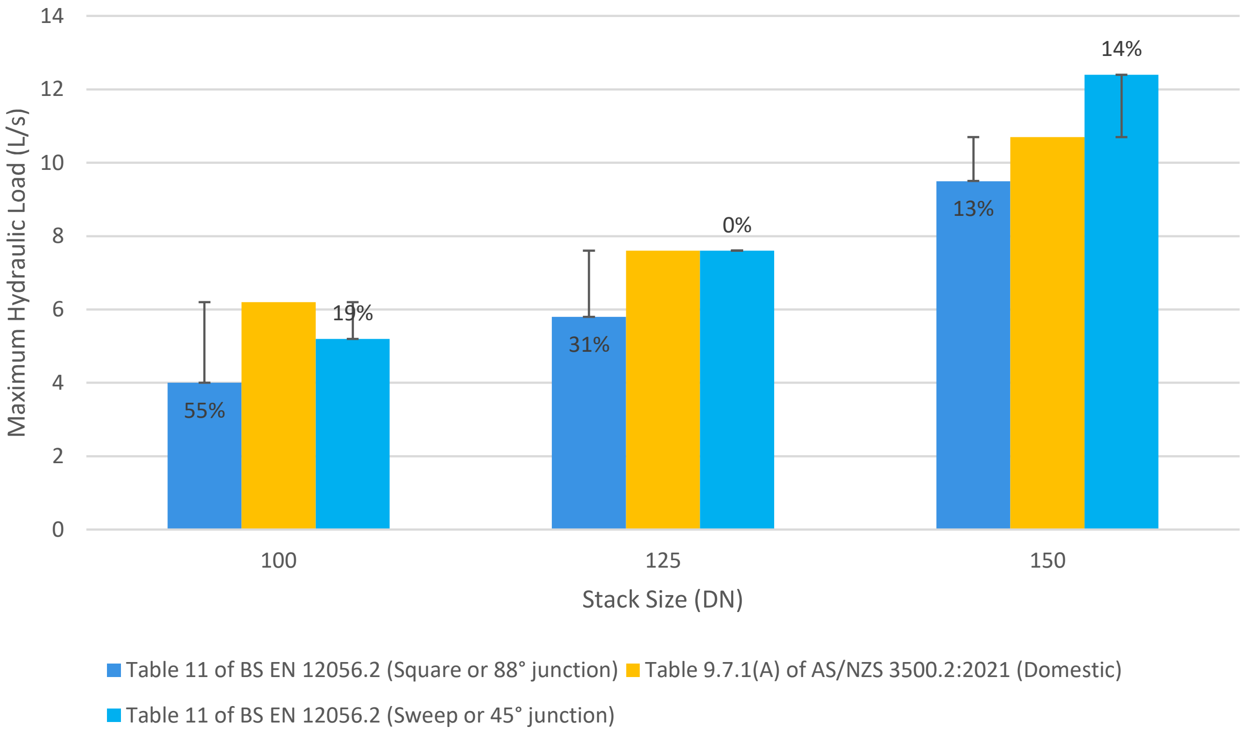


Figure 6: Percentage Difference between Stack Capacities reported in Table 9.7.1(A) of *AS/NZS 3500.2:2021* (Domestic) and Table 11 of BS EN 12056.2 Square or 88° junction, and Sweep or 45° junction

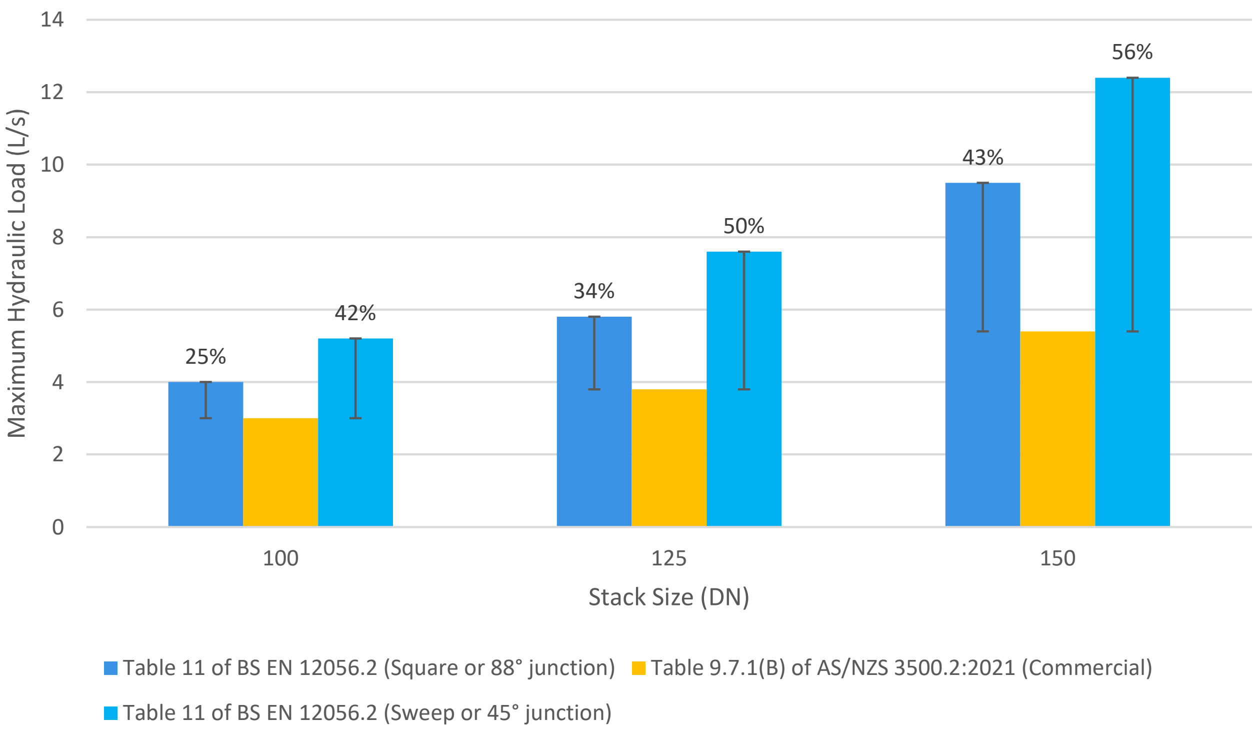


Figure 7: Percentage Difference between Stack Capacities reported in Table 9.7.1(B) of *AS/NZS 3500.2:2021* (Commercial) and Table 11 of BS EN 12056.2 Square or 88° junction, and Sweep or 45° junction

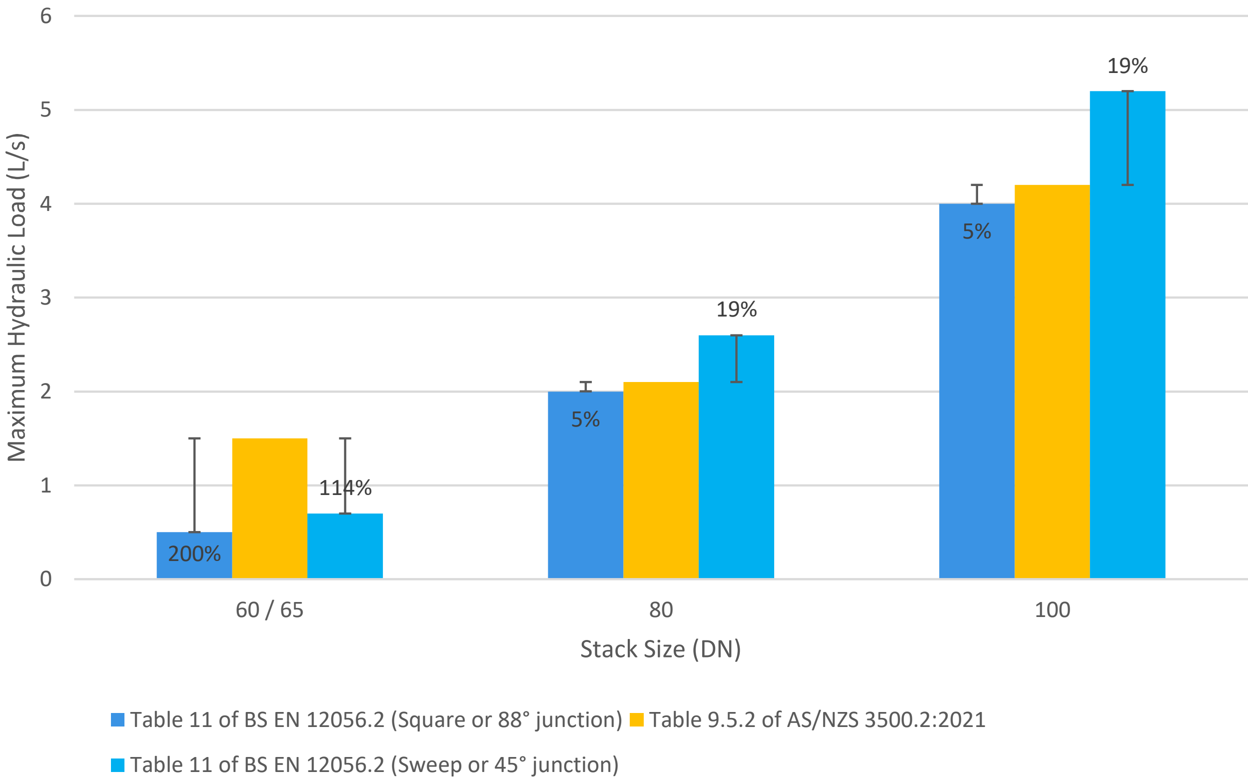


Figure 8: Percentage Difference between Stack Capacities reported in Table 9.5.2 of *AS/NZS 3500.2:2021* and Table 11 of BS EN 12056.2 Square or 88° junction, and Sweep or 45° junction

B.4. Stack Sizing Comparison of AS/NZS 3500.2:2021 Single Stack Modified & Fully Vented and BS EN 12056.2:2000 Secondary Ventilated System

A comparison of the maximum stack capacity specified by *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) system and *BS EN 12056.2:2000* (B.S. Institute, 2000) Secondary Ventilated systems is provided below in Table 26 and plotted in Figure 9. The maximum fixture unit loading provided in *AS/NZS 3500.2:2021* (Standards Australia, 2021) has been converted to an equivalent flow rate using the 'Fixture Unit to Flow Rate' Formula specified in Appendix B.2. Percentage differences between the maximum stack capacities provided in Table 8.2.2(B) of AS3500.2:2021 (Standards Australia, 2021) and those of Table 12 of *BS EN 12056.2:2000* (B.S. Institute, 2000), are tabulated below in Table 27. Table 27 distinguishes percentage differences between 0 and ± 20% in green, between ± 20% and ± 80% are provided in orange and ≥ ± 80% provided in red.

This comparison demonstrates that the stack capacities of the Secondary Ventilated System stack are similar to those calculated using the maximum fixture unit loading of the fully vented (and modified) system for stacks serving both 4 or more floors and 3 or less floors, except for a DN 65 stack where the capacity reported by *BS EN 12056.2:2000* (B.S. Institute, 2000) for an DN60 stack is significantly lower than the DN65 stack in *AS/NZS 3500.2:2021* (Standards Australia, 2021) (0.7 or 0.9 versus 2.9 / 1.6 (≥4 / ≤ 3 floors) respectively).

Whilst not detailed below, it should be noted that the *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) system specifies the maximum loading of a stack per floor level as well as maximum loading per stack; which is 25% for stacks serving 4 or more floor levels, and 33% for stacks serving 3 or less floor levels.

Table 26: Quantitative Comparison of *AS/NZS 3500.2:2021* Fully Vented (and modified) and *BS EN 12056.2:2000* Secondary Ventilated & Ventilated Branch Systems - Maximum Stack Capacities

Stack (DN)	Secondary Ventilated System - Table 12 of *BS EN 12056.2:2000*		Fully Vented (& Modified) - Table 8.2.2(B) of AS3500.2:2021	
	Square or 88° junction	Sweep or 45° junction	≥ 4 Floors	≤ 3 Floors
60 / 65	0.7	0.9	2.9	1.6
80	2.6	3.4	3.4	2.4
100	5.6	7.3	8.6	5.4
125	7.6	10	12.2	8.2
150	12.4	18.3	18.9	10.5

Table 27: Percentage Difference between Maximum Stack Capacities derived from Table 8.2.2(B) of AS3500.2:2021 Fully Vented (& modified) and those provided in *BS EN 12056.2:2000* for Secondary Ventilated Systems

Stack Nominal Diameter (DN)	Percentage Difference between Table 8.2.2(B) of AS3500.2:2021 and Table 12 of *BS EN 12056.2:2000*			
	Table 8.2.2(B) of AS3500.2:2021 (≥ 4 Floors)		Table 8.2.2(B) of AS3500.2:2021 (≤ 3 Floors)	
	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)	AS and BS (Square or 88° junction)	AS and BS (Sweep or 45° junction)
60 / 65	311.5%	220.0%	133.3%	81.4%
80	32.4%	1.3%	-6.4%	-28.4%
100	53.7%	17.9%	-4.0%	-26.4%
125	60.2%	21.7%	7.4%	-18.4%
150	52.1%	3.0%	-15.0%	-42.4%

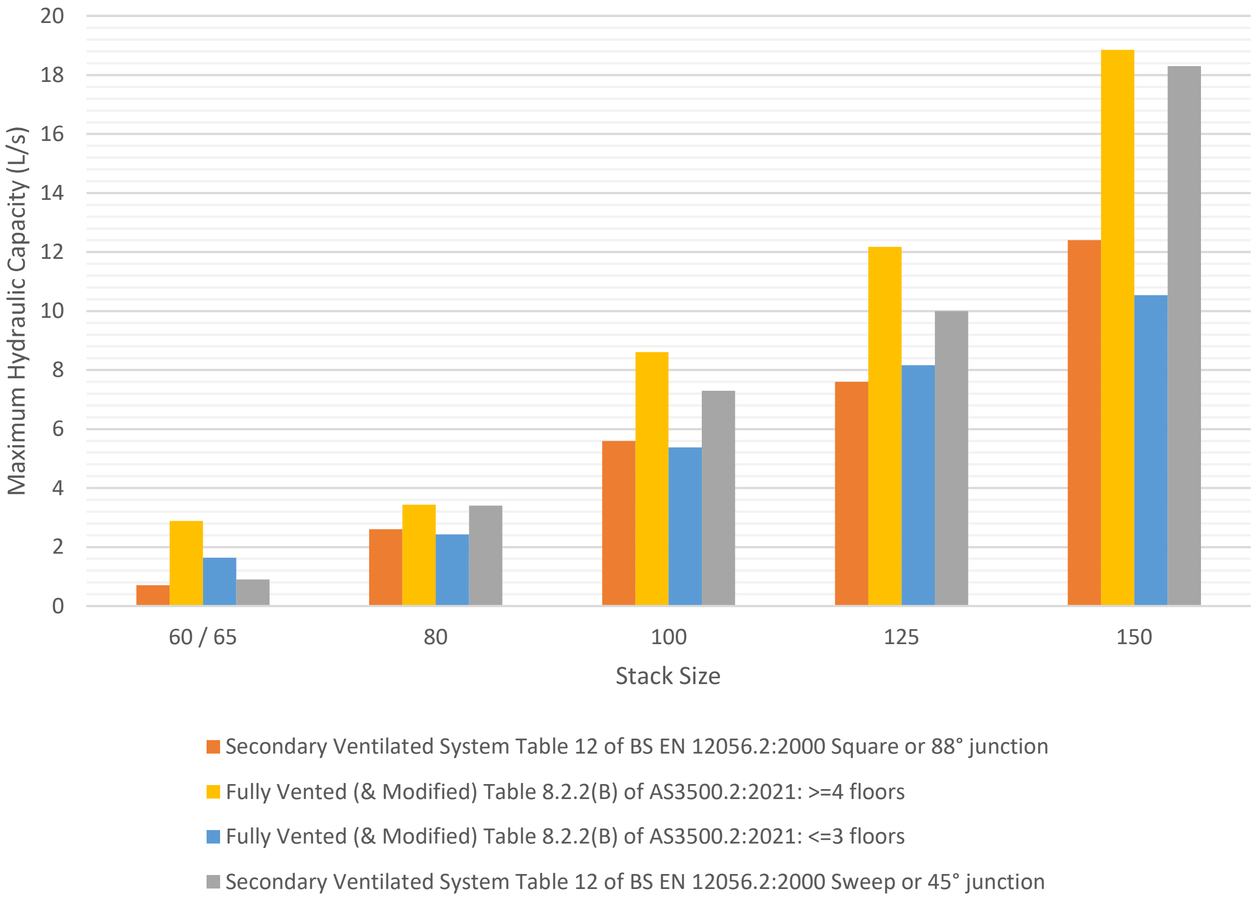


Figure 9: Plot of Maximum Hydraulic Loading on Stacks specified in *AS/NZS 3500.2:2021* Fully Vented (and Modified) System and *BS EN 12056.2:2000* Secondary Ventilated System

A comparison of the maximum stack capacity specified by *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system and *BS EN 12056.2:2000* (B.S. Institute, 2000) Secondary Ventilated systems is provided below in Table 28. Note the following:

- The *BS EN 12056.2:2000* (B.S. Institute, 2000) secondary ventilated system and *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system (for 'other than residential buildings'), both specify a DN 80 secondary vent for a DN150 stack and cross-venting on every floor.

- The *BS EN 12056.2:2000* secondary ventilated system and *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system (for 'other than residential buildings'), specify a DN 70 and 65 secondary vent respectively for a DN125 stack and cross-venting on every floor.

- The *BS EN 12056.2:2000* (B.S. Institute, 2000) secondary ventilated system and *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system (for 'other than residential buildings') specifies a DN50 secondary vent for a DN100 stack and cross-venting on every floor, whilst the *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system for residential buildings provides the stack capacities for the four configurations of using either DN50 or DN65 relief vents with cross-venting on each or every alternate floor.

