PVC Pipe Bore Rippling

1. INTRODUCTION

Bore rippling, or waviness, is a normal and expected outcome of the PVC pipe extrusion process. While it may appear visually as slight internal undulations or wave-like patterns along the internal surface (bore), rippling has no impact on pipe performance, flow capacity, or long-term durability. It is not a defect and does not interfere with hydraulic function, joint sealing, or structural compliance. The following note clarifies why bore rippling should be regarded as a non-issue within the context of pipe standards, performance criteria, and industry best practice.

2. NO IMPACT ON PERFORMANCE

Bore rippling is a normal and expected feature of the PVC pipe extrusion process, as recognised by Australian Standards[1]. It notes defects cannot be completely quantified; and shall not affect the performance or function of the pipe in service. This includes joint integrity—whether solvent-welded (SWJ) or rubber-ring jointed (RRJ)—as bore rippling has no structural impact.

Pipes exhibiting bore ripples continue to meet all relevant manufacturing product standards, including:

- Minimum wall thickness requirements,
- Pipe stiffness rating,
- Pressure rating, and
- Impact resistance specifications.

Despite the visual appearance, the internal surface (bore) remains glassy and smooth to the touch. These minor variations do not significantly alter surface roughness and therefore do not affect hydraulic performance. In particular, the pipe retains its ability to maintain self-cleansing velocities, ensuring efficient fluid transport and prevent sediment build-up when installed at the recommended gradient.

3. WHY IS BORE RIPPLING NORMAL IN PVC PIPE MANUFACTURING

Bore rippling is an inherent outcome of the PVC extrusion process both here in Australia and around the world. During manufacturing, molten PVC is forced through an extruder and shaped by a die. This process naturally leads to minor internal surface features, such as dimples or ripples, without compromising pipe quality.

4. MANUFACTURER VARIATION

The degree and appearance of bore rippling can vary between manufacturers due to differences in:

- Screw and die design,
- Compound formulations and melt rheology,
- Extrusion speed and temperature settings, and
- Overall process control parameters.

As a result, ripples may differ slightly in appearance between suppliers. However, this variation is purely aesthetic and does not reflect differences in pipe quality or performance. It is considered normal within the industry.

5. SUMMARY TABLE – PVC PIPE BORE RIPPLING

Table 1 below provides a summary of the key points regarding PVC pipe bore rippling:

Table 1: Summary of key points

Aspect	Description
What it is	Minor, repetitive undulations (waviness) on the internal (bore) pipe surface.
Cause	Normal result of extrusion process and melt flow dynamics.
Effect on performance	None—pipes with rippling meet all required standards for wall thickness, stiffness, and impact. Does not affect hydraulic performance when installed at recommended gradient.
Surface quality	Remains smooth to touch; no significant impact on roughness or hydraulic performance.
Manufacturing factors	Extruder screw and die design, processing parameters, and material formulation.
Variability	Visual appearance of rippling varies between manufacturers.

6. CLARIFICATION ON HYDRAULIC DESIGN AND INDUSTRY STANDARDS

Questions are occasionally raised regarding the potential impact of bore ripples in PVC DWV pipes on hydraulic performance, particularly in gravity sewer systems installed at shallow gradients (e.g., 0.55% for DN150 and 0.33% for DN225). These gradients align with the design minimums specified in *The Water Services Association of Australia (WSAA) WSA 02 Version 3.3: Gravity Sewerage Code of Australia*[2].

It is important to recognise that WSA 02 applies conservative hydraulic design assumptions. For pipes in the DN150–DN300 range, the standard nominates a Manning coefficient of 0.0128 or, in Colebrook-White terms, a roughness (k) value of 1.5 mm. These values are intended to be conservative and cover a broad range of sewer pipe materials and installation conditions.

