

DAM BUSTER®

Achieve Compliance & Conformance with **Dam Buster® Products**

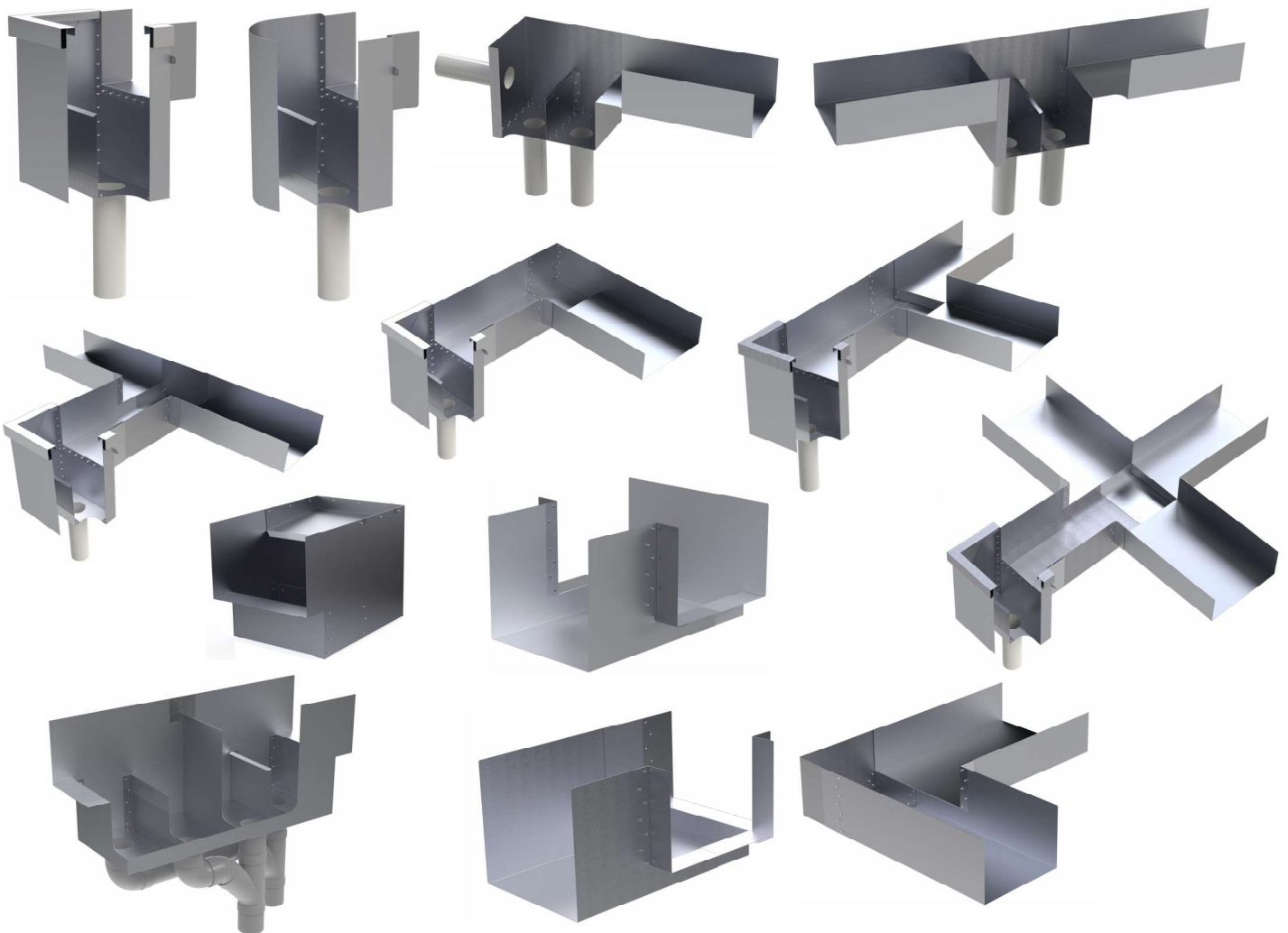
NOTE: All Dam Buster® products are protected by various Australian & International Patents.



This document is to be read in conjunction with the Dam Buster publications titled 'Product Technical Statement' & 'Installation Manual'. Together, these documents form Evidence of Suitability for both the BCA & PCA in accordance with the NCC Governing Requirements parts A5G2, A5G3 & A5G4.

EVIDENCE OF SUITABILITY

Version 6.2 (21 February 2025)



CERTIFIED PRODUCT (DAM BUSTER RAINHEAD)

For testing the Overflow Performance of Dam Buster rectangular rainheads.



**GOOD
DESIGN
AWARD®
WINNER 2018**

**PRODUCT DESIGN
HARDWARE AND BUILDING
DAM BUSTER
RAINHEAD**

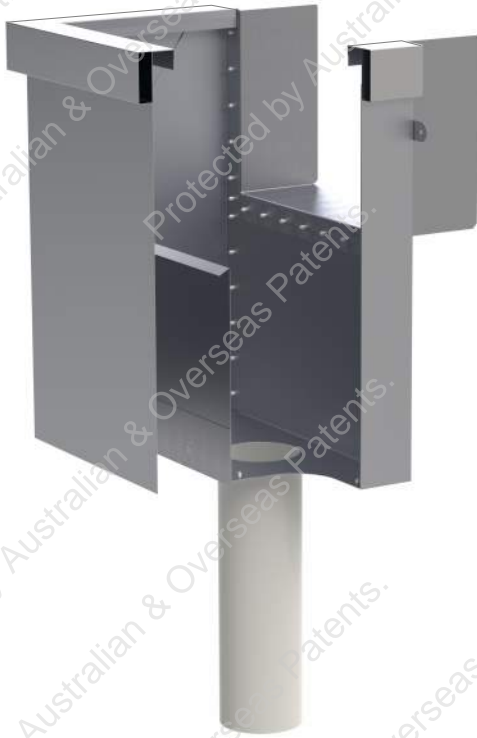
"The Architectural Choice"

www.dambuster.com.au

Dam Buster Roof Drainage System - Product Range

Overflow devices (1 of 2)

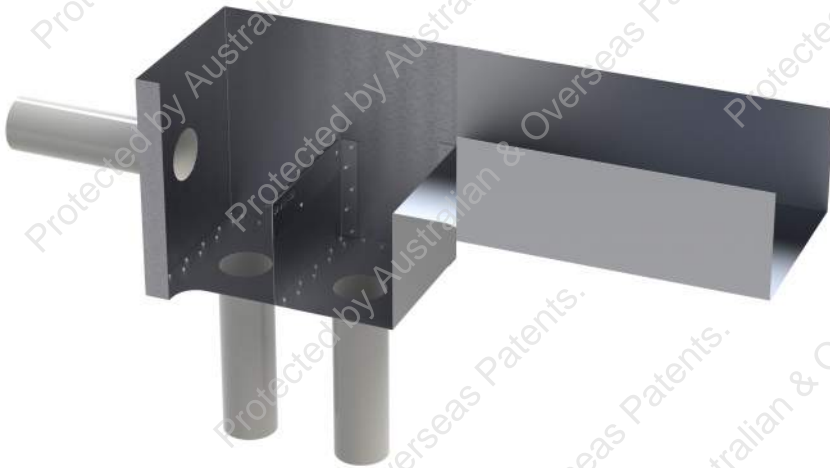
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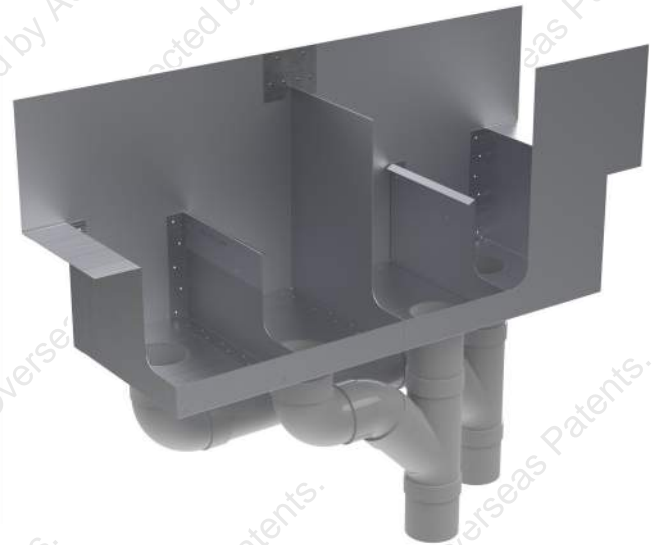
Dam Buster Rainhead



Dam Buster Curved Fronted Rainhead



Dam Buster Sump



Dam Buster Back-to-Back Sump

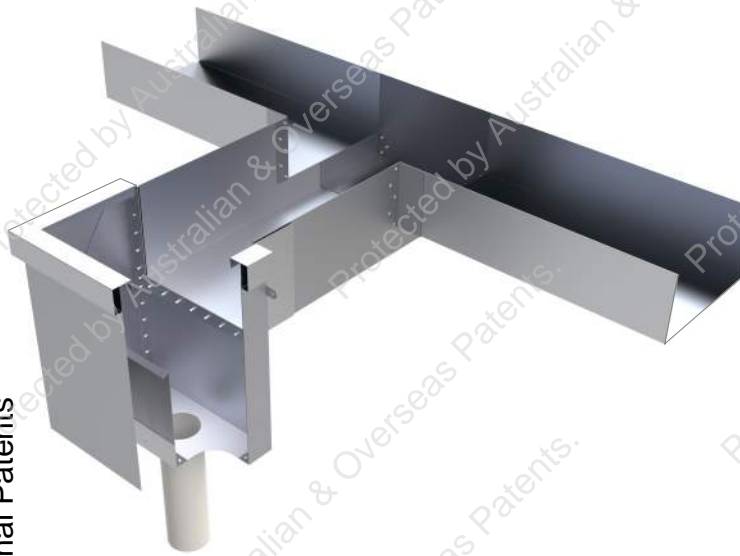


Dam Buster Continuous Sump

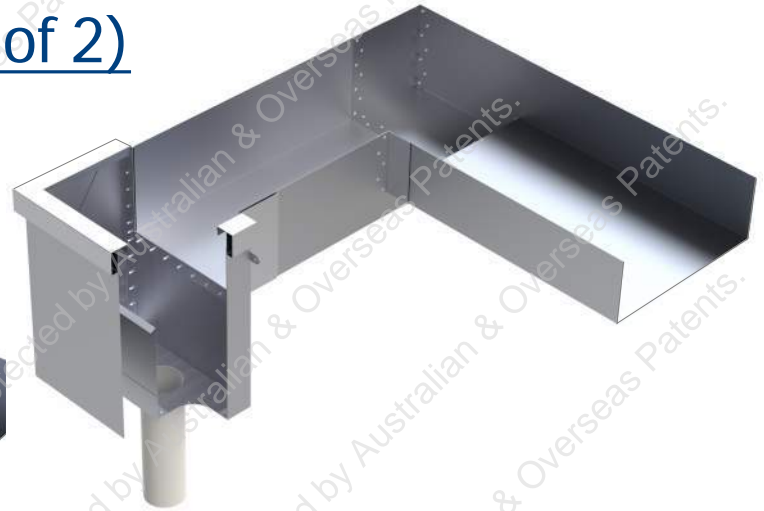
Dam Buster Roof Drainage System - Product Range (cont)

Overflow devices (2 of 2)

Protected by various Australian and International Patents



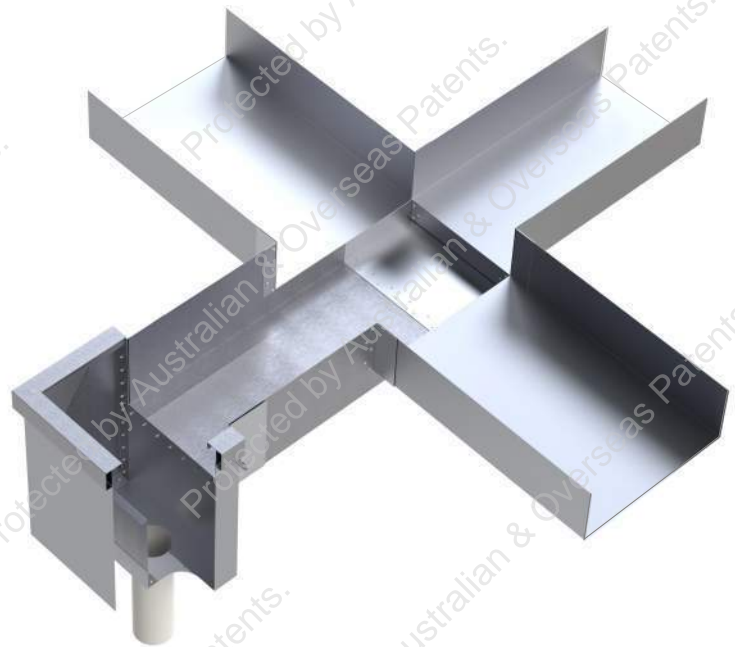
Dam Buster T Side Outlet & Rainhead



Dam Buster END Side Outlet & Rainhead (LH & RH forms available)



Dam Buster CORNER Side Outlet & Rainhead (LH & RH forms available)



Dam Buster CRUCIFORM Side Outlet & Rainhead



Dam Buster END Side Outlet & Sump (LH & RH forms available)