From the below comparison, it is evident that the DN100 stack in a *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system with a DN50 relief vent and cross venting on every floor for a residential building has a similar stack capacity to that reported in *BS EN 12056.2:2000* (B.S. Institute, 2000) secondary ventilated system with sweep junctions and is almost double the value of stack capacity for a building type 'other than residential'. The stack capacity of a DN150 stack with a DN80 relief vent is reported in *BS EN 12056.2:2000* (B.S. Institute, 2000) for a sweep junction was found to be approximately double that provided in *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system and a similar trend is observed for the DN125 stack.

Table 28: Quantitative Comparison of *AS/NZS 3500.2:2021* Single Stack Modified and *BS EN 12056.2:2000* Secondary Ventilated & Ventilated Branch Systems - Maximum Stack Capacities

Stack (DN)	Secondary Ventilated			Single Stack Modified (cross-venting on each floor)					
	Table 12 of *BS EN 12056.2:2000*			Table 9.7.2(B) of AS3500.2:2021 – Residential			Table 9.7.2(B) of AS3500.2 - Other than residential		
	Secondary Vent (DN)	Square or 88° junction (l/s)	Sweep or 45° junction (l/s)	Relief Vent (DN)	Max WWFR (L/s)	Max Floor Levels	Relief Vent (DN)	Max WWFR (L/s)	Max Floor Levels
100	50	5.6	7.3	50 / 65	7.60	15	50	4.2	5 to 12
125	70	7.6	10				65	6.1	13 to 18
150	80	12.4	18.3				80	9.4	19 to 24

B.5. Clearance Zones near the Base of Stacks

The guidance around clearance zones near the base of stacks is summarised below in Table 29. It should be noted that *BS EN 12056.2:2000* (B.S. Institute, 2000) provides more conservative guidance regarding clearance zones near the base of stacks for branch connections, specifying that for stacks greater than 5 storeys high, ground floor appliances cannot be connected to the stack (clearance zone of a minimum of 1 storey); *AS/NZS 3500.2:2021* (Standards Australia, 2021) only requires a clearance zone of 1m for stacks greater than 5 storeys high, and 2.5m for stacks in areas where foaming is a likely occurrence.

AS/NZS 3500.2:2021 (Standards Australia, 2021) guidance on clearance zones is provided in Section 6 (General design requirements for sanitary plumbing systems), making it applicable to both single stack (and modified) and fully vented (and modified) systems. *BS EN 12056.2:2000*'s (B.S. Institute, 2000) guidance on clearance zone is provided in the National annex ND, which is specific to System III design, however it does not specify which configuration (primary or secondary ventilated) it is applicable to, hence suggesting that similar to *AS/NZS 3500.2:2021* (Standards Australia, 2021), it is applicable to both primary and secondary ventilated systems.

It should be noted that the IOP (Whitehead, 2002) builds on the guidance of *BS EN 12056.2:2000* (B.S. Institute, 2000), requiring that buildings over 20 storeys have a clearance zone of 2 storeys from the base of the stack. However, the IOP (Whitehead, 2002) also specifies clearance zones at the base of stacks for primary ventilated discharge stacks. On this note, single stack modified systems in *AS/NZS 3500.2:2021* (Standards Australia, 2021) limit the building height to 20 floors for a DN150, and 30 and 8 floors for single stack systems in domestic (DN150) and commercial (DN150) buildings respectively. *BS EN 12056.2:2000* (B.S. Institute, 2000) does not provide any stack height limitations for primary or secondary ventilated systems, which may justify the more conservative clearance zones specified.

Table 29: *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* Requirements for Clearance Zones near the base of stacks

Location	*AS/NZS 3500.2:2021*	*BS EN 12056.2:2000*
Connections to drains or graded pipes near base of stack	**Section 6.8.1 of *AS/NZS 3500.2:2021*** For stacks ≥ 3 floor levels • No connection closer than 2.5m downstream or 1m upstream of base of stack; and • No discharge pipe connecting a fixture upstream of a junction that connects a stack to a drain or graded pipe shall be closer than 1m from the base of the stack. For stacks ≤ 2 floor levels • No connection closer than 500mm downstream or upstream of base of stack • No discharge pipe connecting a fixture upstream of a junction that connects a stack to a drain or graded pipe shall be within 500mm of the base of the stack.	No guidance provided
Above the base of stack	**Section 6.8.2 of *AS/NZS 3500.2:2021*** No branch connection into a stack within the following distances (measured vertically from stack base to branch invert): • 600mm for stacks extending ≤ 5 floor levels above the base of the stack, or • 1m for stacks extending > 5 floor levels above the base of the stack, or • 2.5m for stacks in areas where foaming is a likely occurrence.	**Figure ND.6 of *BS EN 12056.2:2000*** No branch connection into a stack within the following distances (measured vertically from stack base to branch invert): • ≥450mm for single houses up to 3 storeys high, or • ≥740mm for up to 5 storeys high, or • ≥ 1 storey height for >5 storeys high

B.6. Stack Height

The guidance surrounding stack height in *AS/NZS 3500.2:2021* (Standards Australia, 2021) is as follows:

- The single stack and single stack modified systems in *AS/NZS 3500.2:2021* (Standards Australia, 2021) all detail the maximum number of consecutive floor levels that the stack can serve, except for Table 9.5.2 which provides sizing for stacks less than or equal to DN100 for lower loading applications.
- The fully vented and fully vented modified systems in *AS/NZS 3500.2:2021* (Standards Australia, 2021) have separate sizing tables for stacks serving '3 or fewer floors', or '4 or more floors', and maximum height limitations of each stack and relief vent configuration are enforced through the maximum developed lengths of the relief vents.
- Stacks that are 20 floor levels or more in height are required to have cross-relief venting.
- There is guidance provided on the location of pressure attenuators for up the 50 floor levels.
- Minimum clearance zone at base of stacks specified to be 1m for stacks greater than 5 storeys high, and 2.5m for stacks in areas where foaming is a likely occurrence.

BS EN 12056.2:2000 (B.S. Institute, 2000) does not provide any specific guidance on stack height for either primary or secondary ventilated stack systems. *BS EN 12056.2:2000* (B.S. Institute, 2000) only means of accounting for the design of tall buildings is the requirement that stacks greater than 5 storeys tall cannot have fixtures on the lowest storey connected to the stack (refer to Section B.5 above).

The provision of a stub stack is made to connect these ground-floor fixtures. The requirements of the stub stack are (Section ND.3.4.3 of *BS EN 12056.2:2000* (B.S. Institute, 2000)):

- equal in diameter to the drain,
- total loading $\leq 5L/s$,
- centreline of WC connection to stub stack $\leq 1.5m$ in vertical length from the base of the stack,
- centreline of topmost connection to stub stack $\leq 2.5m$ in vertical length from the base of the stack

B.7. Stack Offsets

The guidance provided around stack offsets in *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) has been summarised below.

The only design guidance regarding stack offsets is provided in Section ND.3.5.4 of *BS EN 12056.2:2000* (B.S. Institute, 2000), specifies that:

- *"Offsets in the wet portion of a discharge stack should be avoided. When they have to be fitted, large radius bends should be used as described in ND.3.5.2.",*
- "*In secondary ventilated stack system connections to the discharge stack should be made above and below the offset (see Figure ND.7)",* and
- "*Offsets above the topmost appliance or branch connection do not require venting."*

Figure ND.7 of *BS EN 12056.2:2000* (B.S. Institute, 2000) demonstrates the ventilation arrangement of a stack offset indicative of a graded offset, showing the requirement of cross-connection between the ventilation stack and discharge stack above and below offset. The venting and restricted zones are as follows:

- No branch connections in shaded area[8] (area between cross-connections above and below offset) unless vented.
- No offset venting is required for lightly loaded systems of up to three storeys in height.
- Offsets above highest branch connections do not require venting.

It should be noted that no clarification between a steep and graded offset is made in *BS EN 12056.2:2000* (B.S. Institute, 2000).

Unlike *BS EN 12056.2:2000* (B.S. Institute, 2000), *AS/NZS 3500.2:2021* (Standards Australia, 2021) distinguishes between steep and graded offsets and provides guidance around their implementation in single stack (and modified) and fully vented (and modified) systems.

- steep offsets are $45°$ or greater to the horizontal, and
- graded offsets are made at an angle of less than $45°$ (minimum grades are 2.5% for $\leq DN80$ stacks and 1.65% for $\geq DN100$ stacks.

A summary of the requirements for stack offsets detailed in *AS/NZS 3500.2:2021* (Standards Australia, 2021) is summarised below in Table 30.

[8] Area between cross-connections above and below offset.

Table 30: Steep and Graded Stack Offset Requirements for *AS/NZS 3500.2:2021* Single Stack (and modified) and Fully Vented (and modified)

Offset Type	System Type	*AS/NZS 3500.2:2021*
Steep	Single Stack (and modified)	Requirements provided for DN100 stacks: • Maximum height of stack is 10 floors, • Minimum distance of 100mm between connection of any fixture discharge pipe and the upper offset bend, • Minimum distances of connections to stack near upper and lower bend of offset and maximum fixture unit loading on stack specified (Table 9.9.2 and Clause 9.9.4 of *AS/NZS 3500.2:2021*), • Laundry troughs connected to stack as per Table 9.9.3 except as provided in Clause 9.9.4 of *AS/NZS 3500.2:2021*),
	Fully Vented (and modified)	• Offset section sized as a straight stack (Clause 8.4(g)(i) of *AS/NZS 3500.2:2021*), • Stack deemed to be straight with one vertical section when considering cross-relief venting, and • No additional relief vents not required, if relief vent installed below lowest connection to stack.
Graded	Single Stack (and modified)	Requirements provided for DN100 stacks: • Maximum of one graded offset per stack, • Maximum height of stack is 10 floors, • Minimum grade of offsets as per Table 8.6.2.2 of *AS/NZS 3500.2:2021*, • Clearance zones and venting as per a graded offset in a Fully Vented (and modified) system, • Minimum distance between centre lines of vertical sections of stack shall be 2m, and • Connections made above the offset limited to a maximum loading of 90 FU and are configured as per Section 9.9.6 of *AS/NZS 3500.2:2021*.
	Fully Vented (and modified)	• Stack offset sized as a graded pipe (Clause 8.4(g)(ii) of *AS/NZS 3500.2:2021*), • Provisions for additional relief venting arrangement for the graded offset, • Minimum grade of offsets as per Table 8.6.2.2) of *AS/NZS 3500.2:2021*, and • Restricted connection zones above, below and within graded offset specified (Section 8.6.2.3 to 8.6.2.5 of *AS/NZS 3500.2:2021*).

A comparison of the influence of steep offsets and minimum clearance from offset bends to fixture discharge pipe connection on maximum hydraulic loading is summarised below in Table 31. These findings demonstrate that *AS/NZS 3500.2:2021* (Standards Australia, 2021) identifies that the presence of a steep offset in a single stack system may influence the maximum permissible loading of the considerably.

Table 31: Influence of the presence of a steep offset in a Single Stack system on Stack height and Maximum Stack Loading as documented in *AS/NZS 3500.2:2021*

Design Criteria	Maximum height in consecutive floor levels above upper offset bend	Minimum distance between upper offset bend and connection of fixture discharge pipe mm	Minimum distance between lower offset bend and connection of fixture discharge pipe mm	Maximum fixture unit loading	Maximum Hydraulic loading (L/s)	Percentage difference between stack with[9] and without offset (%)
Table 9.9.2 – Offset Requirements for DN100 stack	5	450	600	90	3.7	-41.2%
	10	600	600	150	4.7	-24.0%
	10	900	600	260	6.2	0
Table 9.9.2 – Offset Requirements for laundry troughs connected to upper section of DN100 stack	5	450		50	2.7	-56.1%
	10	600		50	2.7	-56.1%
Clause 9.9.4 - Steep Offsets below the lowest connection	As per Table 9.9.2					-
	3	100[10]		30	2.1	-66.0%

B.8. Bends at Base of Stacks

The requirements of *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000)for bends at the base of stacks has been summarised below in Table 32. It should be noted that *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) have similar recommendations for the minimum centre-line radius of a single swept bend, with *AS/NZS 3500.2:2021* (Standards Australia, 2021) slightly more conservative. Furthermore, unlike *BS EN 12056.2:2000* (B.S. Institute, 2000), *AS/NZS 3500.2:2021* (Standards Australia, 2021) specifies the need for a minimum length of the straight pipe separating the 2 x 45° bends. *AS/NZS 3500.2:2021* (Standards Australia, 2021) also presents the option for an 88° bend. It should also be noted that the requirements of bends at the base of stacks in *BS EN 12056.2:2000* (B.S. Institute, 2000) are specified in ND.3.5.2, which is a National Annex detailing System III design requirements.

Table 32: *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* Requirements for Bends at the Base of Stacks

Design Option	*AS/NZS 3500.2:2021*	*BS EN 12056.2:2000*
Single Swept Bend	Minimum centre-line radius: • 225mm for DN $\leq$ 100 mm • 300 for DN $>$ 100 mm, or	Minimum centre-line radius: • 2 $\times$ *ID* of the stack
2 x 45° radius bends	• 2 x 45° radius bends separated by straight pipe of length 2 $\times$ *DN* of the stack pipe.	• No further guidance
88° bend	• For stacks extending through no more than 2 floor levels.	• Option not provided
Other	• No further guidance	• Increasing the diameter of the bend at the base of a stack is an alternative but this may oversize the drain and be uneconomic.

[9] Refer to DN100 loading specified within Table 9.7.1(A) of AS/NZS 3500.2:2021 (6.2L/s or 260 FU).

[10] A laundry trough shall not be connected in this configuration.

B.9. Junctions in Stacks

A summary of the guidance provided in *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) regarding junctions in stacks is summarised below in Table 33.

Table 33: Design guidance specified in *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* for junctions in stacks

Design Component	*AS/NZS 3500.2:2021*	*BS EN 12056.2:2000*
Allowable junctions to connect fixture, branch, or common discharge pipes to stack	• 45° junction • Sweep • Aerator • Ball • Square Restrictions for square and ball junctions and provision for fixtures within 500mm from the stack are detailed in Section 6.7.2 of *AS/NZS 3500.2:2021*.	• Swept • Square Requirements around the use of swept and straight entries for System III are provided in Section ND.3.3.1 of BS EN 12056.2.
Opposed connections	• Opposed connections at ball junctions or aerator junction fittings shall only be used where the opposing pipes are connected to equal numbers of the same type of fixture. • Opposed junctions other than ball or aerator shall only be made using double 45 of double sweep	• Provision for opposed connections of unequal sizes as per ND.3.3.3 of BS EN 12056.2.

Restricted entry zones for opposed connections specified in *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) respectively are summarised in Table 34. The restricted entry zone vertical depths specified in both standards are identical.

Table 34: Restricted entry zones for opposed connections specified in *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000*

AS/NZS 3500.2:2021			*BS EN 12056.2:2000*	
Discharge Pipe Size DN	**Stack Size DN**	**Restricted entry zone vertical depth (mm)**	**Stack Diameter**	**Restricted entry zone vertical depth (mm)**
$40 < DN \leq 65$	$40 < DN \leq 80$	90	65	90
$40 < DN \leq 65$	100	110	100	110
$40 < DN \leq 65$	125	210	125	210
$40 < DN \leq 65$	150	250	150	250
$DN \geq 80$	≥ 80	200		

The influence of junctions on stack capacity, and consequently the sizing of stacks is not specified in *AS/NZS 3500.2:2021* (Standards Australia, 2021), however in *BS EN 12056.2:2000* (B.S. Institute, 2000), maximum stack capacities for square and swept junctions are provided. A comparison is provided below in Table 35.

Table 35: Analysis of Reported Capacities for Square and Swept entries for *BS EN 12056.2:2000* Primary and Secondary Ventilated Systems

Stack and Stack Vent (DN)	Primary Ventilated System			Secondary Ventilated System			
	Square Entry (L/s)	Swept Entry (L/s)	Percentage Difference (%)	Secondary Vent	Square Entry (L/s)	Swept Entry (L/s)	Percentage Difference (%)
60	0.5	0.7	40.0	50	0.7	0.9	28.6
70	1.5	2	33.3	50	2	2.6	30.0
80	2	2.6	30.0	50	2.6	3.4	30.8
90	2.7	3.5	29.6	50	3.5	4.6	31.4
100	4	5.2	30.0	50	5.6	7.3	30.4
125	5.8	7.6	31.0	70	7.6	10	31.6
150	9.5	12.4	30.5	80	12.4	18.3	47.6
200	16	21	31.3	100	21	27.3	30.0
Average			**32.0**	**Average**			**32.5**

B.10. Stack Vent Sizing

A comparison of *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) recommendations for sizing stack vents for each system has been summarised below in Table 36.

This comparison demonstrates that single stack (and modified) systems and the *BS EN 12056.2:2000* (B.S. Institute, 2000) primary ventilated system determined that both standards agree that stack vents should be sized equal to the stack, with a provision in each standard that they stack vent may be downsized given certain criteria. Whilst this provision is clearly defined in *AS/NZS 3500.2:2021* (Standards Australia, 2021) for a single stack (or modified) system, the provision is loosely defined in *BS EN 12056.2:2000* (B.S. Institute, 2000) and does not specify whether it applies to primary and/or secondary ventilated stack systems.

A comparison of *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) systems and the *BS EN 12056.2:2000* secondary ventilated stack system determined that the *BS EN 12056.2:2000* (B.S. Institute, 2000) specifies stack vents to be equal in size to stacks (identical advice to primary ventilated systems), whilst *AS/NZS 3500.2:2021* (Standards Australia, 2021) provisions for stack vents being sized equal to or smaller than the stack, given the fixture unit loading and developed length of the stack does not exceed stated values. Hence, *BS EN 12056.2:2000* (B.S. Institute, 2000) appears to provide a more conservative approach of sizing stack vents for stacks with relief vents, for low rise buildings and/or stacks utilising less than their maximum hydraulic capacity.

It should be noted that Section 6.5.4 of *BS EN 12056.2:2000* (B.S. Institute, 2000) makes the comment that "*Stack vents, ventilating stacks or ventilating branch pipes shall be increased in size if they are long or have many bends",* however, provides no further guidance and instead directs the designer to refer to "*national and local regulations and practice*".