By contrast, independent sources—including the *Wallingford Tables for the Hydraulic Design of Pipes, Sewers and Channels (6th Edition, Volumes I & II, 1994)*[3], lists lower surface roughness values of PVC-U pipes, refer to Table 2 below:

Table 2: Lower surface roughness values of PVC-U pipes

PVC Pipe Configuration	k_s (mm)	Mannings n (calculated)
Pipe with chemically cemented joints	0.03	0.0066
Spigot and socket joints, rubber ring seals at 6 to 9 m intervals	0.06	0.0075

The Wallingford tables state k_s values of 0.03 mm for pipes with chemically cemented joints and 0.06 mm for those with rubber ring spigot and socket joints. These roughness heights translate to Manning coefficients of approximately 0.0066 and 0.0075, respectively.

These values are further validated by the *Hydraulics* chapter of the IWE *Manual of British Water Engineering Practice*[4], for PVC pipes, which denotes "with waviness." This confirms that bore waviness or ripples are typical and accounted for in industry-recognised hydraulic characterisations.

The relationship between the surface roughness k_s and Manning's n shown below, adapted from Marriot[5], was used to estimate the Manning coefficients in the table above.

$$n \approx 0.012(k_s[\text{mm}])^{1/6}$$

In the case of the WSAA the nominated maximum roughness k value of 1.5 mm, this approximates to a Manning's n = 0.0128, i.e., in complete agreement with the values given in WSA 02.

Importantly, while WSA 02 conservatively assumes a maximum roughness k value of 1.5 mm (equating to Manning's n = 0.0128), *AS 2200 Design Charts for Water Supply and Sewerage*[1] identifies a more typical upper limit of n = 0.009 for thermoplastic pipes such as PVC. This indicates that WSA 02 incorporates a safety margin of approximately 1.42 when designing for PVC, further underscoring its conservatism.

The conservative design parameters in WSA 02—including a built-in safety factor of approximately 1.42 for PVC pipes—ensure that typical surface characteristics such as bore ripples have no adverse effect on achieving self-cleansing velocities when installed as specified.

7. FIELD AND LABORATORY VALIDATION ON HYDRAULIC PERFORMANCE IN PVC PIPES

Field measurements of the hydraulic performance of PVC sewer pipes were carried out by Bishop[6] in 1975 in Colorado, USA. The study encompassed 25 individual flow measurements across four different installations, using pipe diameters of 8 and 10 inches (approximately 200 and 250 mm). These pipes had been in service for up to five years at the time of testing.

Observed flow velocities ranged from 0.308 to 1.84 m/s. Notably, several pipes exhibited slime accumulation along the wetted surface or up to the water line. However, in all instances, the slime was reported to be easily removable, indicating no long-term impact on surface roughness.

The study reported an average Manning's 'n' coefficient of 0.00907 with a standard deviation of 0.0012—demonstrating consistent and reliable hydraulic performance over time, even under typical in-service conditions.

More recently, a 2022 study conducted by the Utah Water Research Laboratory[7] evaluated the hydraulic performance of new 6- and 12-inch PVC pipes (approximately 150–300 mm) under controlled laboratory conditions. The study reported Manning's 'n' values ranging from 0.0094 to 0.0080, corresponding to flow velocities between 0.616 and 3.26 m/s.

When considered alongside the earlier field measurements by Bishop (1975)[6], these laboratory results provide strong, complementary evidence supporting the continued use of a Manning's 'n' value of 0.009 for PVC pipes, as specified in AS 2200. This coefficient remains appropriate for both new and in-service pipes operating under typical municipal sewer conditions.

Together, the data reaffirm that minor manufacturing features such as bore ripples do not materially impact hydraulic performance.

8. WATER JET CLEANING OF PVC PIPES

Routine maintenance of pipes often involves high-pressure water jetting to remove blockages, sediment, or build-up from the internal surface. Concerns are sometimes raised about whether this cleaning process may affect the integrity or hydraulic performance of the pipe bore over time.