NOTE

The following Side Outlet & Sump combinations are also possible

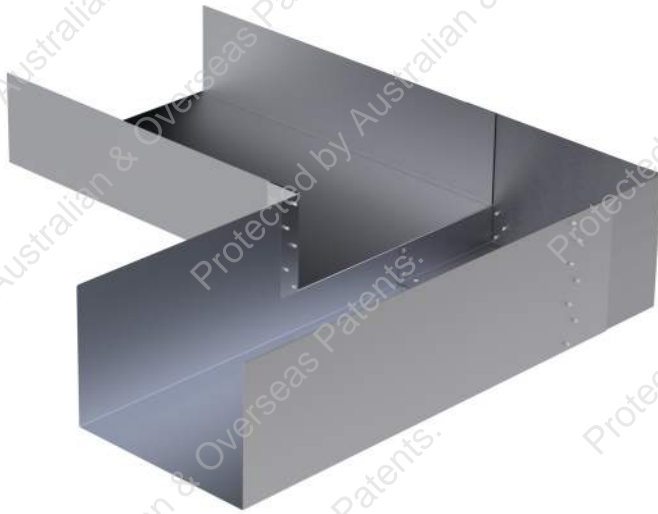
Dam Buster T Side Outlet & Sump

Dam Buster Corner Side Outlet & Sump

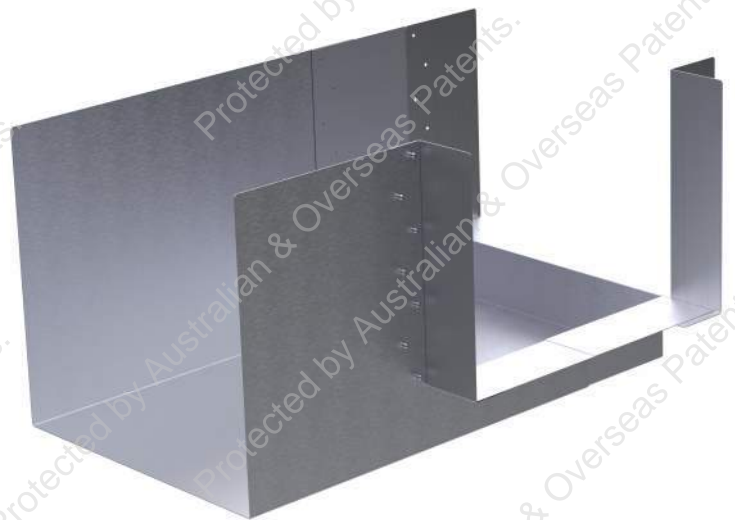
Dam Buster Cruciform Side Outlet & Sump

Dam Buster Roof Drainage System - Product Range (cont)

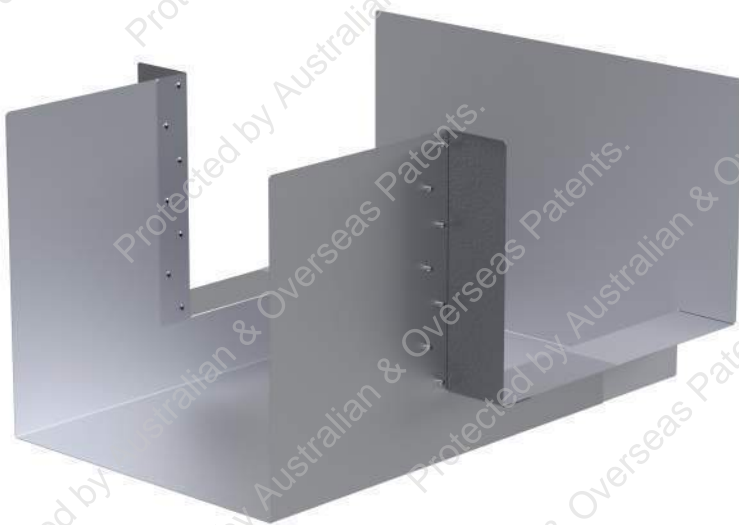
Upstream devices



Dam Buster Elbow



Dam Buster Corner Junction



Dam Buster T Junction



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NOTE

Where this document refers to any code, guide or manual, this reference should be interpreted as being for the current legal version of the code, guide or manual for the relevant state or territory, unless noted otherwise.



1.0 DAM BUSTER PRODUCTS

The components which form the Dam Buster Roof Drainage System can be used in both domestic (including multi-residential) and commercial roof plumbing applications.

Dam Buster products are comprised of Zinalume, Colorbond or other approved metal materials suitable for use in domestic and/or commercial roof drainage systems.

Models:

- Dam Buster **Rainhead**
- Overflow device comprising a **Dam Buster Side Outlet** (4 available types) and a **Dam Buster Rainhead** or a **Dam Buster Sump**
- Dam Buster **Sump, Continuous Sump** and '**Back-to-Back**' **Sump** ('free flow' sumps)
- Dam Buster **Elbow** & Dam Buster **Junctions** (2 available types)

2.0 COMPLIANCE WITH THE NCC

2.1 Governing requirements and Compliance Solutions

In all states and territories, roof drainage falls under the relevant sections of the NCC volumes 1 and 2 (i.e. the Building Code of Australia or BCA). However, in Victoria and Tasmania (only) there are state additions for roof drainage within the NCC Volume 3 (i.e. the Plumbing Code of Australia or PCA), enabling roof drainage to also be carried out as regulated plumbing work under the relevant state Plumbing Regulations.

There are different pathways through the NCC, but in all cases it is necessary to comply with both the **Governing Requirements** and the relevant **Performance Requirements** (which differ, but are similar, between the BCA and the PCA). Note that the Part A Governing Provisions of the NCC is the same for each volume.

Part A2 of the NCC, titled '**Compliance with the NCC**' explains the possible methods of demonstrating compliance with the NCC. It explains the various '**Compliance Solutions**' available, and the appropriate steps that must be taken for each of these pathways. Part A2 includes the following chapters:

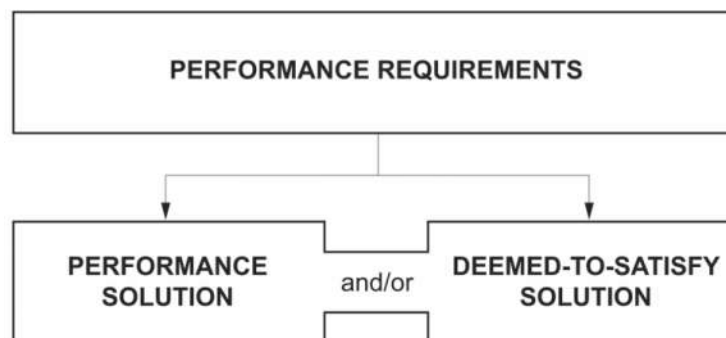
- A2G1 Compliance
- A2G2 Performance Solutions
- A2G3 Deemed-to-Satisfy Solution
- A2G4 A combination of solutions



2.2 **Part A2G1 Compliance**

Part A2G1 states:

- (1) Compliance with the NCC is achieved by complying with-
 - (a) the Governing Requirements of the NCC; and
 - (b) the *Performance Requirements*
- (2) *Performance Requirements* are satisfied by one of the following, as shown in Figure A2G1:
 - (a) Performance Solution
 - (b) Deemed-to-Satisfy Solution
 - (c) A combination of (a) and (b)



2.3 **Part A2G2 Performance Solution**

Part A2G2 Performance Solution states:

- (1) A *Performance Solution* is achieved by demonstrating –
 - (a) compliance with all relevant *Performance Requirements*; or
 - (b) the solution is at least equivalent to the *Deemed-to-Satisfy Provisions*
- (2) A *Performance Solution* must be shown to comply with the *Relevant Performance Requirements* through one or a combination of the following *Assessment Methods*:
 - (a) Evidence of suitability in accordance with Part A5 that show the use of material, product, plumbing and drainage product, form of construction or design meets the relevant *Performance Requirements*



- (b) A *Verification Method* including the following:
 - i. The *Verification Methods* provided in the NCC
 - ii. Other *Verification Methods*, accepted by the appropriate authority that show compliance with the relevant Performance Requirements
- (c) Expert Judgement
- (d) Comparison with the *Deemed-to-Satisfy Provisions*

Section (4) of A2G2 provides details of the **Performance Solution Process** that is required to be followed when preparing a Performance Solution. The four main steps for this process are:

1. Prepare a **Performance Based Design Brief ('PBDB')**
2. Carry out an analysis
3. Evaluation the results
4. Prepare a **Final Report**

As discussed in section 3.2 of this document, it may be necessary to use Dam Buster products under a Performance Solution. However, Dam Buster has prepared Performance Solution templates for the PBDB and Final report, which make this process straightforward.

2.4 Part A2G3 Deemed-to-Satisfy Solution

Part A2G3 Deemed-to-Satisfy Solution states:

- (3) A solution that complies with the *Deemed-to-Satisfy Provisions* is deemed to have met the Performance Requirements.
- (4) A *Deemed-to-Satisfy Solution* can show compliance with the *Deemed-to-Satisfy Provisions* through one or more of the following *Assessment Methods*:
 - (a) Evidence of suitability in accordance with Part A5 that shows the use of a material, product, *plumbing* and *drainage product*, form of construction or design meets a *Deemed-to-Satisfy Provision*
 - (b) Expert Judgement**



3.0 COMPLIANCE OF THE DAM BUSTER BOX GUTTER SYSTEM

3.1 Compliance of BOX GUTTERS discharging to a Dam Buster device

Box gutters discharging to all Dam Buster devices operate under 'free flow' in both the normal flow and overflow conditions. This means that all box gutters discharging to Dam Buster box gutter overflow devices must be designed in accordance with Appendix H, Figure H.1 of AS/NZS 3500.3-2021 in order to be certified as Deemed to Satisfy (DtS) solutions suitable for use with Dam Buster's free flow products.

The design of the upstream box gutter discharging to a Dam Buster Elbow is slightly different; it is designed for a flow rate equivalent to the total catchment area of the roof sections discharging to both the upstream and downstream box gutters, however it is still designed in accordance with Figure H.1. Note, it is not necessary to design the downstream box gutter from the Dam Buster Elbow, as it will automatically comply with Figure H.1 due to its increased depth as a direct result of the vertical drop within the Elbow. The Dam Buster Junctions are however designed slightly differently - please refer to the Product Technical Statement.

Note that all box gutters discharging to Dam Buster devices must be designed for a minimum of 3L/s and a maximum flow rate of 16L/s. If the calculated flow rate is less than 3 L/s, the minimum design flow rate of 3L/s should be adopted instead. Where more than one box gutter discharges into a Dam Buster box gutter overflow device, the overflow device is designed for the total of the actual design flows, but again not less than 3L/s.

The fact that all box gutters discharging to Dam Buster devices operate under free flow in both the normal flow and overflow conditions allows them to be designed 'independently' of the device itself.

In summary, all box gutters (which have been correctly designed for 'free flow' in accordance with Figure H.1, Appendix H, of AS/NZS 3500.3) utilised in conjunction with correctly sized and installed Dam Buster products are Deemed-to-Satisfy Solutions (unless otherwise covered by a separate box gutter Performance Solution, if necessary).



3.2 Compliance Solutions for Dam Buster DEVICES

Compliance of Dam Buster devices can be achieved by using either of the following **Compliance Solutions**:

1. Part A2G3(2)(b) – Deemed-to-Satisfy ('DtS') by Expert Judgement

OR

2. Part A2G2 – Performance Solution

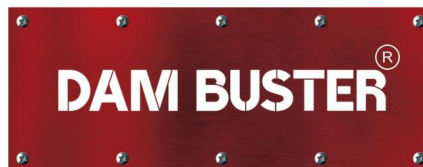
The first method, DtS by Expert Judgement, is preferred, however, if not accepted by the Regulatory Authority and / or Building Surveyor / Certifier, second method, Performance Solution can be used.

3.3 Compliance of Dam Buster DEVICES via Expert Judgement

All Dam Buster devices themselves have been certified as **Deemed-to-Satisfy by Expert Judgement** under part A2G3 (2)(b). Refer to section 6 for details of Dam Buster's hydraulics expert, Adjunct Associate Professor Robert Keller ('Keller').

Keller has reviewed the Dam Buster Box Gutter System, and prepared a number of expert opinions, based on the following:

- Physical testing of Dam Buster rainheads in the overflow condition by Associate Professor Dr. Terry Lucke, AHSCA Research Foundation.
- Physical testing of Dam Buster devices, carried out by Dam Buster, under the supervision of Keller.
- Analyses of Dam Buster devices using hydraulics theory
- Comparison of the physical testing results with the analyses using hydraulics theory
- Benchmark comparison of Dam Buster device with the three DtS box gutter overflow devices in AS/NZS 3500.3, i.e.
 - Rainhead
 - Sump and Side Outlet
 - Sump / High-Capacity Overflow device
- Assessment of whether the Dam Buster devices comply with the general principles in AS/NZS 3500.3



3.4 Compliance of Dam Buster DEVICES via Performance Solution

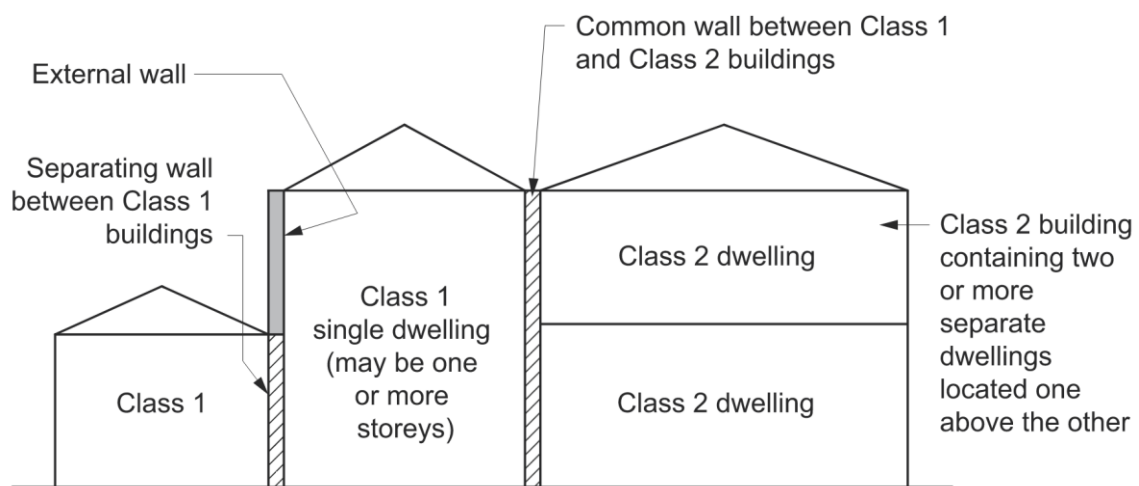
In order to simplify the Performance Solution Process, Dam Buster has prepared the following templates, which may be downloaded from the website.