Table 36: Comparison of Stack Vent Sizing Recommendations in *BS EN 12056.2:2000* and *AS/NZS 3500.2:2021*

***AS/NZS 3500.2:2021* Stack vent Sizing**			**Similar or Equivalent *BS EN 12056.2:2000* Stack vent Sizing**		
System	**Sizing Reference**	**Guidance**	**System**	**Sizing Reference**	**Guidance**
Single Stack & Single Stack Modified	Section 9.6.1 of *AS/NZS 3500.2:2021*	Stack Vent equal to size of stack, with the caveat that "*Stacks that extend not more than three floor levels with a maximum loading of 30 FU may have the vent reduced to DN 50*."	Primary Ventilated	Table 11 of *BS EN 12056.2:2000* Caveat: ND.3.5.1	Stack Vent equal to size of stack with the caveat that: "*In certain cases of one and two storey housing economies can be made by using a DN 80 stack vent without detriment to the performance of the system.*"
Fully Vented & Fully Vented Modified	Table 8.5.3.6 of *AS/NZS 3500.2:2021*	Stack vent may be less than or equal to size of stack, depending on fixture unit loading of stack and developed length of vent.	Secondary Ventilated	Table 12 of *BS EN 12056.2:2000*	Stack Vent equal to size of stack

B.11. Cross Venting

A comparison of recommendations of cross vents/cross-connections for *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system (Table 9.7.2(A) &(B)) and the *BS EN 12056.2:2000* (B.S. Institute, 2000) secondary ventilated stack system (Table 12) determined that both standards agree that cross vents/cross-connections are to be sized equal to that of the relief vent/ventilation stack.

Regarding the location of cross-vents, *AS/NZS 3500.2:2021* (Standards Australia, 2021) specifies that 'other than residential' type buildings must have cross-vents at every floor, whilst residential buildings can either have cross-vents at each floor or every alternate floor, depending on the required loading of the stack. *BS EN 12056.2:2000* (B.S. Institute, 2000) specifies in Section ND.3.6.2.1 that cross-connections are "*usually*" on each floor, not clarifying the cross-connection locations expected to achieve the hydraulic capacity of stacks provided in Table 12 of *BS EN 12056.2:2000* (B.S. Institute, 2000). It should be noted that the reference to cross-connection locations in *BS EN 12056.2:2000* (B.S. Institute, 2000) is in National Annex ND, which is dedicated to System III design details; hence, the applicability of this advice to Systems I and II is unknown.

B.12. Relief Vent and Cross-Relief Vent Sizing

A comparison of relief vent sizing guidance found in *AS/NZS 3500.2:2021* (Standards Australia, 2021) (single stack modified, fully vented (and modified)) was compared to that in *BS EN 12056.2:2000* (B.S. Institute, 2000) for the secondary ventilated stack system and ventilated branch system and is summarised below in Table 37. A comparison of the relief vent sizes recommended by the *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified system and the *BS EN 12056.2:2000* (B.S. Institute, 2000) secondary ventilated system for given stack sizes is provided below in Table 38.

It should also be noted that secondary ventilated + ventilated Branch system in *BS EN 12056.2:2000* (B.S. Institute, 2000) states that a "*ventilating stack of DN 30 is usually sufficient.*" We believe the method of relief vent sizing in Table 8.5.3.5 of *AS/NZS 3500.2:2021* (Standards Australia, 2021) is much more robust and accurate.

It should also be noted that the *BS EN 12056.2:2000* (B.S. Institute, 2000) only mentions the requirement of "cross-connections", which are the equivalent to "cross-venting" in *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified systems, and does not mention the requirement, configuration or sizing of cross-relief vents.

Table 37: Comparison of Relief vent Sizing Guidelines in *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000*

***AS/NZS 3500.2:2021* Relief vent Sizing**			**Similar or Equivalent *BS EN 12056.2:2000* Relief vent Sizing**		
System	**Sizing Reference**	**Guidance**	**System**	**Sizing Reference**	**Guidance**
Single Stack Modified	Table 9.7.2(A) & (B) of *AS/NZS 3500.2:2021*	Specifies size of relief vent given stack size for domestic and 'other than residential' building types.	Secondary Ventilated +Unventilated Branch System	Table 12 of BS EN 12056.2	Specifies size of relief vent given stack size.
Fully Vented & Fully Vented Modified	Table 8.5.3.5 of *AS/NZS 3500.2:2021* Section 8.5.5. of *AS/NZS 3500.2:2021*	Relief vent may be less than or equal to size of stack, depending on fixture unit loading of stack and developed length of vent. Cross-relief vents: • Required for stacks ≥20 floor levels in height. • Located at intervals ≤ 10 floor levels. • Sized equal to the main relief vent or the stack, whichever is smaller.	Secondary Ventilated +Ventilated Branch System	Section ND.3.6.2.3 of BS EN 12056.2	DN30 ventilated stack size deemed "*usually sufficient*". Cross-relief venting is not mentioned in this standard.

Table 38: Comparison of Relief vent Sizing Guidelines of *AS/NZS 3500.2:2021* Single Stack Modified System and *BS EN 12056.2:2000* Secondary Ventilated System

Stack Nominal Diameter (DN)	**Relief Vent Size (DN)**		
	***AS/NZS 3500.2:2021* Single Stack Modified System**		***BS EN 12056.2:2000* Secondary Ventilated System**
	Domestic/Residential	**'Other than residential' type building**	
65	-	-	50
80	-	-	50
100	50/65: Size depending on required stack capacity and location cross-vents (each/alternate floor).	50	50
125	-	65	80
150	-	80	80

B.13. Header Vents

Header vents are provisioned for in *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented and fully vented modified systems, such that stack and relief vents can be interconnected into a common header vent with one termination point (refer to Section 8.5.6 of *AS/NZS 3500.2:2021* (Standards Australia, 2021)). Header vents are sized based on the number of equivalent DN50 vents interconnecting into the header vent.

The provision for header vents is not provided in *BS EN 12056.2:2000* (B.S. Institute, 2000).

B.14. Air Admittance Valves

Both *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) specify the provision of using air admittance valves for branches and discharge stacks. As summarised in Appendix B.2, the sizing recommendations from both standards are identical.

BS EN 12056.2:2000 (B.S. Institute, 2000) requires that air admittance valves comply with a specific standard on Air admittance valve systems (prEN 12380). *AS/NZS 3500.2:2021* (Standards Australia, 2021) specifies requirements for use, location and installation requirements in Section 6.10 of *AS/NZS 3500.2:2021* (Standards Australia, 2021).

B.15. Pressure Attenuators

Pressure attenuators are provisioned for use as an alternative to relief venting in *AS/NZS 3500.2:2021* (Standards Australia, 2021). The requirements, installation and location of pressure attenuators is detailed in Section 6.11 of *AS/NZS 3500.2:2021* (Standards Australia, 2021). Pressure attenuators are not provisioned for by *BS EN 12056.2:2000* (B.S. Institute, 2000).

B.16. Comparison of Fixtures Provisioned for in AS/NZS 3500.2:2021 and BS EN 12056.2:2000

A comparison of the fixtures provided a fixture unit rating in *AS/NZS 3500.2:2021* (Standards Australia, 2021) and the equivalent fixture provided a discharge unit in *BS EN 12056.2:2000* (B.S. Institute, 2000) has been summarised below in Table 39. Where there is no equivalent fixture in *BS EN 12056.2:2000* (B.S. Institute, 2000), the relevant rows are shown in grey.

The following items should be noted:

- The Discharge units in *BS EN 12056.2:2000* (B.S. Institute, 2000) for floor gully's (DN50, 70 and 100) should be disregarded (refer to Figure 10 below). As identified in Table 6.3(A) of *AS/NZS 3500.2:2021* (Standards Australia, 2021), the loading of the floor gully should be as per the fixture rating of the fixtures connected to it. We propose that the equivalent discharge unit of the floor gully is the sum of discharge units for fixtures connected to it.
- *BS EN 12056.2:2000* (B.S. Institute, 2000) provides discharge units for a 'Washing machine up to 12 kg'. We cannot confirm whether this is a suitable equivalent to a 'Clothes-washing machine – commercial', as listed in *AS/NZS 3500.2:2021* (Standards Australia, 2021).
- *AS/NZS 3500.2:2021* (Standards Australia, 2021) distinguishes between single and multiple showers, however these are effectively the same, as the fixture unit rating is specified per shower head.
- *AS/NZS 3500.2:2021* (Standards Australia, 2021) makes no distinction of varying cistern volumes of water closet in the fixture unit rating, whilst *BS EN 12056.2:2000* (B.S. Institute, 2000) does, although the difference between the discharge units is minimal to none (refer to Figure 11 below).
- *AS/NZS 3500.2:2021* (Standards Australia, 2021) provides the same fixture unit rating for urinals that are (1) wall-hung, (2) stalls or (3) each 600mm length of slab, whilst *BS EN 12056.2:2000* (B.S. Institute, 2000) provides varied discharge units for (1) Single urinal with cistern, (2) urinal with flushing valve, and (3) slab urinal (refer to Figure 12 below).
- *AS/NZS 3500.2:2021* (Standards Australia, 2021) distinguishes between (1) Sink - single / double / bar, commercial and (2) Sink – tea / bar, domestic / cleaner / laboratory, in regards to fixture unit ratings, whilst *BS EN 12056.2:2000* (B.S. Institute, 2000) only provides discharge units for a 'Kitchen sink'. It is unclear whether *BS EN 12056.2:2000* (B.S. Institute, 2000) 'Kitchen Sink' relates to 'Sink - single / double / bar, commercial' or 'Sink – tea / bar, domestic / cleaner / laboratory'.

Table 39: Comparison of the fixtures provided a fixture unit rating in *AS/NZS 3500.2:2021* and the equivalent fixture provided a discharge unit in *BS EN 12056.2:2000*

Table 6.3(A) of *AS/NZS 3500.2:2021*	Equivalent fixtures from Table 2 of *BS EN 12056.2:2000*

Fixture	Fixture Unit (FU) Rating	Fixture	Discharge Unit (DU)		
			System I	System II	System III
Autopsy table	3	NA			
Bain-marie	1	NA			
Basin / Bidet	1	Wash basin, bidet	0.5	0.3	0.3
Bath (with or without shower)	4	Bath	0.8	0.6	1.3
Bath (foot) / Bath (baby)	3	NA			
Bedpan sterilizer	4	NA			
Bedpan washer	6 (F. valve) 4 (Cist.)	NA			
Bedpan washer / sterilizer	6 (F. valve) 4 (Cist.)	NA			
Circular wash fountain	4	NA			
Clothes-washing machine - domestic	5	Washing machine up to 6 kg	0.8	0.6	0.6
Clothes-washing machine - commercial	Refer to Table 6.3(B)	Washing machine up to 12 kg	1.5	1.2	1.2
Dental Unit	1	NA			
Dishwashing machine - domestic	3	Dishwasher (household)	0.8	0.6	0.2
Dishwashing machine - commercial	Refer to Table 6.3(B)	NA			
Drinking fountain	1	NA			
Floor waste gully - without fixture	0	NA			
Floor waste gully - with fixture	As per fixture rating	NA			
Glass-washing machine	3	NA			
Potato peeler	3	NA			
Sanitary napkin disposal unit	3	NA			
Shower - single	2	Shower without plug	0.6	0.4	0.4
Shower - multiple	2 per shower head	NA			
Sink - single / double / bar, commercial	3	Kitchen sink	0.8	0.6	1.3
Sink – tea / bar, domestic / cleaner / laboratory	1	NA			
Sink (pot or utility)	5	NA			
Slop hopper	6 (F. valve) 4 (Cist.)	NA			
Trough – ablution	3	NA			
Trough – laundry (single or double)	5	NA			
Urinal – wall-hung (including waterless), stall, or each 600 mm length of slab	1	Single urinal with cistern	0.8	0.5	0.4

Water closet pan	6 (F. valve) 4 (Cist.)	WC with 6,0 l cistern	2	1.8	1.2
Combination pan room sink and flushing bowl	6 (F. valve) 4 (Cist.)	NA			
Combination pan room sink	6 (F. valve) 4 (Cist.)	NA			

Appliance	System I	System II	System III
	DU l/s	DU l/s	DU l/s
Floor gully DN 50	0,8	0,9	-
Floor gully DN 70	1,5	0,9	-
Floor gully DN 100	2,0	1,2	-

Figure 10: *BS EN 12056.2:2000* Discharge Unit Ratings for Floor Gully's

Appliance	System I	System II	System III
	DU l/s	DU l/s	DU l/s
WC with 4,0 l cistern	**	1,8	**
WC with 6,0 l cistern	2,0	1,8	1,2 to 1,7***
WC with 7,5 l cistern	2,0	1,8	1,4 to 1,8***
WC with 9,0 l cistern	2,5	2,0	1,6 to 2,0***

Figure 11: *BS EN 12056.2:2000* Discharge Unit Ratings for Water Closet with varying cistern volumes

Appliance	System I	System II	System III
	DU l/s	DU l/s	DU l/s
Single urinal with cistern	0,8	0,5	0,4
Urinal with flushing valve	0,5	0,3	-
Slab urinal	0,2*	0,2*	0,2*

Figure 12: *BS EN 12056.2:2000* Discharge Unit Ratings for varied urinal configurations

B.17. Branch Pipe and Branch Vent Sizing

Table 6 provided in Section 4.2 is expanded below in Table 40 to detail the guidance provided regarding branch sizing in *AS/NZS 3500.2:2021* (Standards Australia, 2021) and the similar or equivalent branch configuration in *BS EN 12056.2:2000* (B.S. Institute, 2000).

Table 40: Similar or Equivalent Branch Configuration in *BS EN 12056.2:2000* and *AS/NZS 3500.2:2021* and respective Sizing Guidance

***AS/NZS 3500.2:2021* Branch Configuration**		**Similar or Equivalent *BS EN 12056.2:2000* Branch Configuration**	
System & Sizing Reference	**Guidance**	**System & Sizing Reference**	**Guidance**
Single Stack & Single Stack Modified Table 6.3(A) of *AS/NZS 3500.2:2021* Section 9.4 and 9.5 of *AS/NZS 3500.2:2021*	• Minimum size of trap and fixture discharge pipe is based on appliance connections provided in Fixture Unit rating table. • Each fixture connected to stack by a separate unvented fixture discharge pipe. • Provision for range of fixtures connected to a common discharge pipe in commercial buildings. • Provisions for fixture pairs and other acceptable branch connections to stacks are detailed. • Maximum number and type of fixtures that can be connected to a stack at any given level	System III Unventilated Discharge Branches Table 6 of *BS EN 12056.2:2000*	• Sized based on appliance connections provided in sizing table. • Most appliance connections are connected to the stack via separate discharge branch pipes, with a few provisions for fixture ranges to be connected to a common discharge pipe. • Maximum length, number of bends and drop, and allowable pipe gradients provided.
Fully Vented (and modified) Table 8.2.2(A) of *AS/NZS 3500.2:2021*	• Sized based on Fixture unit loading and pipe grade (Table 8.2.2(A) of *AS/NZS 3500.2:2021*). • No limitations to maximum length	System I and II Ventilated Discharge Branches Table 7 of *BS EN 12056.2:2000*	• Sized based on the wastewater flow rate. • Limitations to maximum length, number of 90-degree bends, maximum drop and minimum gradient specified.
NA		System III Ventilated Discharge branches (Table 9 of *BS EN 12056.2:2000)*	Similar sizing table to System III Unventilated discharge branches, with varied sizing recommendations compared to unventilated discharge branches.
NA		System I and II Unventilated Discharge Branches (Table 4 of *BS EN 12056.2:2000)*	Similar sizing table to System I and II ventilated discharge branches, with varied sizing recommendations compared to ventilated discharge branches.

A comparison of branch pipe and branch vent sizing requirements for *BS EN 12056.2:2000* (B.S. Institute, 2000) System I and II Ventilated discharge branches and *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) is summarised below in Table 41, using $Q = \sqrt{\frac{FU}{6.75}}$. Values in green refer to (1) flow rate capacities of branches that are larger than that provided by the other code for the same branch pipe size and (2) branch vent sizes for a given branch pipe size that are smaller than the other code. Values in blue refer to branch pipe sizes with similar/identical flow capacities and branch/group vent sizes. From Table 41, it is noted that the maximum branch capacities and recommended branch vent sizes are similar between *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000), noting the following differences:

- For DN50 branch pipe, branch vent is reduced from DN40 to DN30 using System II *BS EN 12056.2:2000* (B.S. Institute, 2000) as opposed to the *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) sizing method.

- DN80 Branch pipe capacity increased and branch vent reduced (from DN60 to DN50) using *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) sizing method as opposed to *BS EN 12056.2:2000* (B.S. Institute, 2000) System I (System II not provided for DN100).

- DN100 Branch pipe capacity increased significantly, and branch vent reduced (from DN50 to DN40) using *BS EN 12056.2:2000* (B.S. Institute, 2000) System II as opposed to *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) sizing method.

In terms of a general comparison between the methods:

- *AS/NZS 3500.2:2021* (Standards Australia, 2021) sizing of branches in fully vented (and modified) systems proves to be more comprehensive than *BS EN 12056.2:2000* (B.S. Institute, 2000), in that it provides maximum loading of branches for every pipe size and appropriate grade.

- *BS EN 12056.2:2000* (B.S. Institute, 2000) ventilated branch sizing is more conservative than *AS/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) in that limitations to maximum pipe length, bends and drop height are enforced, which is not required in *AS/NZS 3500.2:2021* (Standards Australia, 2021).

- *BS EN 12056.2:2000* (B.S. Institute, 2000)does not provide guidance on group vent or trap vent sizing.

- Minimum grades specified for discharge pipes in *AS/NZS 3500.2:2021* (Standards Australia, 2021) differs to that of *BS EN 12056.2:2000* (B.S. Institute, 2000).