When carried out in line with recommended best practices, water jetting has no significant impact on the internal surface of PVC pipes. POP205 – *Water Jet Cleaning of Plastics Pipes*[8], provides clear guidance outlining safe and effective procedures for the use of high-pressure water jetting on plastic pipe systems.

Best practice, as outlined in POP205, recommends that the selection of cleaning pressures and nozzle types be based on the pipe material and its condition. When these recommended practices are followed, jetting operations are both effective and non-destructive. The smooth bore and durable inner surface of PVC pipes are resilient to properly controlled jetting, and there is no evidence to indicate that such maintenance methods contribute to surface degradation or increased roughness.

Therefore, when carried out in line with best practice, water jet cleaning poses no risk to the hydraulic performance of PVC sewer pipes.

9. CCTV INSPECTION AND INTEPRETATION OF BORE RIPPLES

Closed-circuit television (CCTV) inspection has become a standard practice for assessing the condition of installed sewer infrastructure. The growing adoption of high-definition cameras, advanced lighting, and enhanced magnification has significantly improved the ability to visually inspect internal pipe surfaces. However, these same technological advancements can sometimes lead to misinterpretation of normal pipe features.

Bore ripples, which are expected in PVC pipes due to the extrusion process, may appear exaggerated under CCTV inspection. Camera lighting can cast shadows, and magnified views can distort perspective, making benign features seem more pronounced than they are in reality as shown in figure 1 and 2.

Figure 1: DN225 DWV bore rippling – CCTV view 1.

Figure 2: DN225 DWV bore rippling – CCTV view 2.

In most cases, such features are purely cosmetic and have no bearing on the pipe's performance, structural integrity, or hydraulic capacity. These minor internal surface variations have always existed in PVC pipes and have not compromised system function or longevity. Numerous industry observations have shown that:

- High-definition imaging can misidentify harmless features as defects.
- Visual distortions can exaggerate features like bore rippling or joint gaps.
- Observations can vary significantly between inspectors or equipment types.

In addition, recent measurement exercises clearly demonstrate that relying on photographs—whether taken during CCTV inspections or viewed onsite—as a basis for defining "excessive" rippling is highly unreliable. Lighting conditions, camera angle, and image contrast can dramatically accentuate the appearance of surface variations. What appears pronounced in an image may be barely noticeable in reality and of no consequence to pipe function.

Ultimately, what matters is whether the pipe meets all relevant material and installation standards, not whether minor surface features appear unusual under magnified inspection. Bore ripples that do not affect hydraulic performance, joint integrity, or compliance should not be treated as defects.

10. RIPPLING EVALUATION

Visual evaluation of the pipe bore rippling captured photographically or by CCTV inspection is difficult and not an effective technique on its own. This is due to bore ripple features often being exaggerated as indicated previously.

A more effective evaluation requires quantitative measurement of pipe wall thickness variation at regular intervals along the length of the pipe. This allows for pipe rippling to be characterised in terms of peak to valley ripple height i.e., amplitude.

A measurement exercise was carried out on a range of DWV PVC pipes manufactured by various PIPA members to quantify the normal and expected levels of bore rippling.

In some cases, measurements were also directly compared to photographs taken of the bore rippling (uninstalled) and corresponding in-situ CCTV images. In the figures below a typical example is given for the evaluation of bore ripples in DN150 and DN225 SN8 DWV pipe.

Figure 3: DN150 DWV bore rippling, photo taken at installation site with phone camera.