Performance Based Design Brief template

- This may be used for all volumes of the NCC
- It applies to all classes of buildings

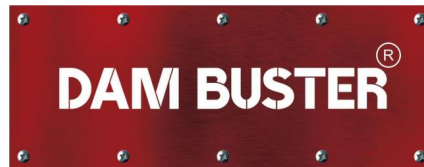
Final Report templates

- The Performance Requirements between the different volumes of the NCC are similar, with some variations. Final report templates are available for
 - BCA Volume 1 – Class 2 to 9 buildings
 - BCA Volume 2 – Class 1 and Class 10 buildings
 - PCA (Victoria)
 - PCA (Tasmania)
- Notes-
 - Individual houses, including townhouse are Class 1
 - Where individual dwellings are located above or below other individual dwellings, they become Class 2, as shown below:



Class 1 & Class 2 dwellings

Refer to page 25 of Dam Buster's Quick Design Guide for a summary of the steps required in the **Performance Solution Process**.



4.0 TECHNICAL APPRAISAL OF THE DAM BUSTER ROOF DRAINAGE SYSTEM BY ADJUNCT ASSOCIATE PROFESSOR DR ROBERT KELLER

Adjunct Associate Profess Dr Robert Keller ('Keller') has prepared numerous expert opinions on Dam Buster's devices over a number of year, as product development proceeded.

Once product development was essentially completed (i.e. no additional device types were anticipated), Keller prepared a very detailed document titled:

'Technical Appraisal – Assessment of Dam Buster Roof Drainage Products for Box Gutters', February 2004 ('the Technical Appraisal').

Refer to Appendix A for a copy of this document.

The Technical Appraisal includes a very detailed comparison of Dam Buster's devices to AS/NZS 3500.3-2021 ('3500.3') and Addendum 1 of the technical Appraisal reviews Dam Buster's devices in relation to 3500.3 in a tabulated format.

Addendum 2 of the Technical Appraisal is Dam Buster's Product Technical Statement ('PTS'), version 6.0 (19 February 2024), which was current at the time of preparation of Keller's advice. Minor changes have been made to the Dam Buster Roof Drainage System since the Technical Appraisal was prepared, and the PTS has been updated accordingly. Version 6.0 of the PTS is not included in Addendum 2 of the Technical Appraisal in Appendix A, however, this document is available upon request.

Keller's Technical Appraisal makes reference to his previous opinions, however, as these opinions contain commercially sensitive information, they are not included within the Technical Appraisal.

A condensed / simplified explanation of the key principles with the Technical Appraisal is provided in the following sections.



4.1 Hydraulic operation

- All Dam Buster devices operate under 'Free flow' in both the 'design flow' and 'overflow' conditions. This compares to the three prescribed DtS devices as follows:
 - *Rainhead*
 - Free flow in the design flow and overflow conditions
 - *Sump & Side Outlet* ('SSO') and *Sump / High-Capacity Overflow* ('HCO') devices:
 - Free flow in the design flow condition
 - Backwatering is required in the overflow condition. This flow regime is hydraulically very complicated.

Consequently, the nature of the flow within Dam Buster's devices is not as complex as the SSO and HCO devices.

- 3500.3 requires that the overflow capacity be at least equal to the design flow capacity. All Dam Buster overflow devices have an overflow capacity at least equal to (or greater than) their design flow capacity.

4.2 Design flow range

- 3500.3 is limited to a maximum of 16 L/s.
- All Dam Buster devices are designed for:
 - A minimum of 3 L/s
 - A maximum of 16 L/s
- Dam Buster adopts the philosophy that for flows less than 3 L/s, the device is designed for 3L/s. 3500.3 does not specifically state that the minimum design flow is 3L/s, however, in general, solutions are only provided for flow between 3 L/s to 16 L/s. The Victorian Building Authority (VBA) has also endorsed this approach in recent webinars and fact sheets.



4.3 Sizing

- 3500.3 requires the width of box gutters to be in the range 200mm to 600mm
- The width of all Dam Buster products is also in the range 200mm to 600mm.
- It is noted that 3500.3, clause 3.7 Box Gutter Systems, sub-clause 3.7.3 *Limitations*, NOTE 3, states *'The minimum width of box gutters used for commercial construction is 300mm. Box gutters 200mm wide may be used for domestic construction, but they are more prone to blockages. Additional height is recommended where possible.'* This clause implies the higher risk of blockage in a narrower gutter can be mitigated by adopting a deeper box gutter (than required).
- This is essentially the philosophy adopted in the design of the DB *Side Outlet, Elbow and Junction* devices i.e. the *'Downstream'* or *'Outlet'* box gutter is significantly deeper than that required by Figure H.1 of 3500.3 in recognition of the possible increased risk in blockage due the effective change in direction. However, this risk is also mitigated by the step in the device itself, due to the turbulence created within the open sided *'sump'*.
- The depth of the *'Downstream'* box gutter is greater than the depth of the *'Upstream'* box gutter by the height of the step in the above noted device.
- Analyses show that backflow cannot occur within the *'Upstream'* box gutter.
- As a consequence of the above noted geometrical constraints, and design philosophy, the freeboard in the *'Downstream'* box gutter (excluding the device itself) is greater than that implied when designed in accordance with Figure H.1 of 3500.3 by an amount which is equal to, or greater than, the height of the step in the device, plus the fall in the *'Upstream'* box gutter.
- As a further consequence of the above noted geometrical constraints and design philosophy, the depth of the *'Downstream'* box gutter (excluding the device itself) automatically exceeds the depth required by Figure H.1 of 3500.3.



4.4 Dam Buster Rainhead

In the design flow condition, the Dam Buster rainhead is designed and constructed in accordance with 3500.3, Figures H.1, H.2 and H.3. The construction of the Dam Buster rainhead, having a box gutter receiver, also facilitates a compliant seal (in accordance with section 4 *Installation of 3500.3*) between the box gutter and the rainhead. It is noted that, in practice, box gutters are typically either not sealed to the rainhead, or not sealed in a compliant manner.

With reference to Figure H.2, NOTE 4 requires *the front of the rainhead to be left open above the overflow weir*. The Dam Buster rainhead complies with this requirement.

There are no other design restrictions specified in 3500.3.

Testing of Dam Buster Rainheads by the AHSCA Research Foundation

Independent testing of all Dam Buster rainheads was carried out by the AHSCA Research Foundation ('AHSCA-RF') at the stormwater research facility located at the University of the Sunshine Coast, Queensland. This testing was primarily for the overflow capacity of the rectangular rainheads, and all Dam Buster rectangular rainheads achieved overflow rates of at least 16 L/s.

The normal flow capacities of all Dam Buster rainheads have been determined in accordance with AS/NZS 3500.3 ('3500.3'), and the flow capacities have also been checked and independently certified by Dr Keller, in addition to the certifications issued by the AHSCA-RF.

Overflow Performance Test Certificates issued by Dr Terry Lucke and Mark Alexander are available on the AHSCA Research Foundation's website at the following web address:

<https://www.ahscaresearch.com.au/dam-buster-rainheads/>

NOTE: The AHSCA-RF also tested the 200-1 rainhead for normal flow capacity with a 100x50mm DP since although 3500.3 permits the usage of this size DP, the 3500.3 design charts have not been updated to include this size.

In summary, the Dam Buster rainhead complies with all the requirements of 3500.3 and is therefore considered to be DtS by Expert Judgement.



4.5 Dam Buster Sump

The Dam Buster Sump could be considered in general terms as an 'internal rainhead'.

In the design flow condition, the Dam Buster *Sump* operates in the same manner as a Rainhead.

In the overflow condition, the Dam Buster *Sump* operates in the same manner as a *Sump* to Figure H.4. Testing has confirmed that the overflow capacity of the Dam Buster *Sump* exceeds its design flow capacity.

The Dam Buster *Sump* has the following additional safety features:

- A minimum downpipe size of 100mm is adopted (even when a 90mm downpipe is hydraulically adequate)
- Where possible, an 'overflow indicator' is added by the installer. The purpose of this is to alert the building owner or occupant of the (unlikely) event that both the design and overflow downpipes are blocked, and also acts as a secondary overflow to a certain degree (but significantly less than the design flow)

In summary, the Dam Buster sump complies with all the requirements of 3500.3 and is therefore considered to be DtS by Expert Judgement.

4.6 Dam Buster Continuous Sump

The Dam Buster continuous sump is simply a series of Dam Buster Sumps connected in sequence. An additional safety feature is provided – the end wall of the overflow compartment, and the upstream wall of the next sump in the series are both cut down by 60mm (which is twice the freeboard specified in 3500.3), such as to allow overflow from the box gutter into the next sump in the series, if necessary.

4.7 Dam Buster Back-to-Back Sump

The Dam Buster Back-to-Back Sump is simply two Dam Buster Sumps joined back-to-back. The rear walls of the overflow compartments are also cut down by 60mm as an additional safety feature.



4.8 Change of Direction – Dam Buster Side Outlets, Elbows & Junctions

- 3500.3 states that:
 - Box gutters must be straight, without change in direction
 - Box gutters must discharge to a sump or a rainhead
- Correctly installed, all box gutters discharging to, and discharging from, a Dam Buster device are straight, and do not change direction.
- As discussed above, the Dam Buster *Side Outlet*, *Elbow* and *Junction* devices are considered to be shallow, open sided sumps, not box gutters, with the deeper '*Downstream*' or '*Outlet*' box gutter discharging through the one open side wall in the 'sump'. Critically, the open sided 'sump' component itself is entirely designed to facilitate an engineered change of direction and thereby transfer discharge from the (straight) '*Upstream*' box gutter to the (straight) '*Downstream*' box gutter. The open sided 'sump' is therefore not designed to retain any water.
- There are two critical aspects of the hydraulic design and operation of the above noted devices, as follows:
 - The depth of the 'sump' or 'step' into the device must exceed the energy loss which occurs within the device due to the change of direction being facilitated. Testing, as well as hydraulic analyses, confirms that this is true for all these devices.
 - The minimum required freeboard within the box gutter and device must be maintained at all locations within the device. Testing, as well as hydraulic analyses, also confirms this to be true for all these devices.

In summary, the *Side Outlet*, *Elbow* and *Junction* devices safely **facilitate** a change in direction, however critically the *Upstream* and *Downstream* box gutters **do not change direction** or contravene 3500.3 in any way. **All box gutters are straight and discharge to either rainheads or sumps***

* The Dam Buster Side Outlet, Elbow and Junction devices are all considered to be open ended sumps.

4.3.9 Summary

Keller's opinions include detailed comparisons of Dam Buster's devices with the DTS provisions within AS/NZS 3500.3 (i.e. for the design of box gutters and overflow devices within this standard). These comparisons indicate that Dam Buster devices are as safe as the DTS provisions.

In particular, it is demonstrated that the freeboard is always at least equal to, or greater than, the freeboard required by the standard. Additionally, the overflow capacity of Dam Buster's box gutter overflow devices significantly exceeds the normal flow capacity in all cases.

5.0 RESPONSIBILITY OF INSTALLING PLUMBER

It is the licensed roof plumber's responsibility to certify all works associated with the installation of the box gutters and Dam Buster devices in accordance with the specific requirements of that State or Territory.

6.0 DAM BUSTER'S EXPERT

Dam Buster's Expert, Adjunct Associate Professor Dr Robert Keller of Monash University. Dr Keller is a highly reputable hydraulic engineer with the qualifications and experience to determine that the Dam Buster roof drainage system devices meet the relevant Performance Requirements of the NCC. Dr Keller has over forty years of experience in Civil Engineering Hydraulics. Currently a consulting engineer, his main areas of expertise are steady and transient flow analyses of pipe network systems, physical and numerical modelling of river works and hydraulic structures, river stability, bank and bed protection, scour studies, and urban storm drainage analyses. He has conducted many technical courses for practising engineers in Australia, New Zealand and Southeast Asia.



Adjunct Associate Professor Dr Robert Keller

Dr Keller was previously an Associate Professor at Monash University, retiring in 2008, and is currently an Adjunct Associate Professor at Monash University who continues to consult in his area of expertise. Dr Keller is the author or co-author of over 120 technical papers in addition to numerous consulting reports and has received various honours and awards for his work.