Table 41: Branch pipe and branch vent sizing requirements for *BS EN 12056.2:2000* System I and II Ventilated discharge branches and *AS/NZS 3500.2:2021* Fully Vented (and modified)

Branch Size (DN)	*BS EN 12056.2:2000*				*AS/NZS 3500.2:2021* Fully Vented (and modified)			
	Ventilated Branches Flow Rate (l/s)		Branch Vent Size (DN)					
System	I	II	I	II	Min Flow Rate[11] (L/s)	Max Flow Rate[12] (L/s)	Branch Vent (DN)	Group Vent (DN)
30		0.6		30				
40		0.75		30	0.77	0.94	32	32
50	0.75	1.5	40	30	1.09	1.49	40	40
60	1.5	2.25	40	30				
65					1.76	2.75	40	40
70[13]	2.25	3	50	40				

[11] Calculated using the fixture unit loadings for a graded discharge pipe at the lowest grade specified for that pipe size from Table 8.2.2(A) of AS/NZS 3500.2:2021.

[12] Calculated using the fixture unit loadings for a graded discharge pipe at 5% grade from Table 8.2.2(A) of AS/NZS 3500.2:2021.

[13] For DN70 ventilated and unventilated discharge branches in System II, no WC's connected to branch.

Branch Size (DN)	*BS EN 12056.2:2000*				*AS/NZS 3500.2:2021* Fully Vented (and modified)			
	Ventilated Branches Flow Rate (l/s)		Branch Vent Size (DN)					
System	I	II	I	II	Min Flow Rate[11] (L/s)	Max Flow Rate[12] (L/s)	Branch Vent (DN)	Group Vent (DN)
80[14]	3	3.4	50	40	1.54	3.10	50	50
90[15]	3.4	3.75	60	50				
100	3.75		60		4.13	7.46	50	50
125					6.13	11.88		
150					8.68	17.04		
225					18.35	32.43		
Maximum pipe length (m)	10	No Limit						
Maximum No. of 90° bends[16]	No Limit	No Limit						
Maximum drop (H) (45° or more inclination)	3	3						
Minimum Grade (%)	0.5	1.5		Minimum Grade (%)	2.5: DN40-65 1.65: DN80-100 1.25: DN125 1: DN150-225			
				Maximum Grade (%)		5		

A comparison of branch pipe and branch vent sizing requirements for *BS EN 12056.2:2000* (B.S. Institute, 2000) System III unventilated discharge branches and *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack (and modified) systems is summarised below in Table 42, using $Q = \sqrt{\frac{FU}{6.75}}$. Values in green refer to (1) values of maximum lengths, number of bends, vertical drops that are larger than the other code, and (2) smaller fixture discharge pipe diameters compared to the other code. Values in blue refer to identical recommendations by both codes.

From Table 42, the following is noted:

- Minimum discharge pipe size of each fixture branch recommended by *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) is the same, except for the three cases identified in green.

[14] For DN80 ventilated and unventilated discharge branches, no WC's connected to branch in System I, or a maximum of 1 WC connected in System II.

[15] For DN90 ventilated and unventilated discharge branches in a System I, a maximum of 2 WC's connected and a maximum of 1 x 90-degree bend.

[16] Connection bend not included.

- Maximum lengths of discharge pipes in specified *BS EN 12056.2:2000* (B.S. Institute, 2000) are generally greater than those specified by *AS/NZS 3500.2:2021* (Standards Australia, 2021), with some fixtures not having an limit on the maximum length.

- Minimum and maximum grades specified for discharge pipes in *AS/NZS 3500.2:2021* (Standards Australia, 2021) differs to that of *BS EN 12056.2:2000* (B.S. Institute, 2000), with *BS EN 12056.2:2000* (B.S. Institute, 2000) typically recommending lower minimum and higher maximum grades than *AS/NZS 3500.2:2021* (Standards Australia, 2021).

- For all fixture discharge branches (except basins), *BS EN 12056.2:2000* (B.S. Institute, 2000)System III Unventilated provides no limit to the maximum number of bends allowed in the discharge branch, whilst *AS/NZS 3500.2:2021* (Standards Australia, 2021) specifies a maximum of 2 bends in the horizontal plane and 2 or 3 bends in the vertical plane.

- For all fixture discharge branches, the maximum vertical drop specified by *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack (and modified) is larger than the equivalent *BS EN 12056.2:2000* (B.S. Institute, 2000) System III Unventilated.

Table 42: Branch pipe sizing requirements for *BS EN 12056.2:2000* System III Unventilated discharge branches and *AS/NZS 3500.2:2021* Singe Stack (and modified)

***AS/NZS 3500.2:2021* Single Stack (and modified)**							**Table 6 of *BS EN 12056.2:2000* System III Unventilated Branches**						
Table 6.3(A)		**Table 9.5.1**			**Section 9.5.4**	**Section 9.5.5**							
Fixture	Min size of trap outlet & fixture discharge pipe (DN)	Maximum length (m)	Min Grade (%)	Max Grade (%)	Maximum No of Bends (bend > 45°)	Maximum Vertical drop (m)	Appliance	Min size of trap outlet & fixture discharge pipe (DN)	Maximum length (m)	Min Grade (%)	Max Grade (%)	Maximum No of Bends	Maximum Vertical drop (m)
Basin' & 'Bidet, bidette'	40	2.5	2.5	5	2 bends (horizontal plane), and 2 bends (vertical plane)	1.5	Wash basin, bidet	30	1.7	-	2.2	0	0
Bath	40	2.5	2.5	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	Bath	40	No Limit[17]	1.8	9	No limit	1.5
Clothes-washing machine - domestic	40	2.5	2.5	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	Washing machine up to 6 kg	40	3	1.8	4.4	No limit	1.5
Dishwashing machine - domestic	40	2.5	2.5	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	Dishwasher (household)	40	3	1.8	4.4	No limit	1.5
Shower - Single	40	2.5	2.5	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	Shower	40	No Limit[17]	1.8	9	No limit	1.5

[17] BS EN 12056.2:2000 provides a note that "*If length is greater than 3 m noisy discharge may result with an increased risk of blockage*."

AS/NZS 3500.2:2021 Single Stack (and modified)							Table 6 of *BS EN 12056.2:2000* System III Unventilated Branches						
Table 6.3(A)		Table 9.5.1			Section 9.5.4	Section 9.5.5							
Sink - Single/Double	50	2.5	2.5	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	Kitchen Sink	40	No Limit[17]	1.8	9	No limit	1.5
Water closet pan (Cistern)	80/100	6	1.65	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	WC	75/100	No Limit	1.8	-	No limit	1.5
Urinal - wall-hung stall[18]	50	2.5	2.5	5	2 bends (horizontal plane), and 3 bends (vertical plane)	2.5	Bowl urinal	40	3	1.8	9	No limit	1.5

[18] Pipe size of DN50 selected as per Table 9.5.1 of AS/NZS3500.2:2021.

B.18. Comparison of Wastewater Flow Rates from AS/NZS 3500.2:2021 Fixture Unit Method and BS EN 12056.2:2000 Discharge Unit Method

B.18.1. Aims

The aims of this comparative study between *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) is to quantify the effect of employing the method for calculating wastewater flowrate in *BS EN 12056.2:2000* (B.S. Institute, 2000) versus the existing method in *AS/NZS 3500.2:2021* (Standards Australia, 2021). This will allow us to benchmark *AS/NZS 3500.2:2021* (Standards Australia, 2021) against the results of the various system options provided in *BS EN 12056.2:2000* (B.S. Institute, 2000). In particular, the influence of varying the system (System I, II or III) and frequency factor selected on the resultant *BS EN 12056.2:2000* (B.S. Institute, 2000) wastewater flow rate will be investigated.

B.18.2. Residential and Office Building Type Study Parameters

A study was conducted on a residential and office building, with a typical appliance group defined for each building type as detailed below in Table 43. Resultant flow rates for multiples of the defined appliance group were calculated using each code and have been plotted below in Figure 14 and Figure 15 below for the residential and office building example respectively.

Table 43: Definition of an (1) 'Appliance Group' for Example Residential and Office Buildings

Residential Building	Office Building
• 1 x Basin, • 1 x Shower, • 1 x Bath, • 1 x Kitchen Sink, • 1 x Water Closet, • 1x Washing Machine, and • 1 x Domestic Dishwasher	• 3 x Basin, • 3 x Urinal, • 4 x Water Closet, • 1 x Kitchen Sink, and • 1 x Domestic Dishwasher

The *AS/NZS 3500.2:2021* (Standards Australia, 2021) fixture unit (FU) rating and Discharge Units (DU) for Systems I to III for each fixture have been summarised below in Table 44. The variation of each fixture's DU for each System has been plotted below in Figure 13, with the percentage differences between System II and System I & III provided on the chart and tabulated in Table 45. It should be noted that values in Table 45 are provided in purple if they are greater than that specified by System II, green if they are equal to those specified by System II, and blue if they are less than that specified by System II. From Figure 13 and Table 45 below the following trends are evident in regard to System I, II and III discharge units for the fixture types analysed:

- System I DU's are larger than those of System II for all fixture types, and
- there is no consistent trend between System III DU's and System II; out of the 8 fixture types, 3 fixture types have equal DU's for System II and III, 2 fixture types have higher DU's for System III than II, and 3 fixture types have lower DU's for System III than II.

Hence, for all buildings, the resultant calculated wastewater flow rate for System I will be larger than System II flow rates, however no consistent trend in the resultant calculated wastewater flow rate for System II and III can be made – i.e., depending on the number and type of fixtures connected to a particular sanitary plumbing component will vary the comparative resultant flow rates using System II and III discharge units. This is further discussed in Appendix B.18.3.

Table 44 *AS/NZS 3500.2:2021* Fixture Unit Rating and *BS EN 12056.2:2000* Discharge Unit (System I-III) for each fixture

Fixture	*AS/NZS 3500.2:2021* FU Rating	*BS EN 12056.2:2000* DU		
		System I	System II	System III
Basin	1	0.5	0.3	0.3
Shower	2	0.6	0.4	0.4
Urinal	1	0.8	0.5	0.4
Bath	4	0.8	0.6	1.3
Kitchen Sink	3	0.8	0.6	1.3
Water Closet	4	2	1.8	1.2
Washing machine - up to 6 kg	5	0.8	0.6	0.6
Domestic Dishwasher	3	0.8	0.6	0.2

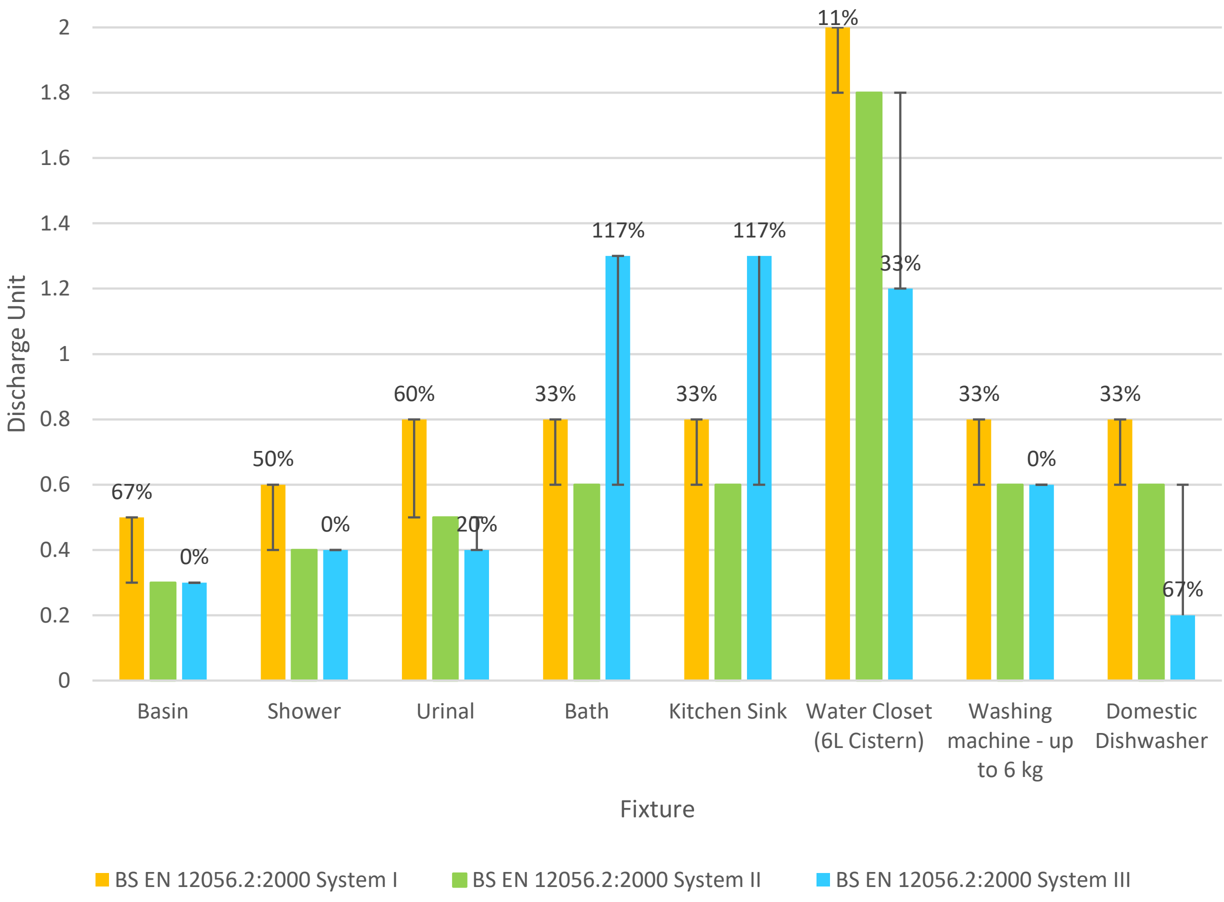


Figure 13: Variation in Discharge Unit of each Fixture for System I to III with Percentage Differences between System II and System I & III

Table 45: Percentage Differences between System II and System I & III

Fixture	Percentage Difference (%) between Discharge Units provided by System II and:	
	System I	System III
Basin	67%	0%
Shower	50%	0%
Urinal	60%	-20%
Bath	33%	117%
Kitchen Sink	33%	117%
Water Closet (6L Cistern)	11%	-33%
Washing machine - up to 6 kg	33%	0%
Domestic Dishwasher	33%	-67%

A comparison of the resultant flow rates for each fixture common to both *AS/NZS 3500.2:2021* (Standards Australia, 2021) and *BS EN 12056.2:2000* (B.S. Institute, 2000) is provided below in Table 46. Values in green are *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates lower than that calculated by *AS/NZS 3500.2:2021* (Standards Australia, 2021), values in red are *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rate values larger than that calculated by *AS/NZS 3500.2:2021* (Standards Australia, 2021), and values in white are *BS EN 12056.2:2000* (B.S. Institute, 2000) equal to that of *AS/NZS 3500.2:2021* (Standards Australia, 2021).

Table 46 Resultant flow rates for each fixture from *AS/NZS 3500.2:2021* Fixture Unit Method and *BS EN 12056.2:2000* Discharge Unit Method

Fixture	*AS/NZS 3500.2:2021* Converted Flow Rate (L/s)	*BS EN 12056.2:2000* (System I) Flow Rate (L/s)			*BS EN 12056.2:2000* DU (System II)			*BS EN 12056.2:2000* DU (System III)		
	K Factor	0.5	0.7	1	0.5	0.7	1	0.5	0.7	1
Basin	0.38	0.35	0.49	0.71	0.27	0.38	0.55	0.27	0.38	0.55
Shower	0.54	0.39	0.54	0.77	0.32	0.44	0.63	0.32	0.44	0.63
Urinal	0.38	0.45	0.63	0.89	0.35	0.49	0.71	0.32	0.44	0.63
Bath	0.77	0.45	0.63	0.89	0.39	0.54	0.77	0.57	0.80	1.14
Kitchen Sink	0.67	0.45	0.63	0.89	0.39	0.54	0.77	0.57	0.80	1.14
Water Closet (6L Cistern)	0.77	0.71	0.99	1.41	0.67	0.94	1.34	0.55	0.77	1.10
Washing machine - up to 6 kg	0.86	0.45	0.63	0.89	0.39	0.54	0.77	0.39	0.54	0.77
Domestic Dishwasher	0.67	0.45	0.63	0.89	0.39	0.54	0.77	0.22	0.31	0.45
Total Flow Rate (sum of all fixtures) (L/s)	**1.85**	**1.33**	**1.87**	**2.66**	**1.16**	**1.63**	**2.32**	**1.19**	**1.67**	**2.39**

A plot of the wastewater flow rate for the model residential and office building is shown below in Figure 14 and Figure 15 respectively.

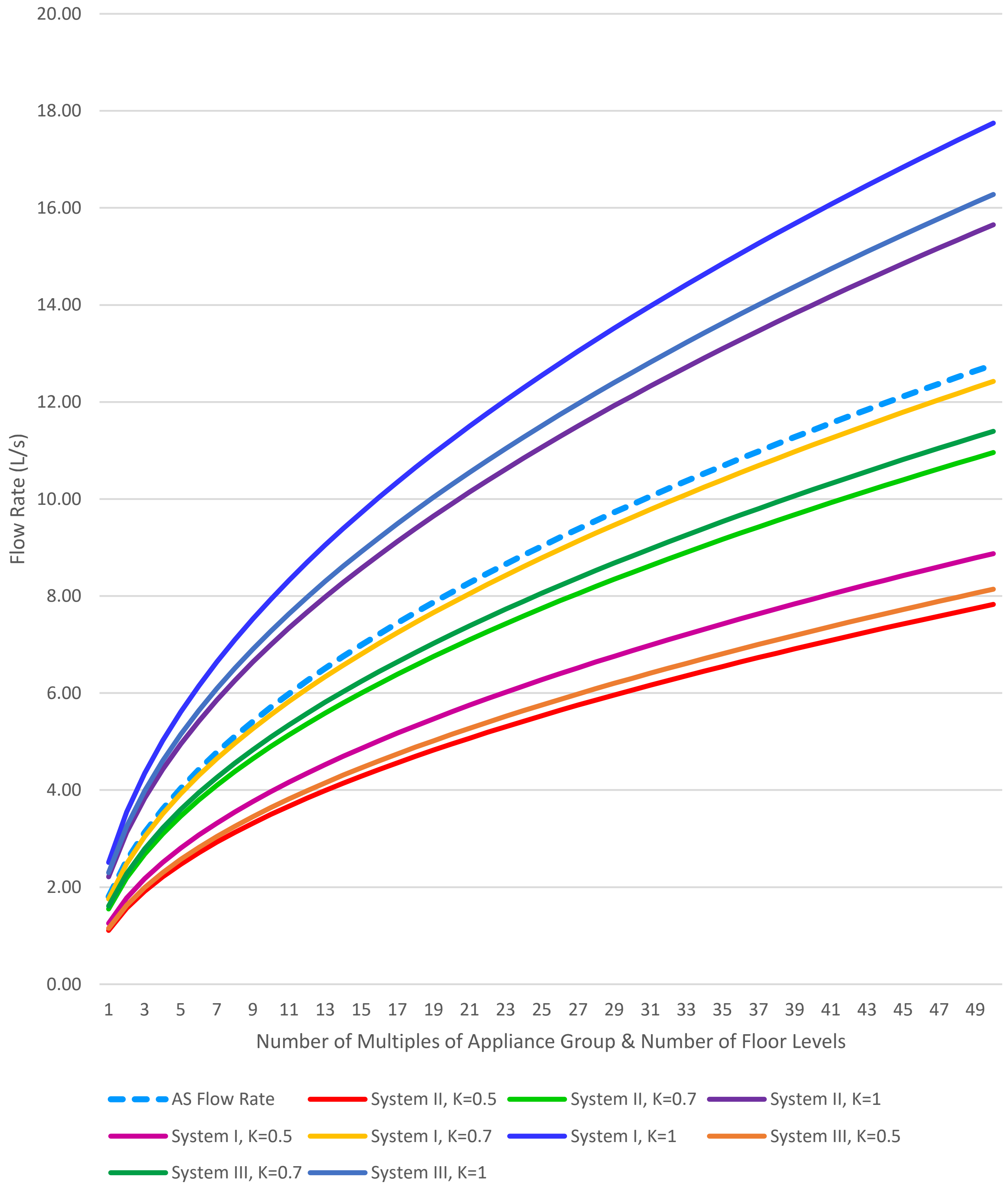


Figure 14: Comparison of Wastewater Flow Rates from *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* for Example Residential Building

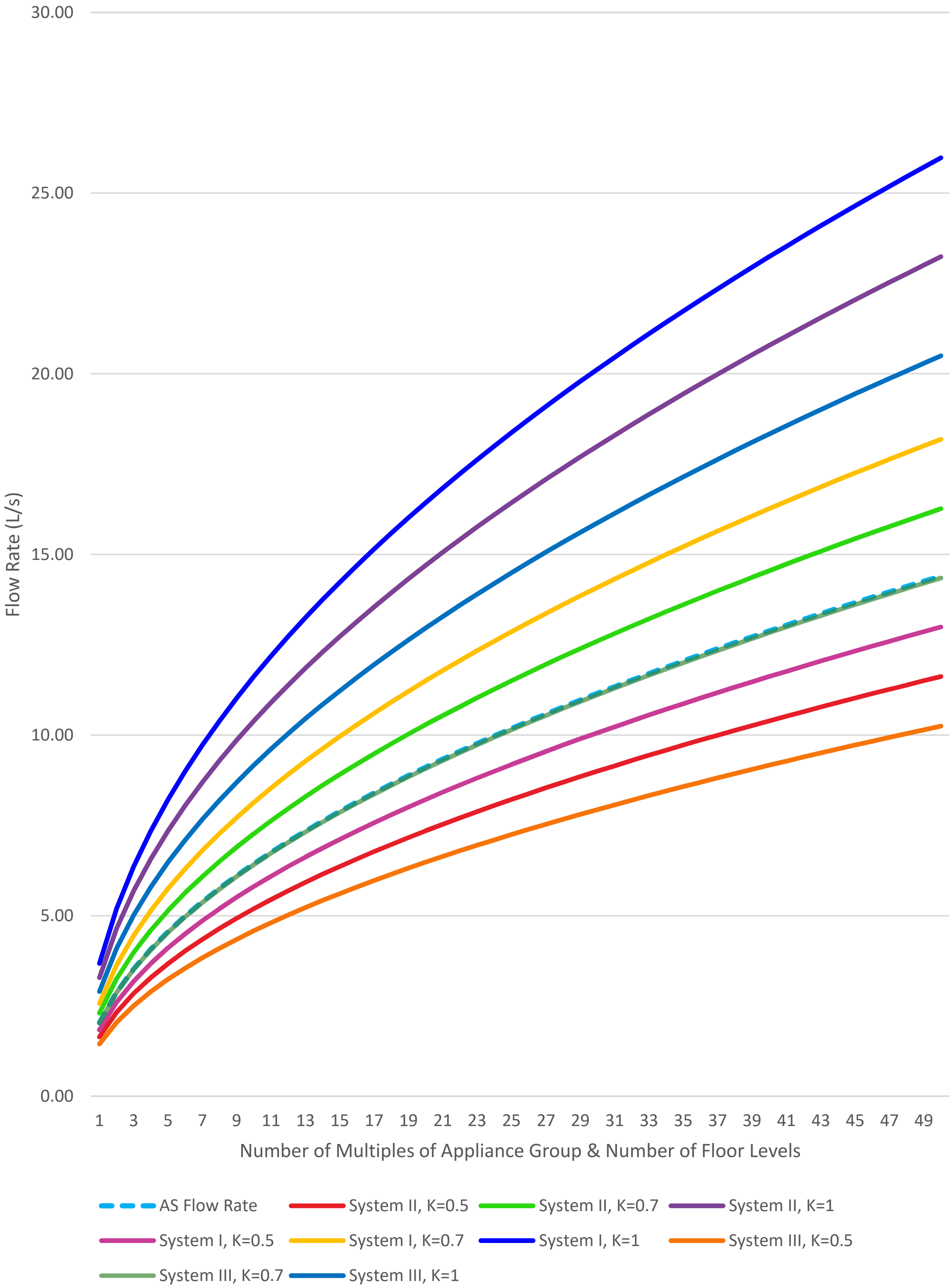


Figure 15: Comparison of Wastewater Flow Rates from *AS/NZS 3500.2:2021* and *BS EN 12056.2:2000* for Example Office Building

B.18.3. Study Findings

The percentage difference[19] between the results of each *BS EN 12056.2:2000* (B.S. Institute, 2000)sizing alternative (System I to III and K-Factor of 0.5 to 1) and that of *AS/NZS 3500.2:2021* (Standards Australia, 2021) was determined as shown below and is summarised in Table 47. The cells in green indicate *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates less than that of *AS/NZS 3500.2:2021* (Standards Australia, 2021), the red cells indicate *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates greater than that of *AS/NZS 3500.2:2021* (Standards Australia, 2021), and the white cells indicate flow rate values approximately equal to that of *AS/NZS 3500.2:2021* (Standards Australia, 2021), for the model buildings tested.

Table 47: Percentage difference between *AS/NZS 3500.2:2021* Flow Rate (Baseline) and *BS EN 12056.2:2000* flow rate values for the residential and office building example

K-Factor	Percentage difference between *AS/NZS 3500.2:2021* Flow Rate (Baseline) and *BS EN 12056.2:2000* values (%)							
	System I		System II		System III		Average	
	Residential Building	Office Building	Residential Building	Office Building	Residential Building	Office Building	**Residential Building**	**Office Building**
0.5	-30.5%	-9.8%	-38.7%	-19.3%	-36.2%	-28.8%	**-35.1%**	**-19.3%**
0.7	-2.7%	26.3%	-14.2%	12.9%	-10.7%	-0.4%	**-9.2%**	**12.9%**
1	39.0%	80.4%	22.6%	61.4%	27.5%	42.3%	**29.7%**	**61.4%**
Average	**2.0%**	**32.3%**	**-10.1%**	**18.3%**	**-6.5%**	**4.4%**		

As demonstrated by the plot in Figure 14 and Figure 15, and by the summarised results in Table 47, the *AS/NZS 3500.2:2021* (Standards Australia, 2021) flow rates are most similar to *BS EN 12056.2:2000* (B.S. Institute, 2000) System I (K=0.7) and System III (K=0.7) for the residential and office building respectively. With regards to resultant *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates, the frequency factor (K) has a greater influence than the System selected (System I to III). It is also noted that for both the building type models, compared to *AS/NZS 3500.2:2021* (Standards Australia, 2021):

- $K = 0.5$ *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates are lower,
- $K = 0.7$ *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates are similar, and
- $K = 1$ *BS EN 12056.2:2000* (B.S. Institute, 2000) flow rates are higher.

The following observations from the data can be made regarding system types:

- System I has the largest flow rate compared to system II and III for all K-Factor values and for both the residential and office building model. This is to be expected since system I discharge units are larger than System I and II for all fixture types, to facilitate 50% filling of the branch discharge pipes.
- System II and III has varying comparative flow rates depending on the number and combination of fixtures connected in a plumbing system. This is evident between the apparent discrepancy between the results of the residential and office building model; for the residential building, System II flow rates are slightly lower than that of System III, and for the office building, System III flow rates being lower than System II. This finding is the result of the relationship between System II and III discharge units not being consistent across all fixture types[20].

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[19] $Percentage\ Difference\ (\%) = 100 \times \frac{\left(Q_{\text{BS EN 12056.2:2000,System X,K=Y}} - Q_{\frac{\text{AS}}{\text{NZS}}\text{3500.2:2021}}\right)}{Q_{\text{AS/NZS 3500.2:2021}}}$

[20] For example, washbasins have the same discharge unit in System II and III, a kitchen sink has a greater discharge unit for System III than System II, and a dishwasher has a smaller discharge unit for System II than System III.

B.19. Comparison of Sizing Recommendations of Sanitary Plumbing Components using, BS EN 12056-2:2000, AS/NZS 3500.2:2021 and a Proposed 'Integrated Method'

B.19.1. Aims

The aim of this study is to quantify and compare the sizing recommendations for sanitary plumbing components (stacks, stack and relief vents and cross-vents/cross-relief vents for the following methodologies:

- *BS EN 12056-2:2000* (B.S. Institute, 2000) System I-III, K = 0.3 and 0.5, Primary and secondary ventilated system,
- *AS/NZS 3500.2:2021* (Standards Australia, 2021) single stack, single stack modified, fully vented (and modified), and
- an integrated method that incorporates:
  - the *BS EN 12056.2:2000* (B.S. Institute, 2000) method of estimating wastewater flow rate to size the loading on the sanitary plumbing system, and
  - the *AS/NZS 3500.2:2021* (Standards Australia, 2021) method of sizing sanitary plumbing components (branches, stacks, vents etc.) by converting FU loading into a flow rate (using formula Q = $\sqrt{\frac{FU}{6.75}}$)

B.19.2. Simulated Residential Tower Model

A study of a residential tower model was developed to compare the sizing recommendations by *BS EN 12056.2:2000* (B.S. Institute, 2000) and *AS/NZS 3500.2:2021* (Standards Australia, 2021). The model was made identical to that conducted by (Swaffield, 2010) for a 20-storey residential block as shown below in Figure 16. This study will vary slightly from that conducted by (Swaffield, 2010) in that testing will be conducted for:

- 3-, 5-, 7-, 10-, 15-, 30- and 50- storey residential towers in addition to a 20-storey building,
- *BS EN 12056.2:2000* (B.S. Institute, 2000) Systems II and III in addition to System I, and
- A K-Factor of 0.3 and 0.5 will be used for this study.

The appliance group connected to each stack per floor level will be as per Table 43 of Section B.18.2 (noting that one and two appliance groups will be connected to the stack per floor), and the fixture and discharge units used to calculate loads in this study are provided in Table 44. It should be noted that these values vary slightly to those used by (Swaffield, 2010), in that:

- A fixture unit of 4 instead of 6 will be used for a WC, and
- A discharge unit of a shower in System I of 0.6 will be used instead of 0.8.

Table 8.6 Summation of DU or FU appliance ratings for a 20-storey residential block

Appliance	*UK*	*AUS/NZ*	*UPC*	*IPC*	*ASPE*
WC (6l)	2.0	6	3	3	6
WHB	0.5	1	1	2	1
Bath	0.8	4	2	2	2
Shower	0.8	2	2	2	2
Sink	0.8	3	2	2	2
Washing machine (6 kg)	0.8	5	2	2	3
Dishwasher	0.8	3	2	2	2
Total per floor	6.5	24	15	15	18
Total for 20 floors	130.0	480	300	300	360

Figure 16: Summation of DU or FU appliance ratings for a 20-storey residential block (Swaffield, 2010)

The fixture and discharge unit totals for each building height tested has been summarised below in Table 48.

Table 48: Net Discharge and Fixture units for Residential Building

Number of Appliance Groups connected per Floor Level	Fixture	*BS EN 12056.2:2000* Discharge Units (DU)			*AS/NZS 3500.2:2021* Fixture Units (FU)
		System I	System II	System III	
	WC	2	1.8	1.2	4
	Basin	0.5	0.3	0.3	1
	Bath	0.8	0.6	1.3	4
	Shower	0.6	0.4	0.4	2
	Sink	0.8	0.6	1.3	3
	Washing Machine	0.8	0.6	0.6	5
	Dishwasher	0.8	0.6	0.2	3
1 appliance group connected per floor	**Total (1 Floor)**	**6.3**	**4.9**	**5.3**	**22**
	3 Floors	**18.9**	**14.7**	**15.9**	**66**
	5 Floors	**31.5**	**24.5**	**26.5**	**110**
	7 Floors	**44.1**	**34.3**	**37.1**	**154**
	10 Floors	**63**	**49**	**53**	**220**
	15 Floors	**94.5**	**73.5**	**79.5**	**330**
	20 Floors	**126**	**98**	**106**	**440**
	30 Floors	**189**	**147**	**159**	**660**

Number of Appliance Groups connected per Floor Level	Fixture	*BS EN 12056.2:2000* Discharge Units (DU)			*AS/NZS 3500.2:2021* Fixture Units (FU)
		System I	System II	System III	
	50 Floors	**315**	**245**	**265**	**1100**
2 appliance group connected per floor	**Total (1 Floor)**	**12.6**	**9.8**	**10.6**	**44**
	3 Floors	**37.8**	**29.4**	**31.8**	**132**
	5 Floors	**63**	**49**	**53**	**220**
	7 Floors	**88.2**	**68.6**	**74.2**	**308**
	10 Floors	**126**	**98**	**106**	**440**
	15 Floors	**189**	**147**	**159**	**660**
	20 Floors	**252**	**196**	**212**	**880**
	30 Floors	**378**	**294**	**318**	**1320**
	50 Floors	**630**	**490**	**530**	**2200**

The wastewater flow rate loading using the above fixture and discharge units has been summarised below in Table 49.

Table 49: Wastewater Flowrate (L/s) from of DU and FU Summation for 3-, 5-, 7-, 10-, 15-, 20-, 30- and 50-storey Residential Tower (K=0.3 and 0.5)

Number of Appliance Groups connected per Floor Level	Number of Floors	*BS EN 12056.2:2000* Flow Rate (L/s)						*AS/NZS 3500.2:2021* Fixture Units Converted Flow Rate[21] (Ls)
		System I		System II		System III		
		0.3	0.5	0.3	0.5	0.3	0.5	
1 appliance group connected per floor	Total (1 Floor)	0.8	1.3	0.7	1.1	0.7	1.2	1.8
	3 Floors	1.3	2.2	1.2	1.9	1.2	2	3.1
	5 Floors	1.7	2.8	1.5	2.5	1.5	2.6	4.0
	7 Floors	2	3.3	1.8	2.9	1.8	3	4.8
	10 Floors	2.4	4	2.1	3.5	2.2	3.6	5.7
	15 Floors	2.9	4.9	2.6	4.3	2.7	4.5	7.0
	20 Floors	3.4	5.6	3	4.9	3.1	5.1	8.1
	30 Floors	4.1	6.9	3.6	6.1	3.8	6.3	9.9
	50 Floors	5.3	8.9	4.7	7.8	4.9	8.1	12.8
2 appliance group connected per floor	Total (1 Floor)	1.1	1.8	0.9	1.6	1	1.6	2.6
	3 Floors	1.8	3.1	1.6	2.7	1.7	2.8	4.4
	5 Floors	2.4	4	2.1	3.5	2.2	3.6	5.7

[21] Refer to formula in Appendix B.2.

Number of Appliance Groups connected per Floor Level	Number of Floors	*BS EN 12056.2:2000* Flow Rate (L/s)						AS/NZS 3500.2:2021 Fixture Units Converted Flow Rate[21] (Ls)
		System I		System II		System III		
		0.3	0.5	0.3	0.5	0.3	0.5	
	7 Floors	2.8	4.7	2.5	4.1	2.6	4.3	6.8
	10 Floors	3.4	5.6	3	4.9	3.1	5.1	8.1
	15 Floors	4.1	6.9	3.6	6.1	3.8	6.3	9.9
	20 Floors	4.8	7.9	4.2	7	4.4	7.3	11.4
	30 Floors	5.8	9.7	5.1	8.6	5.3	8.9	14.0
	50 Floors	7.5	12.5	6.6	11.1	6.9	11.5	18.1

B.19.3. Stack Sizing of Primary Ventilated/Single Stack Systems

A comparison of stack sizing for *BS EN 12056-2:2000* (B.S. Institute, 2000) primary ventilated systems and *AZ/NZS 3500.2:2021* (Standards Australia, 2021) single stack systems is summarised below in Table 50 and Table 51 for residential tower models with 1 and 2 appliance groups connected to the stack per floor level respectively. Values in green are stack sizes that are less than those recommended by the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method (with darker shades indicating increasing pipe DN increment savings, and values in blue are those equal to that recommended by *AZ/NZS 3500.2:2021* (Standards Australia, 2021).