7.0 EVALUATION METHODS

This Evidence of Suitability applies to all sizes of the following components of the Dam Buster Roof Drainage System:

- A. Dam Buster **Rainhead** overflow device
- B. Overflow device comprising a Dam Buster **Side Outlet** (4 available types) and a Dam Buster **Rainhead** or **Dam Buster Sump**
- C. Dam Buster **Sump**, Dam Buster **Continuous Sump** or Dam Buster **Back-to-Back Sump** overflow devices
- D. Dam Buster **Elbow** & Dam Buster **Junctions**

Testing of Dam Buster Rainheads by the AHSCA Research Foundation

Independent testing of all Dam Buster rainheads (product A above) was carried out by the AHSCA Research Foundation ('AHSCA-RF') at the stormwater research facility located at the University of the Sunshine Coast, Queensland. This testing was primarily for the overflow capacity of the rectangular rainheads, and all Dam Buster rectangular rainheads achieved overflow rates of at least 16 L/s.

The normal flow capacities of all Dam Buster rainheads have been determined in accordance with AS/NZS 3500.3 ('3500.3'), and the flow capacities have also been checked and independently certified by Dr Keller in addition to the certifications issued by the AHSCA-RF.

Overflow Performance Test Certificates issued by Dr Terry Lucke and Mark Alexander are available on the AHSCA Research Foundation's website at the following web address:

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NOTE: The AHSCA-RF also tested the 200-1 rainhead for normal flow capacity with a 100x50mm DP since although 3500.3 permits the usage of this size DP, the 3500.3 design charts have not been updated to include this size.



Testing of Dam Buster box gutter overflow devices B and C by Dr Keller

Dam Buster P/L carried out testing of overflow devices B (overflow device comprising a Dam Buster Side Outlet and a Dam Buster Rainhead) and C (Dam Buster Sump) in a custom built flow test rig located in Clayton, Victoria and assembled by Dam Buster P/L.

The flow rates were measured using a Flexim Fluxus F601 ultrasonic transit time flow meter, sourced from PriCam Automation P/L, and installed by a technical representative from this company. The flow meter has a stated accuracy of +/- 1%.

All testing was independently supervised and witnessed by Dr Keller, and this testing formed the basis of his Expert Opinion for devices B and C.

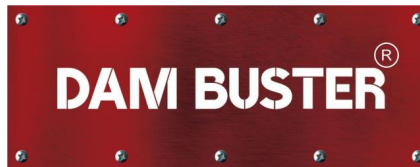
Evaluation of Dam Buster device D (Dam Buster Elbow) by Dr Keller

Development of device D (the Dam Buster Elbow) was initiated on the basis of the results of the physical testing of the Dam Buster device C, as the Elbow is hydraulically similar to the Side Outlet device B.

A numerical analysis of the Dam Buster Elbow was carried out by Dr Keller to ensure backwatering (i.e. the impeding of hydraulic free flow) could not occur in the Dam Buster Elbow. The calculations demonstrated that the head loss in the bend is always significantly less than the step down / 'drop' between the 'upstream' (or 'upper') and the 'downstream' (or 'lower') box gutter. This modelling and analysis by Dr Keller formed the basis of the certification and constraints associated with the usage of the Dam Buster Elbow device.

Physical testing of device D was later carried out in a purpose-built test rig located in Kalorama (Victoria), and the flow rates were also measured using the same instrument as for devices B and C. This testing was supervised and witnessed by Dr Keller.

The physical testing produced results which aligned well with the theoretical hydraulic analyses by Dr Keller. Of particular interest was the maximum water level in the Elbow, which occurred at and near the outer corner of the Elbow where the water changes directions (i.e. immediately downstream of the step down, at the Elbow wall impacted by the discharge).



An analysis of the water level at this location, taking into account Dam Buster's design criteria and Elbow geometry, identified that the freeboard at this critical design location was more than satisfactory, and well within the expectations of 3500.3. The detailed review and commentary of the Elbow by Dr Keller also considered the potential effects of debris within the gutter and noted that "*the turbulence generated by the drop was expected to assist with preventing debris from accumulating in the Elbow and clearing debris in the Elbow*".

8.0 MANUFACTURE OF DAM BUSTER PRODUCTS

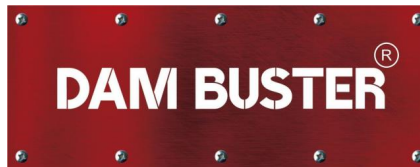
All Dam Buster licensed manufacturers are subject to strict manufacturing requirements, and Dam Buster maintains close communication with its fabricators to provide technical assistance, and also to ensure that a high quality of the Dam Buster products is maintained. All manufacturing and assembly is carried out in Australia using Australian BlueScope steel products. Sealed aluminium rivets used in assembly of Dam Buster products. All Dam Buster products carry clear identification.

9.0 DESIGN & INSTALLATION OF DAM BUSTER PRODUCTS

Design of Dam Buster products should only be carried out in accordance with the **Product Technical Statement** by competent users of AS/NZS 3500.3.

All Dam Buster products must be installed strictly in accordance with the **Dam Buster Roof Drainage System Installation Manual** and the associated box gutters must all be installed in accordance with all relevant codes and standards, as prescribed by the relevant state or territory.

Failure for the Dam Buster devices not to be selected / designed as specified above, or failure to install the devices in accordance with Dam Buster's Installation Manual, will void any warranty on the Dam Buster products and further, Dam Buster Pty Ltd and Dam Buster IP Pty Ltd will not be responsible for any losses whatsoever arising from such failure/s, no matter what their nature, nor how caused.



10.0 LIMITATIONS AND CONDITIONS

Dam Buster products are designed for use in strict compliance with all relevant Australian and New Zealand standards including, but not restricted to, AS/NZS 3500.3. They must not be used for any other purpose or in any way except as permitted in the publication titled '*Dam Buster Product Technical Statement*'. It is the responsibility of the roof plumber and builder to ensure full compliance with this document and with all relevant Australian and New Zealand standards.

11.0 INTELLECTUAL PROPERTY AND KNOW-HOW

Dam Buster is a registered Trademark both in Australia and Overseas, and all Dam Buster products are also protected by a comprehensive range of Australian and Overseas patents. Breaches of Intellectual Property and Know-How rights are serious and will be pursued by Dam Buster Pty Ltd / Dam Buster IP Pty Ltd against any infringers.

With the exception of the AHSCA-RF Overflow Performance Certificates, Dam Buster has chosen not to make testing data, and the various associated Expert Opinions prepared by Keller publicly available, due to this being confidential information. Note that Keller's expert opinions are referred to in his Technical Appraisal of the Dam Buster Roof Drainage System but are not included within this document.

Appendix A

DAM BUSTER ROOF DRAINAGE SYSTEM

Technical Appraisal – Assessment of Dam Buster Roof Drainage
Products for Box Gutters

prepared by

Adjunct Associate Professor Dr Robert Keller – February 2024

DAM BUSTER ROOF DRAINAGE SYSTEM

Technical Appraisal – Assessment of Dam Buster Roof Drainage Products for Box Gutters

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February 2024

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1 Introduction

- 1.1 The purpose of this technical appraisal is to assess the Dam Buster ('DB') roof drainage products for box gutters by making detailed comparisons with the design of box gutter systems to AS/NZS 3500.3:2021 *Storm water drainage code* ('3500.3'). This appraisal:
- (i) Assesses to what extent Dam Buster products comply with the key hydraulic principles and limitations of 3500.3.
 - (ii) Assesses and comments on the extent to which the Dam Buster products fall outside the limitations or scope of 3500.3, noting that the products are innovative.
 - (iii) Confirms that the design methodology for the Dam Buster products is hydraulically sound and that the design tables and procedures are correct.
 - (iv) Comments, to the extent possible, on the safety of the Dam Buster products compared with the safety of box gutter systems designed to 3500.3.
- 1.2 To assess the Dam Buster devices with respect to 3500.3, it has been necessary to carry out a review of technical papers relating to the formulation of design criteria and limitations associated with 3500.3. Much of this information is not referenced within the code itself. Section 2 of this appraisal comprises a discussion of the key hydraulic principles and limitations of 3500.3. It is noted that most of the research and development leading to 3500.3 was carried out in the 1990's. The major contributions were made by Dr. Ralph Jones with other key contributions from Dr Geoffrey O'Loughlin and Dr Simon Beecham. The key research elements are summarised in Section 3.
- 1.3 This appraisal is intended to form the basis of assessment of Dam Buster products in relation to compliance with the National Construction Code, the current version of which is NCC-2022.
- 1.4 The writer does not have specific expertise in building regulation or building surveying in Australia. However, the following is understood:
- The National Construction Code, NCC-2022 comprises the following volumes:
 - NCC Volume 1 i.e. BCA Volume 1 (i.e. Building Code of Australia v1)
 - NCC Volume 2 i.e. BCA Volume 2 (i.e. Building Code of Australia v2)
 - NCC Volume 3 i.e. PCA (i.e. Plumbing Code of Australia)
 - Roof drainage falls within BCA volumes 1 & 2 and is a State Addition in the PCA in Victoria and Tasmania (only).
 - In general, compliance with the NCC is met using one of the following methods:
 - A Performance Solution
 - A Deemed-to-Satisfy Solution
 - A combination of both of the above
 - For each volume, the Deemed to Satisfy Provisions state that where a Deemed-To-Satisfy Solution is proposed, compliance with the relevant Performance Requirements is met by complying with 3500.3.
 - For all solutions, adequate Evidence of Suitability is required.
 - Evidence of Suitability may be provided by various means, as described in Governing Requirements of the NCC.

- 1.5 It is not the writer's intention to determine how compliance with the NCC is ultimately met with respect to the Dam Buster products. Rather, the aim is simply as stated in section 1.1, and it is for others to determine the appropriate compliance pathway through the NCC. This appraisal might, for example, be used to form the basis, or part of the basis, for an assessment of the products under the CodeMark Australia system.
- 1.6 Box gutter systems are designed for water which is potentially contaminated with debris. Roofs require regular maintenance and cleaning, as noted in Clause M.5, Appendix M, of 3500.3, which states:
- 'Sizing of stormwater drainage installations assumes the responsible owner or manager arranges regular inspection and cleaning to remove any obstructions that could reduce the installation's hydraulic capacity or design lifetime, or both.*
- Obstructions that could cause partial or complete reduction in the hydraulic capacity are windborne plastics, drink cans, builder's refuse, balls, bird nests, items deposited by birds, dead birds, leaves, moss, mortar, silt or similar obstructions.*
- Guards on gutters and gutter outlets and screens on outlets from on-site stormwater detention (OSD) facilities are installed to prevent reduction in hydraulic capacity due to obstructions. Installation of such guards and screens does not eliminate the need for regular inspection and cleaning. Guards used with rainwater goods might collect debris during high intensity storms, in spite of regular inspection and cleaning, and for this reason it might be better not to install such guards, particularly on box gutter sumps.'*
- 1.7 In general, this appraisal is based on the hydraulics of clean water, however, consideration is given to the potential effect of debris, particularly with respect to the minimum sizing of roof drainage components; refer to section 2.3 for a discussion on the minimum design flow rate. Refer also to section 3.4 for a paper by A/Prof Terry Lucke which includes discussion regarding debris within box gutter systems.
- 1.8 When assessing the relatively safety of Dam Buster devices compared to box gutter systems designed to 3500.3, it is assumed that regular inspection and cleaning is being carried out. However, some consideration is given to debris which can be present, despite a regime of regular maintenance and cleaning, such as that due to windblown debris during, or shortly prior to, a storm. It is noted that the maintenance and cleaning regime is also highly dependent on the presence of nearby trees, which may generate significant leaf and stick litter in a relatively short period of time. Of particular interest with respect to debris is the Dam Buster Elbow. With regular maintenance and cleaning, this device should not be significantly more prone to blockage than the straight box gutters. With poor / inadequate maintenance of box gutters, particularly those located where there is significant leaf litter, blockage can readily occur at any location along even a straight box gutter due to leaf litter, potentially resulting in overtopping of the gutter itself. Where adequate maintenance and cleaning is carried out, blockages can still occur, due to, for example, wind-blown debris such as plastic bags and rubbish, however, these blockages typically occur at the outlet, and would not be expected to occur specifically within a Dam Buster Elbow. It is for these reasons that the writer holds the opinion that the introduction of Dam Buster's Side Outlets and 'Upstream Devices' (both which facilitate a change of direction in the box gutter) will not significantly increase the risk of failure of the box gutter system.
- 1.9 Continuing from Section 3 of this appraisal, Section 4, addresses the lack of development of AS/NZS 3500.3 with respect to box gutter systems is discussed.
- 1.10 Section 5 examines the key innovations of Dam Buster products.

- 1.11 Section 6 categorizes the various Dam Buster box gutter devices.
- 1.12 In Section 7, previous opinions that are relevant to this appraisal are noted.
- 1.13 Section 8 presents a comparison of Dam Buster devices with key principles and limitations of 3500.3 and references Addendum 1 which is a comprehensive summary of the comparison of Dam Buster devices with the requirements of 3500.3.
- 1.14 In section 9, a schedule is presented comparing Dam Buster devices to the requirements of 3500.3.
- 1.15 In Section 10, an assessment of the risk of failure of Dam Buster devices compared to box gutter systems designed to 3500.3 is presented.
- 1.16 Conclusions, presented in Section 11, complete this appraisal.

2 Background to 3500.3 - Key Hydraulic Principles and Limitations

2.1 Definitions

The following definitions are adopted in this appraisal.

3500.3 AS/NZS 3500.3:2021

RH (Open fronted) rainhead according to Figure 3.7.3(a) and Figure H.2 of 3500.3

SSO Sump / side overflow device according to Figure 3.7.3(b) and Figure H.5 of 3500.3

HCO Sump / high-capacity overflow device according to Figure 3.7.3(c) and Figure H.7 of 3500.3

2.2 Hydraulic principles of 3500.3

A full understanding of the hydraulic principles underlying the design of box gutters to 3500.3 cannot be obtained from this code alone, as some information is 'hidden' from the reader. Additionally, there are some aspects of 3500.3 which are not clear and potentially open to misinterpretation. The key principles and limitations of 3500.3 are discussed in the following sections.

2.3 Minimum design flow rate

In general, the design charts in 3500.3 commence at 3.0 L/s, however, the code does not specifically state 3.0 L/s is the minimum design flow rate. A/Prof Terry Lucke examined this issue in a paper titled '*Box Gutter Design Using General Methods of AS/NZS.3:2018: Minimum Design Flowrates and Gutter Depths*' and concluded '*This paper has shown it is inappropriate to nominate minimum gutter and component sizing less than 3.0 L/s due to a disproportionate increase in blockage potential.*' The writer agrees with this expert opinion, and for the purpose of this appraisal, a minimum design flow rate of 3.0 L/s is assumed.

2.4 Maximum design flow rate

3500.3 limits the maximum design flow rate to 16 L/s. From a literature review (refer section 3), it is evident that this limit has been placed due to testing not being carried out above this flowrate in relation to the two 3500.3 box gutter overflow devices which require backwatering to occur in the overflow condition (SSO & HCO). The hydraulics associated with these devices is very complicated in the overflow condition, compared with free flow which relates to box gutters discharging to rainheads.

2.5 Freeboard

Freeboard is not clearly defined in 3500.3. Clause 3.7.2 states '*The freeboard, (hf) for box gutters shall be 30mm in accordance with Figure I.5*'. However, this is only correct in relation to the overflow condition for the SSO. A literature review (refer section 3) identifies that the following freeboards apply:

Box gutter discharging to a RH:

Design flow condition	60mm (free flow per Figure H.1)
Overflow condition	60mm (as free flow is maintained)

Box gutter discharging to an SSO:

Design flow condition	60mm (free flow to Figure H.1)
Overflow condition	30mm (backwatering occurs)

Box gutter discharging to an HCO:

Design flow condition	60mm (free flow to Figure H.1)
Overflow condition	45mm (backwatering occurs)

2.6 Change of direction in box gutters

Clause 3.7.6 (g) (i) states '*Box gutters shall be straight (without change in direction)*' and for good reason. The problems with changing directions (without an accompanying increase in depth) are twofold:

- i. There will be an energy loss in the bend, potentially resulting in backwatering and therefore loss of 'free flow' within the gutter.
- ii. The freeboard will be reduced towards the outer corner of the change in direction.

There is however no sound hydraulic reason why box gutters cannot change direction, whilst maintaining 'free flow', provided the following conditions are met:

1. The change in direction is accompanied by a step or drop in the box gutter, which is greater than the energy loss in the bend.
2. The magnitude of the step is such that the freeboard is not reduced at any location.

It is noted that in the overflow condition for the SSO, the water changes direction by 90 degrees as it discharges from the box gutter/sump and through the overflow duct. In the overflow condition, it is assumed that the sump does not operate due to a blocked outlet, and in effect the box gutter changes direction by 90 degrees into a duct with a smaller area and with no increase in depth.

A box gutter which changes direction having a step/drop large enough to satisfy items 1 and 2 above is significantly simpler hydraulically than the overflow condition of the SSO.

It follows that there is no fundamental reason why box gutters cannot change direction. The only reason that 3500.3 does not permit box gutters to change direction is that no design rules have been developed to permit a change of direction accompanied by a step/drop (increasing the box gutter depth).

2.7 Jointing a box gutter along its length to increase its depth

Section 4.7 *Joints for metal components*, part 4.7.1 *General* of 3500.3 states '*Gutters shall not be jointed along the length to increase gutter depth*'. It is assumed that this means that a stepped gutter with joints cannot be used in lieu of a tapered box gutter.

The reasons for this are not certain, but may be as follows:

- Unnecessarily introducing joints into a box gutter unnecessarily increases the risk of failure
- Steps in box gutters can result in 'splashing'
- Steps in the sole of the box gutter should not be used to create the fall, as the sections would be flat and a constant fall is required to prevent ponding and reduce the ability for debris to accumulate in the gutter.
- A step down in one location could cause the flow to change from subcritical to supercritical and increase the risk of the flow changing back to subcritical further downstream with an associated hydraulic jump. Refer to the paper by Verstraten, Lucke and O'Loughlin (refer section 3.5) which includes discussion on hydraulic jumps, and notes:

- *'Hydraulic jumps increased water depths, negating any additional hydraulic capacity associated with an increased slope. The underlying assumption, found in all of the design guidelines, that increased gutter slope results in reduced gutter water depth, is not always valid'* and.
- *'Further investigations into the generation of hydraulic jumps in sloping gutters is therefore warranted.'*

2.8 Slope

The slope of gutters designed to 3500.3 is limited to the range 1 in 200 (minimum) to 1 in 40 (maximum). These limitations relate to the testing carried out in relation to the development of 3500.3.

2.9 Box gutter widths

The charts in 3500.3 provide graphs for nominal box gutter widths of 200mm, 300mm, 375mm, 450mm and 600mm. The writer has been advised that these box gutter widths are not necessarily adhered to. In practice it is common for box gutter widths between these nominal dimensions to be used.

The Dam Buster team has advised me that some practitioners opine that interpolation of the graphs is not permitted, and that where a box gutter's width falls between two nominal widths, the design value for the lower box gutter width should be adopted. This is a conservative approach, but also entirely unnecessary. A review of Dr Ralph Jones' notes (refer section 1.2) identifies that specific mathematical equations have been used to create the graphs in Figure H.1, and these equations include the box gutter width as a variable. Thus, these equations could readily be used to generate graphs for any box gutter width in the range 200mm to 600mm and for any slope between 1:40 and 1:200. Consequently, there is no reason why design depths cannot be interpolated for widths between the nominated design widths.

2.10 Minimum design depth applies at the upstream end of box gutter.

3500.3 does not make it clear that the box gutter design depth, determined in accordance with the General Method, applies at the upstream end of the box gutter. Figures H.5 *Sump / side overflow* device and H.7 *Sump / high-capacity overflow* device provide longitudinal sections through these devices, showing the box gutter sloping and having a constant depth i.e. both the top and bottom of the box gutters slope.

The handbook SAA/SNZ HB114:1998 *Guidelines for the design of eaves and box gutters (HB114)* includes design examples for the SSO and HCO. These examples include diagrams which are essentially identical to Figure H.5 and H.7 of 3500.3, except that in both cases, the figures include the additional note '*Applies to full length of box gutter*'. That is to say, the design depth applies at the upstream end. It is not known why this note is not included in Figures H.5 and H.7 of 3500.3. Furthermore, the handbook SA HB39-2015 includes wording which can be easily misinterpreted to assume an arbitrary depth of 75mm may be adopted at its upstream end. It is the writer's understanding that this poor wording, combined with the omission of the note above in Figures H.5 and H.7, has led many practitioners to incorrectly assume that the design depth applies at the downstream end of the box gutter, and that an arbitrary depth of 75mm can be adopted at the upstream end of the box gutter. This would explain why many existing box gutters are found in practice to have an upstream depth of 75mm.

The writer understands that NCC-2022 Volume 3 (PCA) states that where there is a conflict between SA HB39:2015 and 3500.3, then 3500.3 takes precedence. This removes the potential confusion regarding the 75mm depth to some extent. However, the note '*Applies to full length of box gutter*' remains absent from Figures H.5 and H.7 in 3500.3, and consequently 3500.3 remains open to genuine misinterpretation.

2.11 Overflow capacity

3500.3 Clause 3.7.7.1 Hydraulic capacity, states that '*the overflow capacity of an overflow device shall not be less than the design flow for the associated gutter*'.

The depicted open-fronted RH clearly has a very high overflow capacity, and indeed much higher than that required by a box gutter designed to 3500.3, whereas the SSO and HCO are designed to have an overflow capacity equal to the design flow capacity, albeit with reduced freeboards of 30mm and 45mm respectively (compared to the 60mm assumed for the RH box gutter). Fundamentally however, the overflow capacity of the RH is limited by the hydraulic capacity of the box gutter itself, which will fail once the freeboard has been used up with increased flow.

3 Literature Review

The following literature items have been considered in detail as part of this appraisal.

3.1 Memos and notes by Dr. Ralph Jones

The writer, along with the Dam Buster development team, has had access to a collection of memos, notes, and letters from the 1990's, relating to the development of AS/NZS 3500.3.2-1998 which has provided added depth of understanding and insight. The design charts for box gutters and overflow device charts have not changed between the 1998 and the current 2021 version. These notes identify that for free flow,

- A freeboard of 50mm is adopted.
- An additional 10mm is assumed, with the notes stating: “*Allowance for variations above mean due to turbulence = 10mm*”

Consequently, within 3500.3, box gutters designed for free flow have a total freeboard allowance of 60mm.

As discussed in section 2.8, these notes also identify that mathematical equations have been used to generate the graphs in Figure H.1, and these equations include the box gutter width as a variable. Thus, these equations could readily be used to generate graphs for any box gutter width in the range 200mm to 600mm for each of the slopes of 1:40, 1:100, 1:150 and 1:200.

3.2 Paper by Ralph Jones and Eugene Kloti titled ‘A high-capacity overflow device for internal box gutters of roofs’, Proceedings – 8th International Conference On Urban Storm Drainage – Sydney 1999

This paper identifies that an allowance of 45mm was made for “*freeboard and other variations*”.

3.3 Paper by Assoc/Prof Terry Lucke titled ‘Box Gutter Design Using General Methods of AS/NZS.3:2018: Minimum Design Flowrates and Gutter Depths’

As noted in section 2.3, this paper opines that the minimum design flow rate from 3500.3 is 3.0 L/s. Minimum box gutter depths for free flow (i.e. design per Figure H.1) are provided for each nominal box gutter width of 200mm, 300mm, 375mm, 450mm and 600mm.

3.4 Paper by Assoc/Prof Terry Lucke titled ‘Performance Solutions: Is it appropriate to use the overflow equations from AS/NZS 3500.1 to design box gutter systems as per AS/NZS 3500.3?’

This paper contains discussion about debris within box gutter systems, and is provided in relation to the discussion in section 1.6.

3.5 Paper by Verstraten, Lucke and O’Loughlin titled ‘Comparing empirical water depth observations of a box gutter roof drainage system to three different international design guidelines’.

This paper contains discussion around the formation of hydraulic jumps in box gutter systems and is relevant to the discussion regarding jointing a box gutter along its length to increase its depth, refer to section 2.7.

3.6 CSIRO – EBS Notes NSB 151 to 153, September 1978, Roof drainage.

These notes were used by many practitioners for roof drainage design prior to the introduction of AS/NZS 3500.3.2:1998.

4 Lack of Development of AS/NZS 3500.3 with respect to Box Gutter Systems

- 4.1 The following discussion includes information provided by the Dam Buster team during various discussions.
- 4.2 There has essentially been no significant further development of AS/NZS 3500.3 in the last 25 years with respect to box gutter systems. The design procedure for box gutters in AS/NZS 3500.3:2021 is almost identical to that provided in AS/NZS 3500.3.2:1998.
- 4.3 In contrast to the static nature of 3500.3 regarding box gutters systems, the exponential proliferation of so-called ‘contemporary’ building design has changed significantly in the last 25 years, and it is apparent to the writer that the code has not kept pace with these changes. For example, there are no design examples whatsoever in 3500.3 which address box gutter systems for multi-residential buildings. The writer is aware that box gutters are increasingly being used in residential developments due to planning regulations. Allowable building setback profiles from boundaries are resulting in building forms more suitable to ‘Christmas tree’ or ‘tiered wedding cake’ type building profiles, which result in the incorporation of parapet walls and box gutter systems that are generally situated directly above habitable building space. There has also been a significant increase in multi-residential developments, which are subject to similar planning controls, also resulting in increased usage of complex box gutter systems. The lack of development of the code, combined with inflexibility in roof design resulting from the three prescribed (normative) box gutter overflow devices only, has indirectly led to the innovations of the Dam Buster products, referenced in Section 5, which have primarily been developed in the first instance to provide a means of cost-effective retrospective rectification of already identified non-compliant box gutter drainage systems.

5 Innovation of Dam Buster Products

5.1 There are essentially two key innovations associated with Dam Buster products, as discussed below.

5.2 Dam Buster rainhead

The key innovative features of the DB rainhead are (i) the vertical overflow chute and (ii) the box gutter receiver. Prior to these innovations, virtually all installed rainheads, particularly on domestic contemporary style dwellings took the form of what could colloquially be referred to as a ‘Ned Kelly’ or ‘Bush Ranger’ style rainhead. However, this form of the rainhead has always been non-compliant with respect to the requirements of 3500.3. Dam Buster understands that the ‘normative’ references in 3500.3 is considered by the Victorian regulator (the VBA) to be ‘prescriptive’, meaning that, to meet the DtS requirements any rainhead is required to take the precise form of the open fronted rainhead depicted in illustration in Figure H.2 of 3500.3 (referred to as ‘normative’). Nevertheless, this ‘prescription’ has historically not been practically enforced by the VBA nor any other state-based regulator in Australia.