From the below results, it is evident that compared to the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method, the use of the integrated method:

- For the stack with '1 appliance group connected per floor level':
  - Does not result in any reductions to stack size, for all stack heights, systems (1, II, III) and K=0.3 or 0.5.
- For the stack with '2 appliance groups connected per floor level':
  - Does result in a reduction of one DN increment for the 7- and 15-floor building,
  - Does result in a reduction of two DN increments for the 10- floor building, and
  - Does allow for the design of a 20- and 30-floor building using a single stack (using the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method for this model exceeds the maximum capacity of DN150 single stack).

It should also be noted that:

- There is no difference in the recommended stack size using the integrated method with *BS EN 12056-2:2000* (B.S. Institute, 2000) System I, II or III Discharge unit values or K=0.3 or 0.5 to inform loading on stacks.
- Compared to the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method and the integrated method, *BS EN 12056-2:2000* (B.S. Institute, 2000) generally provides comparative stack size reductions, which in the case of the 15-, 20- and 30-floor stacks is primarily due to stack height limitations stipulated by *AZ/NZS 3500.2:2021* (Standards Australia, 2021), which are not provided in *BS EN 12056-2:2000* (B.S. Institute, 2000).
- *AZ/NZS 3500.2:2021* (Standards Australia, 2021) generally stipulates DN100 as the minimum stack size in single stack systems (with some exceptions), whilst *BS EN 12056-2:2000* (B.S. Institute, 2000)

specifies that the minimum stack size where water closets are connected is DN80 for system II and DN100 for system I or III.

- *BS EN 12056-2:2000* (B.S. Institute, 2000) provides more variability in stack sizing by providing the capacity of stacks with square and stack junctions.

Table 50: Stack Sizing for 1 Appliance Group per Floor Level – Primary Ventilated/Single Stack System

Code	*BS EN 12056-2:2000* - Primary Ventilated						*AZ/NZS 3500.2:2021*	Integrated Method - Single Stack					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Stack Size (mm)												
3	100	100	80	80	100	100	100	100					
5	100	100	80	80	100	100	100	100					
7	100	100	80	90	100	100	100	100					
10	100	100	80	90	100	100	100	100					
15	100	100	80	100	100	100	125	125					
20	100	125	90	100	100	100	150	150					
30	100	125	100	125	100	125	150	150					
50	125	150	100	150	100	150	NA (>30 floors)	NA (more than 30 floors)					

Table 51: Stack Sizing for 2 Appliance Groups per Floor Level – Primary Ventilated/Single Stack System

Code	*BS EN 12056-2:2000* - Primary Ventilated						*AZ/NZS 3500.2:2021*	Integrated Method - Single Stack					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Stack Size (mm)												
3	100	100	80	90	100		100	100					
5	100	100	80	90	100		100	100					
7	100	100	80	100	100	100	125	100					
10	100	125	90	100	100	100	150	100					
15	100	125	100	125	100	125	150	125					
20	100	150	100	125	100	125	NA (>10.7L/s)	150					
30	125	150	100	150	125	150	NA (>10.7L/s)	150					
50	125	200	125	150	125	150	NA (>30 floors)	NA (more than 30 floors)					

B.19.4. Sanitary Plumbing Component Sizing of Secondary Ventilated/Single Stack Modified and Fully Vented (and Modified) Systems

A comparison of stack sizing, relief vent sizing and cross-vent locations for *BS EN 12056-2:2000* (B.S. Institute, 2000) secondary ventilated systems and *AZ/NZS 3500.2:2021* (Standards Australia, 2021) single stack modified systems is summarised below in Table 52 to Table 55 and Table 56 to Table 58 for residential tower models with 1 and 2 appliance groups connected to the stack per floor level respectively.

A comparison of stack sizing and relief vent sizing for *BS EN 12056-2:2000* (B.S. Institute, 2000) secondary ventilated systems and *AZ/NZS 3500.2:2021* (Standards Australia, 2021) fully vented (and modified) systems is summarised below in Table 58 to Table 59 and Table 60 to Table 61 for residential tower models with 1 and 2 appliance groups connected to the stack per floor level respectively.

Values in green are stack sizes that are less than those recommended by the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method (with darker shades indicating increasing pipe DN increment savings, values in blue are those equal to that recommended by *AZ/NZS 3500.2:2021* (Standards Australia, 2021), and values in red are those greater than that recommended by *AZ/NZS 3500.2:2021* (Standards Australia, 2021).

From the below results, it is evident that for the single stack modified system, compared to the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method, the use of the integrated method:

- For the stack with '1 appliance group connected per floor level':
  - Does not result in any reductions to stack size or relief vent size, for all stack heights, systems (1, II, III) and K=0.3 or 0.5.
  - Does result in cross-vents only being required at 'alternate floors' as opposed to 'each floor' for the 15- and 20-floor building.
- For the stack with '2 appliance groups connected per floor level':
  - Does not result in any reductions to stack size, for all stack heights, systems (1, II, III) and K=0.3 or 0.5, given that only a DN100 stack is specified for single stack modified systems.
  - Does allow for the design of a 15- and 20- floor building using a single stack modified system (using the *AZ/NZS 3500.2:2021* method for this model exceeds the maximum capacity of a DN100 single stack modified system).
  - Does result in a reduction of one DN increment for the relief vent size of the 10-floor building.
  - Does result in cross-vents only being required at 'alternate floors' as opposed to 'each floor' for the:
    - 7- and 10-floor building,
    - 15-floor building for System II, III and System I with K=0.3
    - 20-floor building, for K=0.3

It should also be noted that:

- There is no difference in the recommended stack size or relief vent size using the integrated method with *BS EN 12056-2:2000* (B.S. Institute, 2000) System I, II or III Discharge unit values or K=0.3 or 0.5 to inform loading on stacks.
- There are differences in the recommended location of cross-vents for stacks connected with 2 appliance groups per floor level:
  - 15-floor building for System I K=0.5 recommends cross-venting on 'each floor', whilst all other configurations recommend 'alternate floors'.
  - 20-floor building for K=0.3 recommends cross-venting on 'alternate floors', whilst K=0.5 recommends 'every floor'

- *AZ/NZS 3500.2:2021* (Standards Australia, 2021) stipulates DN100 as the stack size in single stack modified systems, whilst *BS EN 12056-2:2000* specifies that the minimum stack size where water closets are connected is DN80 for system II and DN100 for system I or III.

- *BS EN 12056-2:2000* (B.S. Institute, 2000) provides more variability in stack sizing by providing the capacity of stacks with square and stack junctions.

From the below results, it is evident that for the fully vented (and modified) system, compared to the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method, the use of the integrated method:

- For the stack with '1 appliance group connected per floor level':
  - Reductions to stack sizes by 1 to 3 DN increments for K=0.3, and by 0 to 2 DN increments for K=0.5,
  - Reductions to relief vent sizes by 1 to 2 DN increments for K=0.3, and by 0 to 1 DN increments for K=0.5,

- For the stack with '2 appliance groups connected per floor level':
  - Reductions to stack sizes by 1 to 3 DN increments for K=0.3, and by 0 to 2 DN increments for K=0.5,
  - Reductions to relief vent sizes by 1 to 2 DN increments for K=0.3, and by 0 to 1 DN increments for K=0.5,
  - Does allow for the design of a 50-floor building using a fully vented (and modified) system (using the *AZ/NZS 3500.2:2021* (Standards Australia, 2021) method for this model exceeds the maximum developed length for a DN150 and DN225 stack given loading.

It should also be noted that:

- There are no differences in the recommended stack or relief vent size using the integrated method with *BS EN 12056-2:2000* (B.S. Institute, 2000) System I, II or III Discharge unit values for K=0.5, with 1 appliance group connected to the stack per level.

- There is one difference in the recommended stack and relief vent size using the integrated method with *BS EN 12056-2:2000* (B.S. Institute, 2000) System I, II or III Discharge unit values for K=0.5, with 2 appliance group connected to the stack per level. This occurs for the 30-floor building; DN100 stack and relief vent size is recommended for System II versus DN125 for System I and III.

- There are differences in the recommended stack and relief vent size using the integrated method with *BS EN 12056-2:2000* (B.S. Institute, 2000) with K=0.3 versus 0.5 for most design cases tested.

- *BS EN 12056-2:2000* (B.S. Institute, 2000) specifies that the minimum stack size where water closets are connected is DN80 for system II and DN100 for system I or III.

Table 52: Stack Sizing – Secondary Ventilated/Single Stack Modified System – 1 Appliance Group

Code	*BS EN 12056-2:2000* - Secondary Ventilated						*AZ/NZS 3500.2:2021* - Single Stack Modified	Integrated Method - Single Stack Modified					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Stack Size (mm)												
3	100	100	80	80	100	100	100	100					
5	100	100	80	80	100	100	100	100					
7	100	100	80	80	100	100	100	100					
10	100	100	80	90	100	100	100	100					
15	100	100	80	90	100	100	100	100					
20	100	100	80	100	100	100	100	100					
30	100	100	90	100	100	100	NA[22]	NA[22]					
50	100	125	100	125	100	125	NA[22]	NA[22]					

Table 53: Relief Vent Sizing – Secondary Ventilated/Single Stack Modified System – 1 Appliance Group

Code	*BS EN 12056-2:2000* - Secondary Ventilated						*AZ/NZS 3500.2:2021* - Single Stack Modified	Integrated Method - Single Stack Modified					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Relief Vent Size (mm)												
3	50						50	50					
5	50						50	50					
7	50						50	50					
10	50						50	50					
15	50						50	50					
20	50						65	65					
30	50						NA[22]	NA[22]					
50	50	70	50	70	50	70	NA[22]	NA[22]					

[22] Greater than 20 floors.

Table 54: Cross-Vent Locations – Secondary Ventilated/Single Stack Modified System – 1 Appliance Group

Code	*BS EN 12056-2:2000* - Secondary Ventilated						*AZ/NZS 3500.2:2021* - Single Stack Modified	Integrated Method - Single Stack Modified					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Cross-Vent location												
3	Each floor						Alternate floors	Alternate floors					
5	Each floor						Alternate floors	Alternate floors					
7	Each floor						Alternate floors	Alternate floors					
10	Each floor						Alternate floors	Alternate floors					
15	Each floor						Each floor	Alternate floors					
20	Each floor						Each floor	Alternate floors					
30	Each floor						NA[22]	NA[22]					
50	Each floor						NA[22]	NA[22]					

Table 55: Stack Sizing – Secondary Ventilated/Single Stack Modified System – 2 Appliance Group

Code	*BS EN 12056-2:2000* - Secondary Ventilated						*AZ/NZS 3500.2:2021* - Single Stack Modified	Integrated Method - Single Stack Modified					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Stack Size (mm)												
3	100	100	80	80	100	100	100	100					
5	100	100	80	90	100	100	100	100					
7	100	100	80	90	100	100	100	100					
10	100	100	80	100	100	100	100	100					
15	100	100	90	100	100	100	NA (>8.6 l/s)	100					
20	100	125	90	100	100	100	NA (>8.6 l/s)	100					
30	100	125	100	125	100	125	NA[22]	NA[22]					
50	125	150	100	150	100	150	NA[22]	NA[22]					

Table 56: Relief Vent Sizing – Secondary Ventilated/Single Stack Modified System – 2 Appliance Group

Code	*BS EN 12056-2:2000* - Secondary Ventilated						*AZ/NZS 3500.2:2021* - Single Stack Modified	Integrated Method - Single Stack Modified					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Relief Vent Size (mm)												
3	50						50	50					
5	50						50	50					
7	50						50	50					
10	50						65	50					
15	50						NA[23]	50					
20	50	70	50	50	50	50	NA[23]	65					
30	50	70	50	70	50	70	NA[22]	NA[22]					
50	70	80	50	80	50	80	NA[22]	NA[22]					

Table 57: Cross-Vent Locations – Secondary Ventilated/Single Stack Modified System – 2 Appliance Group

Code	*BS EN 12056-2:2000* - Secondary Ventilated						*AZ/NZS 3500.2:2021* - Single Stack Modified	Integrated Method - Single Stack Modified					
	System I		System II		System III			System I		System II		System III	
K-Factor	0.3	0.5	0.3	0.5	0.3	0.5		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Cross-Vent location												
3	Each floor						Alternate floors	Alternate floors					
5	Each floor						Alternate floors	Alternate floors					
7	Each floor						Each floor	Alternate floors					
10	Each floor						Each floor	Alternate floors					
15	Each floor						NA[23]	Alternate floors	Each floor	Alternate floors			
20	Each floor						NA[23]	Alternate floors	Each floor	Alternate floors	Each floor	Alternate floors	Each floor
30	Each floor						NA[22]	NA[22]					
50	Each floor						NA[22]	NA[22]					

[23] Exceeds maximum capacity.

Table 58: Stack Sizing – Fully Vented (and Modified) System – 1 Appliance Group

Code	*AZ/NZS 3500.2:2021* – Fully Vented (and modified)	Integrated Method - Fully Vented (and modified)					
		System I		System II		System III	
K-Factor		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Stack Size (mm)						
3	100	50	80	50	80	50	80
5	100	50	65	50[24]	65	50[24]	65
7	100	65[24]	80	65[24]	80	65[24]	80
10	100	65	100	65[24]	100	65[24]	100
15	100	80	100	65	100	65	100
20	100	80	100	80	100	80	100
30	125	100					
50	150	125[24]	125	100	125[24]	125[24]	125[24]

Table 59: Relief Vent Sizing – Fully Vented (and Modified) System – 1 Appliance Group

Code		*AZ/NZS 3500.2:2021* – Fully Vented (and modified)	Integrated Method - Fully Vented (and modified)					
			System I		System II		System III	
K-Factor			0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Developed Length of Vent[25] (m)	Relief Vent Size (mm)						
3	18	65	50	65	50	65	50	65
5	27	80	50	65	50	65	50	65
7	36	80	65	80	65	80	65	80
10	49.5	80	65	80	65	80	65	80
15	72	100	80	100	65	100	65	100
20	94.5	100	80	100	80	100	80	100
30	139.5	125	100					
50	229.5	150	125	125	100	125	125	125

[24] Stack upsized one DN increment due to maximum developed length of vent exceeding that specified in Table 8.5.3.5 of AZ/NZS 3500.2:2021.

[25] Developed length of vent for this study calculated by assuming that the floor height for each level is 4.5 m. and the length of the vent above the top floor is 4.5 m.

Table 60: Stack Sizing – Fully Vented (and Modified) System – 2 Appliance Group

Code	*AZ/NZS 3500.2:2021* – Fully Vented (and modified)	Integrated Method - Fully Vented (and modified)					
		System I		System II		System III	
K-Factor		0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Stack Size (mm)						
3	100	80	100	65	100	80	100
5	100	65	100	50	100	50	100
7	100	65	100	65	100	65	100
10	100	80	100	80	100	80	100
15	125	100					
20	125	100					
30	150	100	125	100	100	100	125
50	NA[26]	125[24]	150	100	150[24]	125[24]	150[24]

Table 61: Relief Vent Sizing – Fully Vented (and Modified) System – 2 Appliance Group

Code		*AZ/NZS 3500.2:2021* – Fully Vented (and modified)	Integrated Method - Fully Vented (and modified)					
			System I		System II		System III	
K-Factor			0.3	0.5	0.3	0.5	0.3	0.5
No. of Floors	Developed Length of Vent[25] (m)	Relief Vent Size (mm)						
3	18	65	65	65	50	65	50	65
5	27	80	65	80	50	80	50	80
7	36	80	65	80	65	80	65	80
10	49.5	80	80					
15	72	100	100					
20	94.5	125	100					
30	139.5	150	100	125	100	100	100	125
50	229.5	NA[26]	125	150	100	150	125	150

[26] Stack exceeds maximum developed length for DN150 and DN225 for given loading.

Appendix C - Collected Data

Maximum hourly probabilities of supply points for fixtures within small and large occupancy flats, hospital wards and office buildings provided by data from previous literature have been summarised by (Wise & Swaffield, 2002) as shown below in Figure 17. Maximum hourly probabilities for discharge in domestic use for water closets, wash basins and sinks are also provided as shown below in Figure 18.

	Water supply point	Weekday		Saturday		Sunday	
		Maximum probability	Period (hours)	Maximum probability	Period (hours)	Maximum probability	Period (hours)
Flats							
Small, 1.5 occupants on average	WC	0.0155	7–8	0.0133	7–8	0.0116	10–11
	Washbasin (C)	0.0085	8–9	0.0142	14–15	0.0080	9–10
	Washbasin (H)	0.0038	8–9	0.0039	9–10	0.0037	8–9
	Sink (C)	0.0034	9–10	0.0055	8–9	0.0152	10–11
	Sink (H)	0.0154	17–18	0.0136	8–9	0.0179	10–11
	Bath (C)	0.0017	7–8	0.0041	14–15	0.0020	13–14
	Bath (H)	0.0059	16–17	0.0427	14–15	0.0042	13–14
Large, 3.2 occupants on average	WC	0.0501	7–8	0.0417	8–9	0.0443	10–11
	Washbasin (C)	0.0076	7–8	0.0050	9–10	0.0053	9–10
	Washbasin (H)	0.0108	7–8	0.0080	7–8	0.0085	9–10
	Sink (C)	0.0258	17–18	0.0329	10–11	0.0441	11–12
	Sink (H)	0.0342	18–19	0.0310	9–10	0.0415	10–11
	Bath (C)	0.0030	18–19	0.0038	9–10	0.0035	10–11
	Bath (H)	0.0068	22–23	0.0142	11–12	0.0125	14–15
Hospital ward	Washbasin (C)	0.031					
	Washbasin (H)	0.042					
Office building	WC (Men)	Av. interval between uses: 1200 s. Period: 9–12 h Probability based on 75 s inflow duration: 0.0625					
50 men, four WCs 50 women, six WCs	WC (Women)	Av. interval between uses: 600 s. Period: 11–12 h Probability based on 75 s inflow duration: 0.125					

Figure 17: Maximum hourly probabilities of supply points for fixtures within small and large occupancy flats, hospital wards and office buildings (Wise & Swaffield, 2002)

	Duration of discharge, t(s)	Interval between discharges, T(s)	$p = t/T$
WC	5	1140	0.0044
Washbasin	10	1500	0.0067
Sink	25	1500	0.0167

Figure 18: Maximum hourly probabilities for discharge in domestic use (Wise & Swaffield, 2002)

(Wise & Swaffield, 2002) also summarises the results of a study conducted by (Butler, 1991) as shown below in Figure 19. These results are based on a survey of 28 households of varying occupancy (1 to 5+ occupants) in the southeast of England over 7 consecutive days in December 1987.