In the writer’s opinion, the Dam Buster rainhead complies with 3500.3 (via Expert Judgement), for the following reasons:

- The rainhead has been designed in accordance with the calculations contained within the General Method in 3500.3.
- The rainhead incorporates a full width overflow weir, set 25mm below the sole of the box gutter receiver.
- The overflow capacity of the rainhead significantly exceeds the design capacity as stated in the Dam Buster rainhead design table for each rainhead size/downpipe combination.
- The overflow capacity of the open-fronted weir design as currently depicted in Figure H.2 of 3500.3 is clearly very high. However, as discussed in section 8.5, it has no advantage over the Dam Buster rainhead design, because the box gutter itself will fail at a flow rate significantly lower than the overflow capacity of the Dam Buster rainhead (and the open-fronted rainhead). Note, the failure flow rate is the theoretical hydraulic capacity of the box gutter, determined using the equations for defining the free flow curves in Figure H.1, and assuming there is no freeboard.
- As required by Note 4 in Figure H.2. of 3500.3, there is nothing above the weir.
- Due to the size, and geometry of the (vertical) overflow chute, the risk of obstruction of the overflow chute is insignificant.
- The Dam Buster rainhead also incorporates a built-in device to seal the rainhead very effectively to the box gutter.

On 30 July 2021, amendment 1 of SA HB 39-2015 was issued. This amendment removed Clause 5.7.3 and Figure 5.7.3, which depicted a manifestation of the so-called Ned Kelly style rainhead. The writer understands that up until the release of amendment 1, this now deleted figure had been widely used to justify this general style of rainhead - which was by no means being used in a prescriptive manner. However, the design procedure provided was unclear; no formulas were provided to calculate the flow depth, and the configuration was also inconsistent with 3500.3 and HB114 (both of which post-dated the original release of HB39 in 1997).

5.3 Change of direction devices

The second principal innovation of Dam Buster's products involves a change in direction of the box gutter flow i.e. the Side Outlet and Rainhead combination devices, and the 'Upstream' devices (i.e. the Elbow and the Junctions). Refer also to section 6 for a summary of the Dam Buster products.

The requirement to be able to change direction in a box gutter system is driven by the increasing complexity of particularly smaller roof sections in contemporary building designs. An ability to change direction also provides far greater flexibility for building designers.

As discussed in section 2.6, it is the writer's opinion that there is no fundamental hydraulic reason why box gutters - which are essentially open channel drains - cannot change direction. It appears that the only reason box gutters are not permitted to change directions in 3500.3 is that no design rules have been developed to permit a change of direction which must, by necessity, be accompanied by a step / drop (increasing the box gutter depth). Additionally, as discussed in section 1.8, in the writer's opinion, there is no material increase in the risk of blockages for box gutter systems using the Dam Buster change of direction devices, as long as they are regularly maintained and cleaned as required by 3500.3.

As discussed in section 2.7, the clause in 3500.3 which states that box gutters cannot be jointed along their length to increase their depth is not relevant to Dam Buster devices, which have been designed and tested with a specific, 'engineered' increase in depth at the change in direction. It is noted that that the change in depth ranges between 50mm and 70mm. Consequently, as observed under test conditions, very little, if any, splashing occurs as a result of the depth change.

6 Dam Buster Box Gutter Devices

6.1 This assessment is made based on the information provided in the following document:

Dam Buster Product Technical Statement version 6.0, dated 19 February 2024 refer Addendum 2.

6.2 Dam Buster devices are categorized broadly as follows:

Box Gutter Overflow devices

- ***DB Rainhead***
 - R-*www* - Rectangular rainhead
 - CR-*www* - Curve fronted rainhead
- ***DB Side Outlet and DB Rainhead combination***
 - TSO-*www* - Tee Side Outlet
 - ESO-*www-h* - End Side Outlet
 - CSO-*www-h* - Corner Side Outlet
 - XS0-*www* - Cruciform Side Outlet
- ***DB Sump***
 - SU-*www-ddd* - Singular sump

The DB Sump can also be arranged as a ‘Continuous Sump’ or a ‘Back-to-back’ sump.

Change of direction devices

- ***DB Elbow***
 - ELB-*www-h*
- ***DB Junction***
 - TJN-*www* - Tee Junction
 - CJN-*www-h* - Corner Junction

where	‘ <i>www</i> ’	denotes the box gutter width
	‘ <i>ddd</i> ’	denotes the sump depth
	‘ <i>h</i> ’	denotes the hand, L or R

7 Previous opinions

7.1 The following previous opinions have been prepared, which are relevant to this appraisal:

(1) 1 October 2020

- Opinion regarding whether Dam Buster P/L and Dam Buster IP P/L box gutter overflow devices may be considered to be Deemed-To-Satisfy Solutions to the relevant Performance Requirements of NCC-2019
- These opinions also include reference to the Dam Buster Rainhead Overflow Performance Certificates (for rectangular Dam Buster rainheads only) prepared by the AHSCA Research Foundation, refer <https://www.ahscaresearch.com.au/dam-buster-rainheads/>
- Note that this opinion includes a number of previous opinions.
- One of these previous opinions, dated 28 January 2020, contains an opinion regarding the overflow capacity of the Curve fronted Dam Buster rainheads, confirming their overflow capacities exceed 16 L/s.
- This opinion also refers to a previous opinion titled '*The T-Side Outlet Addendum*', dated 30 September 2020, which provided a recommendation that the maximum permitted length of the SBG ('short box gutter' or outlet box gutter) was 600mm. At the time of writing this opinion, the step / drop for the 200mm Side Outlet series was 40mm. However, this was subsequently increased to 50mm. Of the three Side Outlet sizes (200mm, 300mm and 400mm), the 200mm size was critical, as the calculated value for 95% of the uniform depth exceeded the drop (whereas, for the 300mm and 400mm series, this value was less than the step / drop). With an increase in the drop of the 200mm series to 50mm, this is no longer the case (i.e., 95% of the uniform depth is now less than the step / drop). Consequently, the writer has re-assessed the maximum length of the 'SGB' and advises this may be increased to 1200mm (the Dam Buster team queried whether this value may be acceptable with the increased step/drop in the 200mm Side Outlet series).

(2) 29 January 2021

- The Dam Buster (DB) Elbow

(3) 18 July 2023

- Opinion re DTS Solution to NCC-2022
- This opinion confirms that previous opinions (1) and (2) above, which were based on NCC-2019 (and AS/NZS 3500.3-2018) remain valid for NCC-2022 (and AS/NZS 3500.3:2021)

7.2 Opinions (1) and (2) contain commercially sensitive information and (as advised by Dam Buster) are consequently not made available, except under a confidentiality agreement.

7.3 Since preparing the above noted opinions, the Dam Buster product range has been extended as follows:

- Back-to-back Sump added
- Junctions added

These devices generally follow the same principles as the other devices and have been reviewed as part of this appraisal.

7.4 Previous opinions have considered Dam Buster devices to be Deemed-To-Satisfy by Expert Judgement. This pathway whilst referenced, is not clearly defined in NCC-2019 or NCC-2022, and the writer understands that Dam Buster is considering alternative pathways. The compliance pathway(s) adopted does(do) not affect this technical appraisal.

7.5 AS/NZS 3500.3-2018 included the following statement in the Preface:

‘PROVISION FOR REVISION

This Standard necessarily deals with existing conditions, but is not intended to discourage innovation or to exclude materials, equipment and methods that may be developed in future. Revisions will be made from time to time in view of such developments and amendments to this edition will be made only when absolutely necessary.’

As discussed later in this opinion, the Dam Buster products fall partly outside the scope of 3500.3 by virtue of introducing the concept that box gutters can change direction when accompanied by an appropriate step/drop. Due to the discussion above regarding provision for innovation, it was considered that this extension of the scope could be considered as being a Deemed-To-Satisfy Solution by Expert Judgement. Note that for an unknown reason, the above statement which had consistently been in earlier editions of 3500.3 was removed from the 2021 version of the code.

7.6 Ultimately the compliance pathway is a matter for building surveying professionals and building authorities.

8 Comparison of Dam Buster devices with key principles and limitations of 3500.3.

8.1 Various aspects of the hydraulic design and operation of Dam Buster's devices are discussed below in relation to 3500.3.

8.2 Design flow range

- 3500.3 is limited to 16 L/s.
- All Dam Buster devices are designed for:
 - A minimum of 3 L/s
 - A maximum of 16 L/s
- Dam Buster adopts the philosophy that for flows less than 3 L/s, the device is designed for 3L/s. Also refer Section 2.3.

8.3 Hydraulic operation

- All Dam Buster devices operate under 'Free flow' in both the 'design flow' and 'overflow' conditions. This compares to hydraulic operation of the three DtS devices in 3500.3 as below:
 - *Rainhead*
 - Free flow in the design flow and overflow conditions (60mm freeboard)
 - *SSO and HCO*
 - Free flow in the design flow condition (60mm freeboard)
 - Backwatering is required in the overflow condition, with 30mm and 45mm freeboards respectively. This flow regime is hydraulically very complicated.

Consequently, the nature of the flow within Dam Buster's devices is significantly less complex than the SSO and HCO devices.

- The design of all box gutters discharging to Dam Buster devices is independent of the overflow device (because free flow is maintained). This means that all box gutters discharging to Dam Buster overflow devices can be designed to 3500.3 Figure H.1, noting that where a change of direction is made, the downstream box gutter component (i.e. the box gutter section downstream of the Dam Buster device itself) will be deeper than that required by the code.
- 3500.3 requires that the overflow capacity of the box gutter overflow device be at least equal to the design flow rate (for a 1% AEP event). All Dam Buster overflow devices have an overflow capacity at least equal to their design flow rate. As discussed in section 8.6, the overflow capacity of the Dam Buster rainhead is much higher than its stated design flow capacity (for each rainhead size and downpipe size combination in the Dam Buster rainhead design table), and additionally, the 'open fronted' rainhead depicted in Figure H.2 has no advantage over the Dam Buster rainhead because the box gutter will fail before the overflow capacity of the Dam Buster rainhead is reached.

8.4 Sizing

- 3500.3 requires the width of box gutters to be in the range 200mm to 600mm.

- The width of all Dam Buster products is also in the range 200mm to 600mm.
- It is noted that 3500.3, clause 3.7 *Box Gutter Systems*, sub-clause 3.7.3 *Limitations*, NOTE 3, states ‘*The minimum width of box gutters used for commercial construction is 300mm. Box gutters 200mm wide may be used for domestic construction, but they are more prone to blockages. Additional height is recommended where possible.*’ This clause implies the higher risk of blockage in a narrower gutter can be mitigated by adopting a deeper box gutter (than required) however no details regarding the additional depth are given.
- For the DB Side Outlet, Elbow and Junction devices:
 - The depth of the ‘Downstream’ box gutter (excluding the device itself) is greater than that required by Figure H.1 by an amount which is equal to, or greater than, the height of the step in the device (plus the fall in the ‘Upstream’ box gutter).
 - The ‘Downstream’ box gutter (excluding the device itself) is therefore safer than a box gutter designed to Figure H.1 due to the additional freeboard.

8.5 Dam Buster Rainhead

In the design flow condition, the Dam Buster rainhead is designed and constructed in accordance with 3500.3, Figures H.1, H.2 and H.3. The construction of the Dam Buster rainhead, having a box gutter receiver, facilitates a compliant seal (in accordance with 3500.3, section 4 *Installation*) between the box gutter and the rainhead. It is noted that, in practice, box gutters are typically either not sealed to the rainhead, or not sealed in a compliant manner.

In the overflow condition, the Dam Buster rectangular rainhead has been tested by the AHSCA Research Foundation, which demonstrated that the overflow capacity of the smallest Dam Buster rainhead, the R-200 (for a 200mm wide box gutter) exceeds 16 L/s. Overflow test certificates are available at <https://www.ahscaresearch.com.au/dam-buster-rainheads/>

As noted in section 5.2, the overflow capacity of the 3500.3 ‘open-fronted’ rainhead is limited by the hydraulic capacity of the box gutter itself. Refer to Figure 1 below, which shows how the box gutter will over top and fail if the flow rate is gradually increased until all the freeboard has been used up. It is also important to note, that with respect to debris, and ignoring failure of the box gutter itself, the open-fronted rainhead does not have unlimited capacity, since there is an inevitable ‘catch point’ for debris where any box gutter passes through the parapet wall (noting that the downstream end parapet wall is not shown in the Figures of 3500.3).

As an example, the Dam Buster R-200 rainhead has a maximum design flow rate of 5.0 L/s when fitted with a 100mm diam. downpipe. At 5.0 L/s, the design box gutter depth is 119mm for a slope of 1 in 100. If the box gutter depth is increased by 60mm (to 179mm), the design flow rate becomes 14.5 L/s, which is less than 16 L/s. Hence, the box gutter fails before the Dam Buster rainhead fails. This demonstrates that there is no advantage of having an open fronted rainhead over a Dam Buster rainhead for even the (smallest) 200mm size. Analyses of the other Dam Buster rainheads indicates that this holds true for the other sizes.

Note that due to the size and nature of the vertical overflow chute in a Dam Buster rainhead, it is considered very unlikely that the overflow chute would become blocked

with debris. Furthermore, there is the advantage of being able to visually observe the status of the overflow chute from ground level.

As discussed in section 5.2, in the writer's opinion, the Dam Buster rainhead range complies with all the hydraulic requirements of 3500.3 and is therefore considered by the writer to be DtS by Expert Judgement. Refer to section 11.2 for further comments.

8.6 Dam Buster Sump

The Dam Buster Sump may be considered in general terms as an 'internal rainhead'.

The Dam Buster '*Continuous Sump*' is an extension of the use of the *Sump* to continuous one-way flow.

The Dam Buster '*Back-to-Back Sump*' is essentially a double Dam Buster '*Sump*'.

In the design flow condition, the Dam Buster *Sump* operates in the same manner as a Rainhead.

Testing has confirmed that the overflow capacity of the Dam Buster *Sump* exceeds its design flow capacity.

The Dam Buster *Sump* has the following additional safety features:

- For box gutters 300mm wide or greater, a minimum downpipe size of 100mm is adopted (even when a 90mm downpipe is hydraulically adequate)
- Where possible, a 90mm diameter 'overflow indicator' is added. The purpose of this is to alert the building owner or occupant of the (albeit unlikely for a well-maintained box gutter) event that both the design and overflow downpipes are blocked, and acts as a secondary overflow to a certain degree (but may be significantly less than the design flow). Note that an overflow indicator may only be used where the sump is located immediately adjacent to an external wall.

The following safety comparisons are made between the Dam Buster Sump and the HCO

- Where a Dam Buster Sump is located immediately adjacent to an external wall, and an overflow indicator is used:
 - The Dam Buster Sump is considered safer compared to the HCO (where the overflow indicator pipe is fitted).
- Where the Dam Buster Sump is located internally:
 - And it is an individual sump, its safety is similar to the HCO.
 - And it is used as a 'Continuous' or 'Back-to-Back' Sump, the safety of the sump is similar to a series of HCO's due to the cut down in the end wall of the overflow chamber and upstream end of the box gutter for the Continuous Sump,
 - For the Continuous Sumps, water can flow from one box gutter to an adjacent box gutter if both the primary and overflow downpipes' become blocked.
 - For the Back-to-back Sump, water can flow from one overflow chamber to the adjacent overflow chamber.

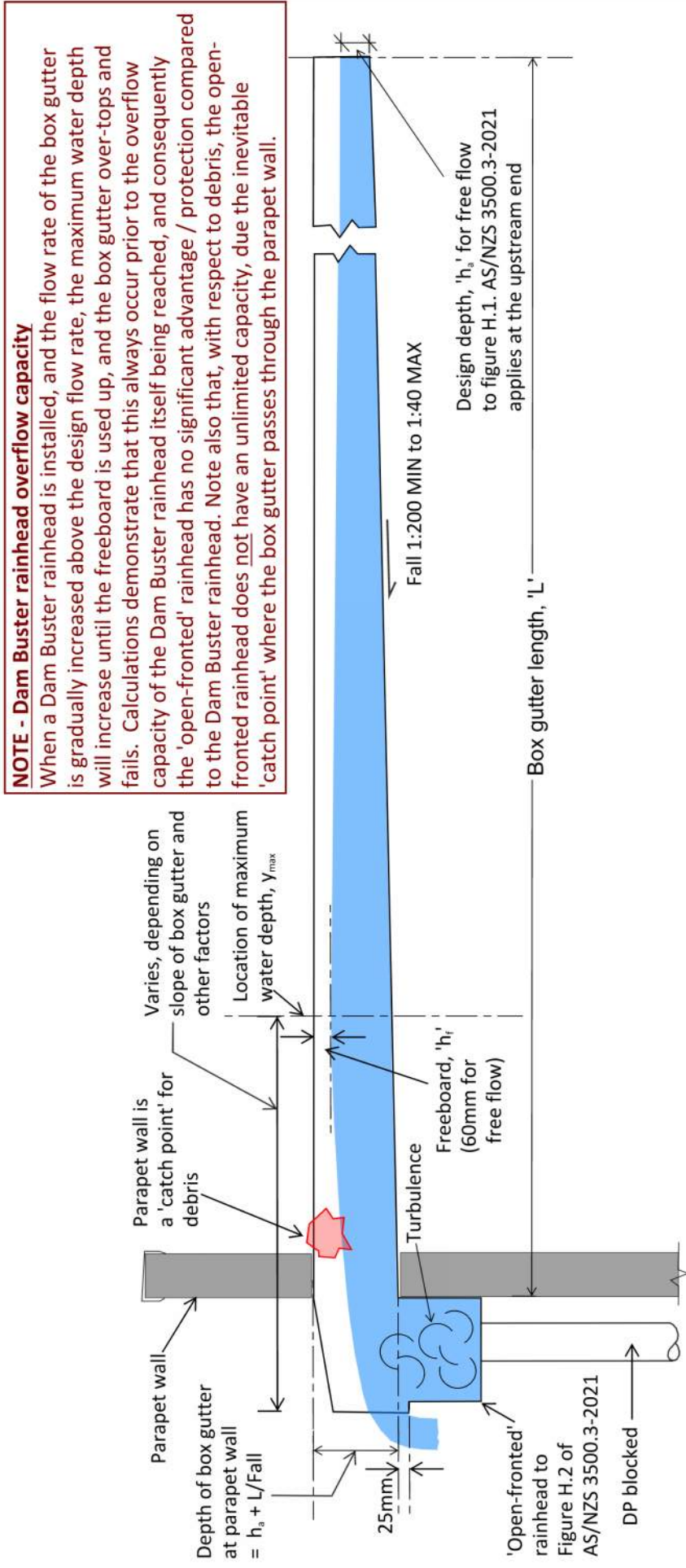


FIGURE 1 - Section through box gutter with 'open-fronted' rainhead per Figure H.2 of AS/NZS 3500.3-2021 in the overflow condition, with the flow rate equal to the design flow

8.7 Change of Direction devices – Dam Buster Side Outlet, Elbow and Junction devices

These devices may be considered in two ways:

- Change of direction devices
- Shallow ‘sumps’*, having a deeper ‘outlet’ box gutter discharging through the one open side wall in the ‘sump’. The box gutter discharging to the ‘sump’ is referred to as the ‘*Upstream*’ box gutter and the (deeper) box gutter discharging from the ‘sump’ is referred to as the ‘*Downstream*’ (or ‘*Outlet*’) box gutter.

* Note that a sump is traditionally effectively a local increase in the box gutter depth for the purpose of increasing the hydraulic capacity of the outlet. Hence, the first description above is considered more appropriate.

Regardless of the description, the hydraulic operation of these devices is sound, as discussed in section 8.3.

It is noted that in the overflow condition for the SSO, the water changes direction and discharges through an overflow duct, having a smaller size than the box gutter, and without a step / drop.

There is no hydraulic reason for why box gutters cannot change directions, provided there is an accompanying adequate step/drop to allow for any local head losses, and the hydraulic design criteria discussed in section 2.6 are met.

Also, as discussed in section 2.6, it follows that the only reason box gutters are not permitted to change directions in 3500.3 is that no design rules have been developed to permit a change of direction accompanied by a step/drop (increasing the box gutter depth).

In section 2.7, 3500.3 does not permit box gutters to be jointed along their length to increase their depth. This is not considered to be relevant to Dam Buster’s change in direction devices.

8.8 Freeboard

Refer to section 2.5 for a discussion of the freeboard assumed for the 3500.3 devices in the primary and overflow conditions.

All box gutters discharging to Dam Buster devices are designed for free flow in accordance with Figure H.1, and therefore have the same freeboard of 60mm in the normal flow and overflow conditions.

The freeboard in the critical outer corner of a Dam Buster Elbow (and similarly, the Dam Buster End Side Outlet) has been determined by testing to be greater than 60mm, and this is also supported by theoretical calculations carried out by the writer which estimate the energy loss in the bend and determine the water depth by conservatively assuming zero velocity at this location.

For Dam Buster’s change of direction devices, the freeboard exceeds 60mm within the lower portion of the device.

9 Schedule summarizing the comparison of Dam Buster devices to 3500.3

- 9.1 Refer to Addendum 1 for a summary of the comparison of Dam Buster devices to the requirements of 3500.3.

10 Risk of failure of Dam Buster devices compared to box gutter systems designed to 3500.3.

- 10.1 The following comparisons are made between the Dam Buster box gutter devices, and box gutter systems designed to 3500.3.

10.2 Straight box gutter to a Dam Buster rainhead

- The ‘open-fronted’ rainhead depicted in Figure H.2 of 3500 is not considered to be significantly safer than the DB rainhead, because the DB rainhead has much greater capacity in the overflow condition than in the design condition. It can be demonstrated that the box gutter itself will fail by overtopping prior to the DB rainhead reaching its overflow capacity.
- The DB rainhead has a box gutter receiver, which facilitates a compliant seal between the box gutter and the rainhead. This is in accordance with the Installation section of the code which deals with lap seal joints in box gutters and eaves gutters. Although 3500.3 requires that the box gutter is sealed to the rainhead, it is not made clear in the section of the code that deals with rainheads as to how this should be achieved. As a result, box gutters are typically poorly sealed to non-DB rainheads, creating a potential point of water entry into the building when the rainhead becomes blocked.
- In summary, the DB rainhead is considered to be equally as safe as the 3500.3 ‘open-fronted’ rainhead in theory. However, in practice, due to the innovative box gutter receiver facilitating a good seal between the box gutter and the rainhead, the DB rainhead is safer.
- Referring to Figure 1 above, a ‘catch point’ for debris is where the box gutter passes through the parapet wall. When designing to 3500.3, the box gutter depth, including fall, could be as low as 120mm (for example, a 400mm wide box gutter, 6m long, having a slope of 1:200, and designed for the minimum flow rate of 3 L/s, would have a depth of $90 + 30 = 120$ mm at the parapet wall). Dam Buster has adopted a minimum depth of the penetration through the parapet wall of 150mm for a straight box gutter discharging to a rainhead.

10.3 Dam Buster Side Outlet and Rainhead combinations.

- As previously discussed, where the roof is adequately maintained and cleaned, the safety of the Side Outlet is not considered to be significantly less safe than a straight box gutter, noting that the outlet box gutter is significantly deeper than required for free flow by Figure H.1.

10.4 Dam Buster Sump, Continuous Sump and Back-to-Back Sump

- Refer to section 8.6 for a discussion of the safety of the DB Sumps compared to the HCO.
- In relation to the HCO:
 - Where located immediately adjacent to an external wall, and the overflow indicator is used, the DB sump is considered safer than the HCO
 - Where located internally, the DB sump is considered as safe as the HCO.
- Where a Dam Buster Sump is used immediately adjacent to an external wall in lieu of an SSO:
 - Where an overflow indicator is used, the safety of the DB sump is considered to be as safe as the SSO
 - Where an overflow indicator is not used, the SSO is considered to be safer than the DB Sump which is why the incorporation of an overflow indicator is recommended.

10.5 Dam Buster Upstream Devices

- The depth of the downstream box gutter of all ‘upstream devices’ (i.e. the DB Elbow and Junctions) is significantly greater than required by Figure H.1
- Consequently, where the box gutters are maintained as required by 3500.3, the DB Upstream Devices are not considered to be less safe than a straight box gutter.

10.6 Summary

The discussion below regarding current practice is informed by the Dam Buster team members.

The safety of each box gutter system will vary, depending on the roof layout and its various constraints. In general, box gutters designed using the Dam Buster roof drainage system will be as least as safe as box gutter systems designed to 3500.3.

The Dam Buster products provide the building designer with much greater flexibility and consequently it is often much easier to find a solution complying with the NCC when Dam Buster products are used.

Current practice is such that roof drainage is often not designed using the General Method at building permit stage, and therefore sizing and other details are not properly coordinated with the architecture and structure. The roof plumber typically does not become involved in a project until ‘framing stage’, by which time it is commonly very difficult, if not impossible, to achieve a compliant solution (because there has been no coordination with the architecture or structure). This leads to the installation of non-compliant roof drainage, resulting in a higher risk of failure. This is evident in the current environment, where non-compliant roof drainage and the resulting water damage is being frequently reported on social media as well as formally documented in university research publications.

To improve the quality of roof drainage systems incorporating box gutters, the following is required:

- Detailed design at Building Permit stage, to allow proper coordination with the architecture and the structure.
- Dam Buster products should be available for use in addition to the 3500.3 devices, noting that the DB devices provide much greater flexibility for architects/building

designers than the 3500.3 devices in the context of the ongoing proliferation of contemporary and high-density building designs.

11 Conclusions

11.1 The following is a summary of the outcomes of this appraisal with respect to the aims listed in section 1.1.

(i) *Assess to what extent Dam Buster products comply with the key hydraulic principles and limitations of 3500.3.*

All Dam Buster products comply with all the key hydraulic principles of 3500.3.

(ii) *Assess and comment on the extent to which the Dam Buster products fall outside the limitations or scope of 3500.3, noting that the products are innovative.*

The Dam Buster Side Outlet and Upstream devices (Elbow and Junctions) allow a change of direction in the box gutter in conjunction with the introduction of a step / drop within the device, designed such that (i) the height of the step is greater than the energy loss in the bend and (ii) the required freeboard is maintained in all locations within the device.

It is the writer's finding that the only reason box gutters are not permitted to change direction in 3500.3 is that no design rules have been developed to permit a change of direction accompanied by a step/drop (increasing the box gutter depth). It is noted that, in the overflow condition for the sump / side outlet to 3500.3, the water changes direction into an outlet having a significantly smaller area than the box gutter, and without a step. In comparison, not only do the above noted Dam Buster devices incorporate a step, but the outlet box gutter is also deeper than the inlet box gutter.

(iii) *Confirm that the design methodology for the Dam Buster products is hydraulically sound and that the design tables and procedures are correct.*

The writer has reviewed the design tables and procedures for Dam Buster products, as set out in the Dam Buster Product Technical Statement version 6.0, dated 19 February 2024, and found this information to be correct.

(iv) *Comment, to the extent possible, on the safety of the Dam Buster products compared with the safety of box gutter systems designed to 3500.3.*

In general, box gutters designed using the Dam Buster roof drainage system are considered at least as safe as box gutter systems designed to 3500.3. Furthermore, the following common non-compliances should be eliminated from use in the building industry:

- Usage of non-compliant 'Ned Kelly' style rainheads, noting that prior to the Dam Buster rainhead there was no aesthetically acceptable and compliant rainhead available in the marketplace
- Box gutters not adequately sealed to the rainhead.