Appliance	Uses per hour per dwelling	
	Average	Peak
WC	0.42	1.20
Basin	0.38	1.53
Bath	0.026	0.14
Shower	0.035	0.32
Sink	0.22	0.76
Washing machine	0.018	0.03

Figure 19: Frequencies of appliance weekday usage per dwelling

(Wise & Swaffield, 2002) also smoothed and plotted the data collected in (Butler, 1991) and is shown below in Figure 20.

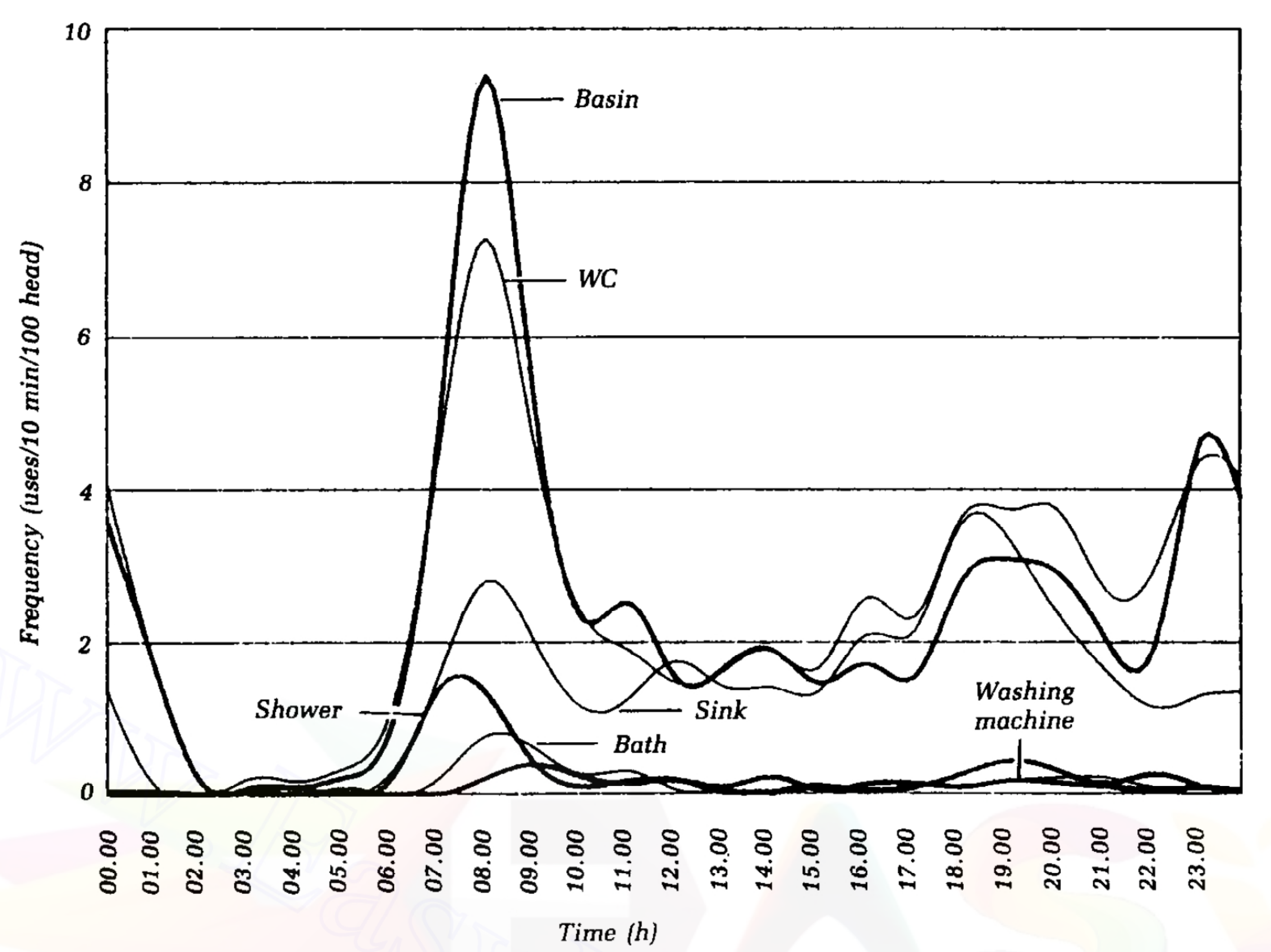

Figure 20: Water usage over a day (Butler, 1991)

Appendix D - Data Analysis Methodology

D.1. Assumptions

The following assumptions have been made by this data analysis methodology:

1. Every supply event has a corresponding discharge event. I.e., this method does not account for the fact that a sink tap may be turned on (supply event) without a consequent discharge event (e.g., filling up a water bottle from a tap result in little/no sanitary discharge). This is a conservative assumption.

2. The time of discharge for fixtures with cisterns (urinals and Water Closets) is determined as per to D.2.1, and bases its calculation on the following:

   a. WELS ratings of fixtures are used to determine flush volume of urinals and water closets.

   b. *Innovation Engineering* waste flow rate and fixture volume data is used to determine discharge time of fixtures with cisterns.

3. The time of discharge for plugged fixtures (Baths and Sinks) is determined as per D.2.2 and bases its calculation on the following:

   a. Note that all bath and sink usage events are assumed to be with fixtures plugged.

   b. *Innovation Engineering* (Innovation Engineering, 2019) waste flow rate and fixture volume/capacity data is used to determine discharge time of sinks.

   c. (Wise & Swaffield, 2002) waste flow rate data and the capacity/volume of a bath tested by *Innovation Engineering* (Innovation Engineering, 2019) data will be used to determine discharge time of baths. This analysis inherently assumes that both (Wise & Swaffield, 2002) and *Innovation Engineering* (Innovation Engineering, 2019) tested baths of similar capacities.

4. For unplugged fixtures, it is assumed that the average time of discharge is equal to the average time of supply for a given fixture (refer to Section D.2.3).

   a. Basins are considered to be ‘not plugged’. Whilst this is an accurate assumption in commercial/industrial buildings, this may not be accurate in residential buildings. Plugging basins results in higher flow rates and lower fixture discharge durations. Given that the difference between the fixture discharge time of a basin that is (a) plugged or (b) not plugged, would be small compared to the time interval between each fixture usage, we need this assumption to be appropriate and non-consequential to the accuracy of the results.

Based on a comparison of the waste flow rates provided by *Innovation Engineering* (Innovation Engineering, 2019) to that in (Wise & Swaffield, 2002), we consider the waste flow rates of urinals, water closets, and sinks provided by (Innovation Engineering, 2019) to be appropriate and accurate enough for use in this purpose. For a bath, we consider the waste flow rate value provided in (Wise & Swaffield, 2002) to be more appropriate than that provided by (Innovation Engineering, 2019). Hence our analysis of a bath will consist of the volume specified in (Wise & Swaffield, 2002) and the waste flow rate specified in (Innovation Engineering, 2019).

D.2. Calculations to Determine Time Interval between Fixture Discharge Events averaged over Peak Period

D.2.1. Time of Fixture Discharge for fixtures with Cisterns (Urinal and Water Closets)

The average time of discharge ($t_{d,F}$) for a given fixture with cisterns (F) can be approximated as:

$$t_{d,F} = \frac{V_F}{WFR_F}$$

Where:

- V_F is the total volume supplied to a fixture (L), and
- WFR_F is the waste flow rate of fixture F (L/s).

The waste flow rates and volumes of Water Closets and Urinals have been obtained from testing data collected by (Innovation Engineering, 2019) (refer to Figure 23) and have been used to calculate discharge times, as summarised below in Table 62.

Noting the similarity in fixture discharge times of 6/3L and 4.5/3L Water closet cisterns calculated below in Table 62, and given that *AS/NZS 3500.2:2021* (Standards Australia, 2021) only provides one fixture unit value for a cistern water closet (see Figure 21 below), and the discharge units provided in *BS EN 12056.2:2000* (B.S. Institute, 2000) for different volume cisterns are equal (see Figure 22 below), an average fixture discharge time will be used.

Noting also that the reported Caroma Urinal Stall flow rate of 3.85L/s by *Innovation Engineering* appears to be quite large in comparison to the wall hung urinal (0.29L/s), which results in fixture discharge times of 0.5 and 2.8 seconds respectively.

Table 62: Calculated Fixture Discharge Times for Water Closets and Urinals using *Innovation Engineering* Waste Flow Rates and Cistern Volumes

Fixture	Fixture Model	Waste Flow Rate (L/s)	Cistern Volume[27] (L)	Fixture Discharge Time (s)
Water Closet (4.5/3L)	CAROMA AIRE 4.5/3L	2.1	4.5	2.1
Water Closet (6/3L)	CAROMA SLIMLINE 6/3L	2.13	6	2.8
Water Closet (Average)				**2.5**
Urinal (Caroma Wall hung[28])	CUBE 0.8L SERIES II	0.29	0.8[29]	**2.8**

[27] Cistern volumes are provided in the description of the appliance tested.

[28] Cube 0.8L Series II

[29] WELS 6 star rated, 0.8L per flush

Table 6.3(A) *(continued)*

Fixture	Fixture abbreviations	Min. size of trap outlet and fixture discharge pipe DN		Fixture unit rating	
			NZ (only)		
Water closet pan	WC	80		6 (F. valve)	4 (Cist.)
Water closet pan	WC	100		6 (F. valve)	4 (Cist.)

Figure 21: *AS/NZS 3500.2:2021* Fixture Unit Rating for Water Closets with cisterns (Original Document Edited)

Appliance	System I	System II	System III	System IV
	DU l/s	**DU** l/s	**DU** l/s	**DU** l/s
WC with 4,0 l cistern	**	1,8	**	**
WC with 6,0 l cistern	2,0	1,8	1,2 to 1,7***	2,0
WC with 7,5 l cistern	2,0	1,8	1,4 to 1,8***	2,0
WC with 9,0 l cistern	2,5	2,0	1,6 to 2,0***	2,5

Figure 22: *BS EN 12056.2:2000* Discharge Units for Water Closets with 4 to 9L cisterns (Original Document Edited)

INNOVATION ENGINEERING

IT19001_FIXTURE UNIT RATINGS

TEST UPDATE

RESULTS

TEST #	ID #	Category	PART #	Description	Waste Size (mm)	Water Depth* (mm)	Waste Flow Rate (L/s)
1	EUT01	BASIN	865635W	CARBONI II - Grate	40	45	**0.33**
2	EUT02	BASIN	675100W	METRO 35	50	100	**0.68**
3	EUT03	BASIN	674103W	LABORATORY	50	100	**0.65**
4	EUT04	BATH	NU7W	NEWBURY 1675 - Popup	40	100	**0.46**
5	EUT04	BATH	NU7W	NEWBURY 1675 - Grate	40	100	**0.63**
6	EUT05	SHOWER	857570W	DOLPHIN SHOWER BASE	50	50	**1.12**
7	EUT06	TROUGH	8011	EUREKA 45 TUB	50	100	**0.47**
8	EUT07	SINK	1503.1R	ADVANCE SINGLE	50	100	**0.45**
9	EUT08	SINK	2503.1L	ADVANCE 1.75	50	100	**1.05**
10	EUT09	SINK	811592W	CLEANERS SINK	50	100	**0.69**
11	EUT10	PAN	618320W	SLOP HOPPER	85	200	**2.75**
12	EUT11	URINAL	678800W	CUBE 0.8L SERIES II	50	50	**0.29**
13	EUT12	CISTERN	233036W	CAROMA SLIMLINE 6/3L	50	240	**2.13**
14	EUT13	CISTERN	234040W	CAROMA AIRE 4.5/3L	50	240	**2.10**
15	EUT14	BIDETTE	611515W	CAROMA CUBE WF BIDETTE	50	100	**0.43**
16	EUT15	S/HOPPER	618320W	SLOP HOPPER 6/3L	85	240	**1.70**
17	EUT16	TOILET PAN / CISTERN	984330W	UNISET 2 CONCORDE 6/3L	85	240	**2.86**
18	EUT17	TOILET PAN / CISTERN	989200W	CARAVELLE EH 4.5/3L	85	240	**1.13**
19	EUT18	URINAL	JRS001	CAROMA URINAL STALL	100	100	**3.85**
20	EUT19	FLUSH VALVE	KH0017	CAROMA MAINS FLUSH	100	240	**2.1**

*measured above waste

Figure 23: *Innovation Engineering* Fixture Unit Ratings – Test Update Results (Innovation Engineering, 2019)

D.2.2. Average Time of Fixture Discharge for Plugged Fixtures (Bath and Sink)

Assuming sink and bath models similar to those tested by (Innovation Engineering, 2019) are used, the values provided below in Table 63 may be used. It should also be noted that to derive the fixture discharge time of a bath, the volume specified by the fixture model 'NEWBURY 1675 - Grate' in (Innovation Engineering, 2019) (280L) is used, and the flow rate specified by (Wise & Swaffield, 2002) of 1.1 l/s is employed (refer to extract of (Wise & Swaffield, 2002) in Figure 24 below).

If the capacity of the sink or bath is unknown, the volume/capacity of the fixture may be determined using the WELS rating of the tap (to indicate flow rate) and the time of supply. It should be noted that the latter method is more accurate, given that the fixture won't be filled to maximum capacity at every usage.

Table 63: Calculated Fixture Discharge Times for Baths and Sinks using *Innovation Engineering* (Innovation Engineering, 2019) Waste Flow Rates and Volume of Fixture Models Tested

Fixture	Fixture Model	Waste Flow Rate (L/s)	Volume (L)	Fixture Discharge Time (s)
Sink (Plugged)	ADVANCE 1.75[30]	1.05	18.5	17.6
Baths (Plugged)	NEWBURY 1675 - Grate[31]	1.1	280	254.5

Appliance	Interval between uses (s)	Supply		Discharge	
		Flow rate (l/s)	Demand unit	Discharge rate (l/s)	Discharge unit
Washdown WC	1200	0.11	0.9	2.3	7(10)
9 litre flush	600	0.11	1.8	2.3	14(20)
12 mm supply (13 litre in parentheses)	300	0.11	3.6	2.3	28(40)
Washbasin	1200	0.15	0.3	0.6	1
12 mm supply, hot or cold	600	0.15	0.8	0.6	3
30 mm trap	300	0.15	1.5	0.6	6
Bath	4500	0.30	1.0	1.1	7
18 mm supply, hot or cold, 40 mm trap	1800	0.30	3.3	1.1	18
Sink	1200	0.30	1.0	0.9	6
18 mm supply, hot or cold	600	0.30	2.5	0.9	14
40 mm trap	300	0.30	5.0	0.9	27
Group — domestic WC, bath and/or shower, basin and sink*	—	—	—	—	14
Urinal (per unit)	1200	0.004	—	0.15	0.3
Shower	—	0.1	—	0.1	—
Spray tap basin	—	0.05	—	0.05	—

Figure 24: Examples of supply and discharge data (Wise & Swaffield, 2002)

[30] https://www.clark.com.au/products/kitchen/kitchen-sink/advance-175-end-bowl---1th-lhb

[31] https://www.caroma.com.au/bathroom/baths/classic/newbury-1675-bath

D.2.3. Average Time of Fixture Discharge of Unplugged Fixtures (Basins and Showers)

The average time of discharge for an unplugged fixture (F) over a given period of use (ΔT) can be approximated as:

$$t_{d,F,avg,\Delta T} = t_{s,F,avg,\Delta T}$$

Where:

- $t_{d,F,avg,\Delta T}$ is the average time of discharge (s), and
- $t_{s,F,avg,\Delta T}$ is the average time of supply (s).

D.2.4. Summary of Fixture Discharge Time

A summary of the discharge times for each fixture has been provided below in Table 64.

Table 64: Summary of Fixture Discharge Times

Fixture	Testing Condition	Calculated Fixture Discharge Time (s)
Water Closet	Cistern	2.5
Urinal	Cistern	2.8
Sink	Plugged	17.6
Bath	Plugged	254.5
Basin	Unplugged	Equal to average supply time
Shower	Unplugged	Equal to average supply time

D.2.5. Time Interval between Fixture Discharge Events Averaged over Peak Period

The time interval between fixture discharge events of a certain fixture (F) over a given peak period of use (ΔT_P) is determined as:

$$T_{d,F,avg,\Delta T} = \frac{\Delta T_P - \left(t_{d,F,avg} \times Y_{F,\Delta T}\right)}{Y_{F,\Delta T}}$$

Where:

- $T_{d,F,avg}$ is the time interval between consecutive uses of a given fixture F (s) averaged over a peak period, and

- $Y_{F,\Delta T}$ is the number of fixture activations over a given peak period.

Appendix E - Data Analysis

Using the data on peak hourly usage of each fixture per dwelling provided by (Wise & Swaffield, 2002) (refer to Figure 19), and the fixture discharge times calculated in Appendix D.2, average time intervals between fixture discharge events have been calculated, as shown below in Table 65. The fixture discharge of the basin is taken from the value provided in Figure 18 and an average shower time reported of 7 minutes (Bright-R, 2019) is used for this analysis. K-Factors have then been calculated using the formula presented in Section 3.1.

It is worth noting that this example demonstrates, that depending on whether or not fixtures such as the shower and bath are included in the building average for time interval between fixture discharge events, will alter the building average value significantly (9233 versus 3356 seconds respectively), which consequently influences the resultant K-Factor for the building.

Table 65: K-Factor Assessment of an example Residential Building

Appliance	Peak Uses per hour (Residential)	Fixture Discharge Time (s)	Total Discharge Time per Hour (s)	Total fixture idle time per hour (s)	Percentage of Time Fixture is Discharging (%)	Time interval between fixture discharge events averaged of peak period (s)	K-Factor
WC	1.2	2.5	2.98	3597.0	0.1	2997.5	0.32
Basin	1.53	10	15.3	3584.7	0.4	2343	0.36
Shower	0.32	420	134.40	3465.6	3.9	10830	0.17
Sink	0.76	17.6	13.39	3586.6	0.4	4719	0.25
Bath	0.14	254.5	35.64	3564.4	1.0	25460	0.11
Average (All Fixtures)						**9270**	**0.18**
Average (WC, Basin, Sink)						**3353**	**0.30**

Appendix F - NCC Volume 3 2025 Amendments

F.1. C1 Sanitary Plumbing Systems

Proposed amendments to NCC Volume 3 2025 Verification Method for C1 Sanitary Plumbing Systems are documented below. Note that green text refers to additions and red strikethrough refers to deletion.

F.1.1. Frequency Factors

Table C1V1a of NCC 2022 Volume 3 should be amended as shown below in Table 66 with an explanatory note as provided below.

Table 66: Proposed Amendments to Frequency Factor Table for NCC 2022 Volume 3 (Table C1V1a)

NCC Building Class	NCC Building Class Example	Frequency Factor (K)	Time interval between Fixture Use averaged over Peak Period (s)
Class 1	Residential dwelling, duplexes, or townhouses	0.5	1200
Class 2	Apartment or unit	0.5 – 0.8	450 – 1200
Class 3	Hotel, hostel, dormitory	0.6 – 0.8	450 - 800
Class 4	Caretaker’s residence within storage facility	0.5	1200
Class 5	Office or commercial building	0.6 - 0.8	450 - 800
Class 6	Retail, shop, restaurant, café	0.6 - 0.8	450 - 800
Class 7	Carpark, warehouse, storage building	0.6 - 0.8	450 - 800
Class 8	Factory, workshop, laboratory	0.6 - 0.8	450 - 800
Class 9a	Healthcare building, hospital, and GP clinics	0.6 - 0.8	450 - 800
Class 9b	Public event buildings, stadiums, theatres, schools, universities, and churches	1.0 - 1.2	200 - 300
Class 9c	Aged care facilities	0.6 - 0.8	450 - 800

Explanatory Information

The hydraulic practitioner shall use their own judgement to select the frequency factor most appropriate to their design based on the estimated average time between fixture usage during peak periods of use.

F.1.2. Discharge Units

Table C1V1b of NCC 2022 Volume 3 should be amended by removing System III discharge units column from Table C1V1b, and editing Table C1V1b to be as shown below in Table 67.

Table 67: Proposed Amendments to Discharge Units Table for NCC 2022 Volume 3 (Table C1V1b)

Fixture	~~System I~~	Discharge Units (DU)	~~System III~~
Basin	~~0.5~~	0.3	~~0.3~~
Bidet	~~0.5~~	0.3	
Bath (with or without shower)	~~0.8~~	0.6	~~1.3~~

Fixture	System I	Discharge Units (DU)	System III
Washing machine up to 6 kg	0.8	0.6	0.6
Washing machine up to 12 kg	1.5	1.2	
Domestic Dishwasher	0.8	0.6	0.2
Shower (single or per shower head)	0.6	0.4	0.4
Kitchen sink	0.8	0.6	1.3
Urinal – wall-hung (including waterless), stall, or each 600 mm length of slab	0.8	0.5	0.4
Water closet	2	1.8	1.2
Floor Waste Gully (80mm or 100mm)		Sum of DU from connected fixtures	

C1V1b Explanatory Information should be adjusted as show below:

System types referred to in Table C1V1b are as follows:

- System I – A sanitary plumbing system where branch discharge pipes are designed with a filling degree of 50%.
- System III – A sanitary plumbing system where branch discharge pipes are designed with a filling degree of 100%.
- System I and 2 are similar to the fully vented modified system and System III is similar to the single stack system detailed in AS/NZS 3500.2.

Considerations when using Table C1V1b are as follows:

-
- The Discharge Unit (DU) values in Table C1V1b are based on the BS EN 12056.2 System II fixture values where branch discharge pipes are designed with a filling degree of 70%. The use of these fixture values is up to the discretion of the practitioner.
- Filling degree is defined as the ratio between the height of the fluid in a pipe at design flow (h), and the internal diameter of the pipe (D), or h/D.
- Where a washing machine is connected to a sink trap, only the sink discharge unit is considered.
- The practitioner may introduce their own fixture values where a desired fixture type is not listed, or the provided DU value is considered to be outdated. Evidence of engineering best practice, careful consideration and experimentation demonstrating the real-life performance of the fixture(s) compared with the proposed DU values shall be provided.

F.1.3. System Design

- Remove current Sections C1V2 to C1V5 and their content (inclusive), and
- Add the following sizing guidance:

C1V2 System Design using Wastewater Flow Rates

1. Compliance with C1P5 for pipe sizing is verified for the plumbing design when-

a) Full vented systems and fully vented modified systems are designed accordance with Section 8 of AZ/NZS 3500.2,

b) Single stack systems and single stack modified systems are designed accordance with Section 9 of AZ/NZS 3500.2, and

c) Consideration by the designer is given to expanding the exclusion zones references in AS/NZS 3500.2 (1m exclusion zone at the base of the stack) for high rise buildings.

2) For the purposes of (1), for each pipework section, the probable simultaneous wastewater flowrate determined through C1V1 may be converted to an equivalent AS/NZS 3500.2 Fixture Unit (FU) in accordance with the following:

$$FU_{Total} = 6.75Q^2_{Total}$$

3) In the equation shown at (2)-

a) Q = the wastewater flowrate (l/s); and

b) FU = the equivalent fixture units converted from a flowrate (dimensionless)

4) For the purposes of (1), all relevant sizing tables and design guidance referencing FU in AS/NZS 3500.2 may alternatively be converted to an equivalent flow rate using the following:

$$Q = \sqrt{\frac{\sum FU}{6.75}}$$

5) In the equation shown at (4)-

a) $\sum FU$ = the sum of fixture units to be converted (dimensionless)

Explanatory Note

- Fixture units calculated using (2) must be rounded up to the next integer.
- The use of the approach identified in (2) results in all relevant sizing tables and design guidance in AS/NZS 3500.2 for the purpose of (1) to be used directly.

F.2. C2 Sanitary Drainage Systems

Proposed amendments to NCC Volume 3 2025 Verification Method for C2 Sanitary Drainage Systems are documented below. Note that green text refers to additions and red strikethrough refers to deletion.

F.2.1. Frequency Factors

Table C2V3a of NCC 2022 Volume 3 should be amended as shown below in Table 66 with an explanatory note as provided below.

Table 68: Proposed Amendments to Frequency Factor Table for NCC 2022 Volume 3 (Table C2V3a)

NCC Building Class	NCC Building Class Example	Frequency Factor (K)	Time interval between Fixture Use averaged over Peak Period (s)
Class 1	Residential dwelling, duplexes, or townhouses	0.5	1200
Class 2	Apartment or unit	0.5 – 0.8	450 – 1200
Class 3	Hotel, hostel, dormitory	0.6 – 0.8	450 - 800
Class 4	Caretaker's residence within storage facility	0.5	1200
Class 5	Office or commercial building	0.6 - 0.8	450 - 800
Class 6	Retail, shop, restaurant, café	0.6 - 0.8	450 - 800
Class 7	Carpark, warehouse, storage building	0.6 - 0.8	450 - 800
Class 8	Factory, workshop, laboratory	0.6 - 0.8	450 - 800
Class 9a	Healthcare building, hospital, and GP clinics	0.6 - 0.8	450 - 800
Class 9b	Public event buildings, stadiums, theatres, schools, universities, and churches	1.0 - 1.2	200 - 300
Class 9c	Aged care facilities	0.6 - 0.8	450 - 800

Explanatory Information

The hydraulic practitioner shall use their own judgement to select the frequency factor most appropriate to their design based on the estimated average time between fixture usage during peak periods of use.

F.2.2. Discharge Units

Table C2V3b of NCC 2022 Volume 3 should be amended by removing System III discharge units column from Table C2V3b, and editing Table C2V3b to be as shown below in Table 67.

Table 69: Proposed Amendments to Discharge Units Table for NCC 2022 Volume 3 (Table C2V3b)

Fixture	~~System I~~	Discharge Units (DU)	~~System III~~
Basin	~~0.5~~	0.3	~~0.3~~
Bidet	~~0.5~~	0.3	
Bath (with or without shower)	~~0.8~~	0.6	~~1.3~~
Washing machine up to 6 kg	~~0.8~~	0.6	~~0.6~~
Washing machine up to 12 kg	~~1.5~~	1.2	
Domestic Dishwasher	~~0.8~~	0.6	~~0.2~~

Fixture	~~System I~~	Discharge Units (DU)	~~System III~~
Shower (single or per shower head)	~~0.6~~	0.4	~~0.4~~
Kitchen sink	~~0.8~~	0.6	~~1.3~~
Urinal – wall-hung (including waterless), stall, or each 600 mm length of slab	~~0.8~~	0.5	~~0.4~~
Water closet	~~2~~	1.8	~~1.2~~
Floor Waste Gully (80mm or 100mm)		Sum of DU from connected fixtures	

C2V3b Explanatory Information should be relocated to below the table and adjusted as show below:

System types referred to in Table C1V1b are as follows:

- ~~System I – A sanitary plumbing system where branch discharge pipes are designed with a filling degree of 50%.~~
- ~~System III – A sanitary plumbing system where branch discharge pipes are designed with a filling degree of 100%.~~
- ~~System I and 2 are similar to the fully vented modified system and System III is similar to the single stack system detailed in AS/NZS 3500.2.~~

Considerations when using Table C2V3b are as follows:

-
- The Discharge Unit (DU) values in Table C1V1b are based on the BS EN 12056.2 System II fixture values where branch discharge pipes are designed with a filling degree of 70%. The use of these fixture values is up to the discretion of the practitioner.
- Filling degree is defined as the ratio between the height of the fluid in a pipe at design flow (*h*), and the internal diameter of the pipe (D), or h/D.
- Where a washing machine is connected to a sink trap, only the sink discharge unit is considered.
- The practitioner may introduce their own fixture values where a desired fixture type is not listed, or the provided DU value is considered to be outdated. Evidence of engineering best practice, careful consideration and experimentation demonstrating the real-life performance of the fixture(s) compared with the proposed DU values shall be provided.

F.2.3. System Design

- Add the following sizing guidance:

C2V4 Sanitary Drainage Design

1. The design guidance provided within this clause is applicable to main drains and branch drains.

2) Sanitary drainage pipework shall be sized in accordance with AS 2200 to the requirements of-

   a) Clause C2V1; or

   b) C2P1

3) The following limitations shall be applied-

a) The size of the drain shall be of nominal size as specified in Table 3.4.1 of AS 3500.2:2021;

b) The minimum size of a main drain shall be as per Clause 3.3.2 of AS 3500.2:2021;

c) The minimum size of a branch drain shall be as per Clause 3.3.3 of AS 3500.2:2021; and

d) Not more than two water closet pans shall be connected to a vented DN 80 branch drain (Clause 3.3.4 of AS 3500.2).

4) When using the Colebrook-White equation provided in AS 2200-

a) Minimum and maximum pipe grades shall be designed such that (2) is satisfied;

b) The filling degree shall be designed such that (2) is satisfied;

c) The flowrate of the designed drain must be greater than or equal to that calculated in C2V3; and

d) The hydraulic practitioner shall use the following default design values:

i) 1.5mm for pipe roughness; and

ii) $1.01 \times 10{-}6\ m^2s^{-1}$ for kinematic viscosity.

e) The hydraulic practitioner may apply alternative values to suit pipe materials and design life at their own discretion.

Appendix G - Design Guidance Using Verification Method

G.1. General

The purpose of this appendix is to provide design guidance on how to use the sanitary plumbing and drainage verification method (VM) within NCC 2025 Volume Three. High level engineering considerations and workflows are provided for guidance. New design concepts introduced to the VM will be explained in further detail.

The primary feature of the VM is its amalgamation of the two standards:

- *BS EN 12056.2:2000* (B.S. Institute, 2000) – the official English language version of the European Standard EN 12056.2:2000 standard; and
- *AZ/NZS 3500.2:2021* (Standards Australia, 2021) – the standard used to provide the deemed to satisfy solutions for:
    - the National Construction Code (NCC) Volume Three, Plumbing Code of Australia (PCA); and
    - the New Zealand Building Code, Clause G13 Foul Water.

The VM also references the following standard for sanitary drainage pipe sizing:

- *AS 2200:2006* (Standards Australia, 2006) – the standard provides design charts for sizing pipework.

For reference, the flowchart below in Figure 25 identifies the major steps and decisions required by a practitioner when utilising the VM.

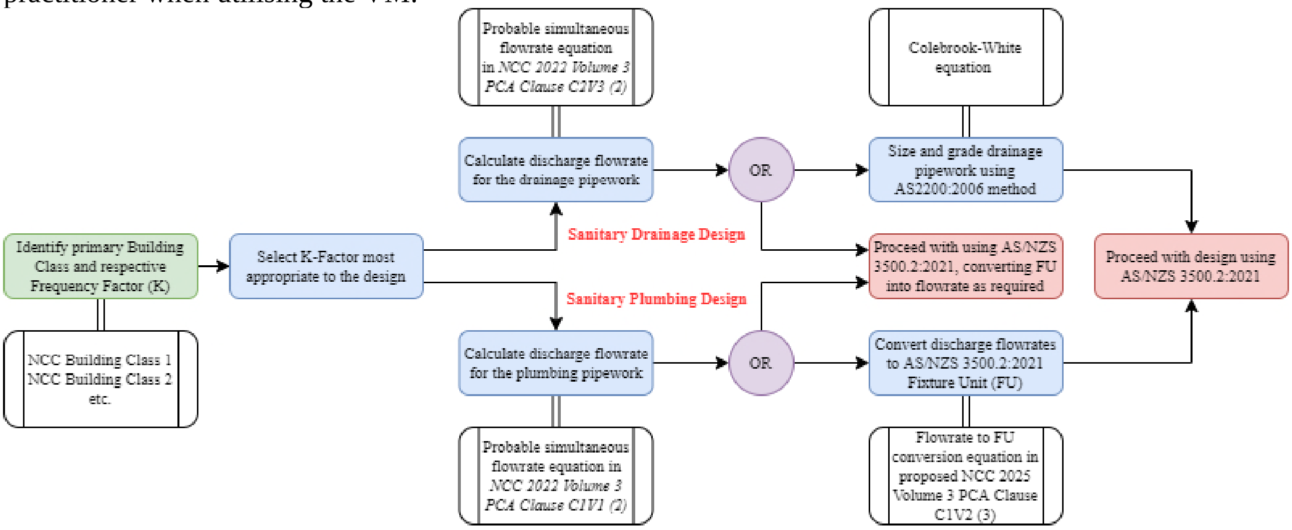

Figure 25: Verification Method Workflow for Sanitary Plumbing and Drainage Designs

In conjunction with the standards identified above, the VM, and the design guidance provided within this appendix, the practitioner should also exercise their own best judgment and hydraulic design experience to design a good sanitary plumbing and drainage system.

The current industry recognised good sanitary system designs and considerations as identified by *CIBSE Guide G* (CIBSE, 2014), *Plumbing Engineering Services Design Guide* (Whitehead, 2002), and *NCC 2022 Volume Three PCA* (Australian Building Codes Board, 2023) are summarised by the ability to achieve following criteria:

- Provide means of discharging and venting sanitary waste from fixtures and appliances in a manner that safeguards the people, public and environment from illness, injury or loss due to a failure within the system.

- Minimise the frequency the any blockage through effective system design with provisions for adequate pipe access for clearance of such blockages.
- Conserve water and energy use through water saving measures, particularly with water intended primarily for human consumption.

It should be noted however, this list is by no means exhaustive, and all the technical guides and codes should be considered in detail when designing the sanitary system.

G.2. Selection of K-Factor

Using Table 4 within Section 3.4, or Table C1V1a of NCC 2022 Volume 3, a range of frequency factors can be selected to design the pipe sizes of the sanitary plumbing and drainage system within a building. Each NCC Building Class has been identified by a separate line item and provided with a short list of examples pertaining to each Building Class. From the respective row, the practitioner has the option to select a K-Factor from within a range that best aligns with the fixture usage profile of their building. The larger the K-Factor value, the shorter the average time between fixture uses. Each decimal increment starting from the lowest value inclusively represents an intermittent, frequent and congested use case. For example, a Class 6 building like a bar may expect more congested use of fixtures and may select a K-Factor of 0.8, whereas another Class 6 building such as a fine dining restaurant may expect more infrequent use of fixtures and may select a K-Factor of 0.6.

Additionally, the selected K-Factor should represent the average time between fixture use that would account for a 99th percentile fixture use case. In other words, the K-Factor should be representative of the peak fixture usage period within a time frame. For a dwelling this peak period may be during the mornings and evenings whereas for a stadium it may be during the intermission of the event. It would be up to the practitioner's judgement to determine when this period takes and whether additional modelling or data taking would be warranted. As a guide, the following technical documents provide some information relating to peak period of hot water use for various building types which is still applies conceptually:

- *CIBSE Guide G* (CIBSE, 2014) – Clause 2.4.2.1 and Figure 2.4
- *Plumbing Engineering Services Design Guide* (Whitehead, 2002) – Figure 8 and Figure 9

The average time between fixture uses have also been provided as a guide for selecting the appropriate frequency factor. It is however imperative to note that the K-Factor is inversely proportional to the average time between fixture use. I.e., a frequency factor of 0.6 would correlate with an average time between fixture use of 800 seconds, a K-Factor of 0.8 would correlate with an average time between fixture use of 450 seconds, and so on.