11.2 The compliance pathway through the NCC for Dam Buster products should be determined by a Building Surveying professional. However, in the writer's opinion, Dam Buster products generally comply with 3500.3, except for the change of direction in box gutters, which is considered to be a hydraulically sound extension of the scope of 3500.3. The preface of the 2018 version of AS/NZS 3500.3 stated:

‘This Standard necessary deals with existing conditions, but is not intended to discourage innovation or to exclude materials, equipment and methods that may be developed in future.’

Whilst interpretation of this statement may be subjective, the writer remains of the opinion that it could be inferred from this statement that the Dam Buster products may be considered to be Deemed-To-Satisfy by Expert Judgement, with the added proviso that an opinion from a building surveying professional is also required to confirm this. Furthermore, approval may also be required from the relevant state or territory building regulator.

- 11.3 It is important to note that because all Dam Buster devices operate under free flow in both the primary and overflow conditions, all box gutters can be sized for their design flow in accordance with Figure H.1 of AS/NZS 3500.3-2021. This contrasts with the SSO and HCO devices, where design of the box gutter using the General Method is an integral part of the design of the overflow device.



Dr R. J. Keller

20th February 2024

**ADDENDUM 1 - Schedule comparing Dam Buster devices to
AS/NZS 3500.3-2021**

Clause	Sub clause	Requirement	Comments
			Notation: 3500.3 = AS/NZS 3500.3:2021, SSO = Sump / Side overflow to 3500.3, HCO= Sump / high capacity overflow to 3500.3
3.7.1 General		Box gutter systems shall incorporate overflow devices in accordance with Clause 3.7.7	Dam Buster has two types of devices, as follows: <u>Box gutter overflow devices</u> All box gutter overflow devices have provision for overflow. Refer to appraisal section 8.5 which discusses the Dam Buster rainhead and shows that there is no advantage of the 'open-fronted' rainhead to 3500.3. Note that the overflow device comprising a Side Outlet and a Rainhead is a effectively a change of direction device plus a box gutter overflow device. <u>Upstream devices</u> The upstream devices comprise the Elbow and Junctions. These devices allow a change of direction. Refer to appraisal sections 5.3 and 8.7. All upstream device discharge to box gutter overflow devices. In summary, any box gutter system using Dam Buster devices incorporate provision for overflow which is compliant and comparable to the 3500.3 devices. Refer to appraisal section 10 for a discussion on the risk of failure of Dam Buster devices compared to 3500.3 devices.
3.7.2 Freeboard		Freeboard for the sump and side overflow is required to be 30mm.	The freeboard assumed by 3500.3 is mostly hidden but has been identified in full as a result of a literature review, refer to appraisal section 2.5. As discussed in appraisal section 8.8, all box gutters discharging to Dam Buster devices are designed for free flow in accordance with Figure H.1, and therefore have the same freeboard of 60mm in the normal flow and overflow conditions. For Dam Buster's change of direction devices, the freeboard exceeds 60mm with the lower portion of the device.
3.7.3 Limitations	(a) Gradients	Box gutter gradients to be in the range 1:40 to 1:200	All box gutters discharging to Dam Buster devices must comply with 3500.3 and are designed for free flow in accordance with Figure H.1. Dam Buster provides box gutter design charts for each gradient 1:200, 1:100, 1:150 and 1:40. Dam Buster devices were tested using box gutters with slopes of 1 in 200. The experimental results agreed with hydraulic analysis. Hydraulic analysis of other allowable slopes indicated that the Dam Buster devices would perform equally well and there would be no reduction, or no significant reduction, of freeboard in the change of direction devices for the higher slopes.
	(b) Rainheads	(i) design flows not to exceed 16 L/s (ii) downpipes to be per Figure H.3	The design flow rates for Dam Buster rainheads do not exceed 16 L/s and the downpipes sizes are limited to those in Figure H.3. Refer to further comments below. <u>Design of Dam Buster rainheads</u> Dam Buster rainheads are designed fully in accordance with 3500.3. For each tabulated rainhead / DP / maximum flowrate combination (for a particular rainhead size), the length and depth required were determined in accordance with Figure H.3. The largest of these values were then used to set the length and depth of the rainhead (i.e. the dimensions of the main compartment, excluding the vertical overflow chute). Hence, the rainhead dimensions are 'pre-designed' for each rainhead size / DP / maximum flowrate combination. As a result, no design is required for the rainhead, and the rainhead size / DP combination is selected to ensure the design flow rate is equal or less than the maximum allowable flow rate for the selected combination. Or in other words, the Dam Buster rainhead is pre-designed to 3500.3.
	(c) Sump DPs	Sump DPs are limited to those in Figure H.3	Dam Buster sumps are only used with the DPs listed in Figure H.3. Furthermore, the DPs are limited to circular DPs. Rectangular DPs are not permitted, as these would be fabricated from metal, which is more prone to leakage and therefore not considered suitable for internal usage.
	NOTE 1	Figure H.6 & H.8 assume that box gutter slopes are in the range 1:40 and 1:200	These figures relate to the design of the HCO are not directly relevant to the Dam Buster devices
	NOTE 2	This note relates to the criteria for box gutter overflow devices and refers to Clause 3.7.7 and Figure 3.7.3.	Refer below for a discussion clause 3.7.7. Figure 3.7.3 depicts the three code box gutter overflow devices. This appraisal compares DB devices to the three code devices.
	NOTE 3	The minimum width for box gutters is 300mm, however 200mm may be used for domestic construction.	Dam Buster devices use standard widths of 200mm, 300mm, 400mm, 500mm and 600mm. It is the responsibility of the designer to select an appropriate box gutter width.
	NOTE 4	Examples of the General Method are provided in Appendix I	This does not apply to Dam Buster devices. However the following is noted in relation to the General Method, as this cannot be understood without knowledge of the 'hidden' freeboards assumed by 3500.3. The general method requires that the SSO and HCO are firstly designed for free flow in accordance with Figure H.1 and then the overflow is designed. The freeboard implied for free flow is 60mm, but only 30mm and 45mm respectively for the SSO and HCO. In the overflow condition, free flow is lost, as the water level must rise up to either discharge through the overflow duct of the SSO or flow over the weir in the HCO. In both cases backwatering occurs. It is not obvious whether the design box gutter depth will be greater during the design flow or in the overflow condition, and this is why both cases must be checked.

Clause	Sub clause	Requirement	Comments
Figure 3.7.3	(a) Rainhead	Diagram of rainhead	The diagram of the rainhead is incomplete as it does not include the parapet wall. Refer to appraisal section 8.5 and Figure 1. The diagram of the rainhead is misleading because it gives the impression that there is unlimited overflow capacity of the rainhead. This is incorrect for two reasons: Firstly, with increasing flows above the design flow, the box gutter will fail due to loss of freeboard and Secondly, there is a 'catch point' for debris where the rainhead passes through the wall. For the Dam Buster rainhead, it can be shown that, as the flow rate increases above the maximum design flow rate for the rainhead / DP combination, the box gutter will fail before the overflow capacity is reached. Consequently, the open-fronted rainhead has no advantage over a Dam Buster rainhead.
	(b) Sump / side overflow device	Diagram of sump / side overflow device	It is noted that in the overflow condition, the water must change directions and flow out of the box gutter / sump through a duct which has a smaller area than the box gutter. As discussed in appraisal section 8.7, there is no hydraulic reason for why box gutters cannot change directions, a provided there is an accompanying step / drop, and the hydraulic design criteria discussed in appraisal section 2.6 are met.
	(c) Sump / high capacity overflow device	Diagram of sump / high capacity overflow device	The Dam Buster Sump is a much simpler device than the HCO, because free flow also occurs in the overflow condition. In practice the HCO is rarely constructed, and instead a 'non-compliant' vertical piped overflow is installed, which cannot be designed to 3500.3. This has been occurring for 25 years, since the introduction of AS/NZS 3500.3.2-1998.
3.7.4	(a), (b) & (c)	General method for the design of the three box gutter overflow devices	As discussed above, in the design flow condition the Dam Buster rainhead is (pre) designed in accordance with general method.
3.7.5 Hydraulic capacity		The hydraulic capacity (eg. maximum design flow) of a box gutter is based on the sole width and gutter depth, the gradient and the type of overflow devices.	Box gutters discharging to Dam Buster devices operate under free flow in the design and overflow conditions. Consequently, the design of the box gutter is carried out in accordance with 3500.3 and is not dependent on the type of Dam Buster overflow device or type of Upstream device.
3.7.6 Layout requirements for box gutter systems	(a)	The location and size of box gutter shall be taken into consideration	This applies to all box gutter systems designed using Dam Buster devices.
	(b)	The size of the support system shall be taken into consideration	This applies to all box gutter systems designed using Dam Buster devices.
	(c)	Provision for thermal expansion	Box gutters discharging to Dam Buster devices must contain provision for expansion in accordance with section 4 of 3500.3
	(d)	Consideration for the location of vertical downpipes with sumps	This applies to all box gutter systems designed using Dam Buster devices.
	(e)	The minimum depth of the HCO is 150mm	This is not relevant to Dam Sumps. Standard depth for Dam Buster sumps are 100mm, 125mm, 150mm and 200mm.
	(f)	The normal outlet may be moved longitudinally to clear the overflow channel for the SSO. The outlet shall not be moved laterally to cross the longitudinal centreline of the overflow device.	The reason for the second requirement is not clear. Section 6.02 <i>Swirl</i> of the CSIRO-ESB 1978 Roof drainage note ' <i>The performance of an outlet with $h > 1/3 D$ will be reduced if swirl occurs at the outlet. Swirl can be eliminated and the diameter reduced by about 10 percent if the outlet is placed at a distance equal to or less than its diameter from the nearest vertical side (see Fig 3). Swirl can be ignored at outlets with $h < 1/3 D$.</i>
	(g) (i)	Box gutters shall be straight	All box gutter discharging to Dam Buster devices are straight. Dam Buster Side Outlets and Upstream devices (Elbows and Junctions) include a step down which is greater than the energy loss at the change of direction and the required freeboard is maintained (in fact, exceeded) throughout the device. Refer appraisal sections 5.3 and 8.7.
	(g) (ii)	Have a horizontal constant base (sole) width with vertical sides in cross-section	All box gutters discharging to Dam Buster devices must comply with 3500.3.
	(g) (iii)	Have a constant slope between 1:200 and 1:40	All box gutters discharging to Dam Buster devices must comply with 3500.3.
	(g) (iv)	Discharge at the downstream end without a change in direction (i.e. not to the side)	All box gutters discharging to Dam Buster devices must comply with 3500.3.
(g) (v)	Be sealed to the rainheads and sumps	Dam Buster rainheads and sumps include box gutter receivers which facilitate a good seal between the box gutter and the rainhead and sump. It is noted that 3500.3 is not clear on how a box gutter is sealed to a rainhead. In practice, the majority of box gutters are either not sealed, or inadequately sealed to the rainhead, and this is a common leakage point into the building. Commonly, a rectangular opening is cut in the back of the rainhead, and the box gutter is inserted into this opening, often protruding a distance into the rainhead, thereby effectively reducing the length of the rainhead. The seal commonly comprises silicone only between the box gutter and rainhead, with no laps and no rivets. In many instances there is not even any silicone. This issued has not been adequately addressed in the last 25 years.	

Clause	Sub clause	Requirement / second sub-clause	Comments
3.7.7 Overflow devices	3.7.7.1 Hydraulic capacity	The hydraulic capacity of the overflow is required to be at least equal to the design flow for the gutter(s).	The Dam Buster rainhead has a much higher overflow capacity than the maximum allowable design flowrate for the largest DP which may be used with the rainhead size. As previously discussed, for a number of reasons, there is no advantage of the 'open-fronted' rainhead to 3500.3 over the Dam Buster rainhead. The overflow capacity of the Dam Sumps is either equal to, or exceeds, the design flow.
	3.7.7.2 Operation	There shall be an increase of flow in the box gutter devices that discharge to the SSO or HCO	
3.7.8 Downpipes	(a)	DPs to be at least 90mm DIAM or 100x50mm	This applies for all Dam Buster devices, except for the R-200 rainhead, which allowable flow rates are provided for an 80mm DIAM DP, based on testing carried out by AHSCA research foundation. In this case, the overflow capacity of the rainhead is more than four times the design flow capacity.
	(b)	DPs to discharge to a surface water drainage system with the capacity to convey run-off from a 1% AEP storm event	This applies to all box gutter systems.
4.7 Joints for metal components	4.7.1	Gutters shall not be jointed along their length to increase gutter depth	Refer to appraisal section 2.7
	4.7.2 Type of joints	4.7.2.1 Soldered	Dam Buster products do not utilise (nor recommend) soldered joints.
		4.7.2.2 Sealant	Dam Buster products have sealant joints applied in compliance with this section of the code. Dam Buster have elected to specifically utilise rivets as the mechanical fasteners at maximum 40mm centres with sealant sandwiched between the lap joints on all assembled products.
		4.7.2.3 Laps	Dam Buster products have a minimum of 25mm laps at all joints and mechanical fasteners are spaced at maximum 40mm centres and set no closer than 10mm from the edge of a joint in compliance with this section of the code.

**ADDENDUM 2 - Dam Buster Product Technical Statement
version 6.0 dated 19th February 2024**

NOTE - This document was current at the time the Technical Appraisal was carried out. Minor changes have since been made to the Dam Buster Roof Drainage System, and the Product Technical Statement ('PTS') has been updated accordingly. Version 6.0 of the PTS is available upon request.