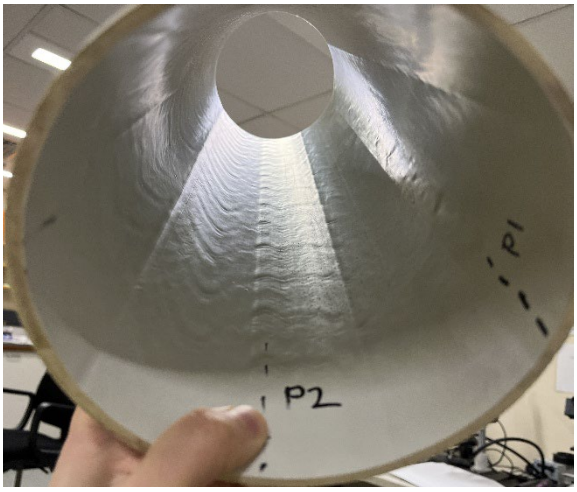


Figure 4: The same section of DN150 DWV bore rippling, photo taken in laboratory with phone camera.

Figure 5: DN225 DWV bore rippling – view 1 photographed by phone camera.

Figure 6: DN225 DWV bore rippling – view 2 photographed by phone camera.

Photographs and CCTV images clearly show that bore ripples are consistent in form and occur at reasonably regular intervals.

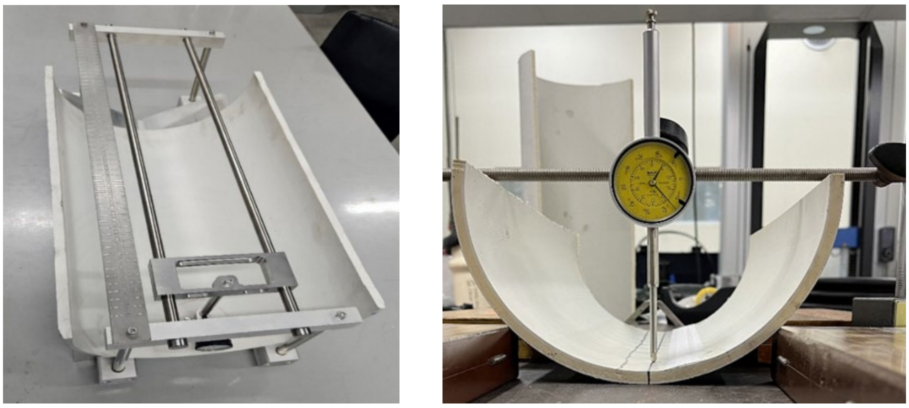
Measuring Technique: Quantifying the visual effect of bore rippling

Visual observations of axial rippling inside PVC pipe bores can sometimes appear more pronounced than they are in physical terms. To objectively quantify this visual effect and assess its dimensional significance, a measurement technique was developed and applied by three PVC pipe manufacturers. The aim was to demonstrate how the perceived rippling correlates with actual wall thickness variation—i.e., quantifying what appears to be seen versus what is quantifiably real.

Axial ripple zones were first assessed both visually and by touch to identify the most prominent areas along the pipe bore. These zones were marked on the pipe, after which a 500 mm section was cut and split lengthwise (axially) to expose the ripple profile.

Within each sample, the most visually prominent ripple zone was selected. A straight axial line was then marked along the crest of the ripple waveform in this zone. This line served as the path for precise wall thickness measurements, taken using either a micrometer or a dial/digital indicator mounted for consistent accuracy (see Figure 7). Measurement intervals were no greater than 10 mm, and instruments used had an accuracy of 0.01 mm or better.

Figure 7 - Dial gauge test jig for pipe bore ripple measurement



Results – Ripple amplitude across manufacturers

Table 3 below summarises the results of ripple amplitude measurements from three different manufacturers. Pipe diameters tested included DN150, DN225, and DN300.

Table 3 – Summary of manufacturers measurements

Manufacturer	Mean Ripple Amplitude
Manufacturer 1	0.28 mm
Manufacturer 2	0.30 mm
Manufacturer 3	0.23 mm

In all cases, the peak-to-valley height of the ripples did not exceed 0.5 mm, and the internal bore surface remained smooth to the touch.

This assessment confirms that while bore rippling in PVC pipes may appear visually pronounced, actual dimensional variation is minor and consistent across manufacturers. The findings demonstrate that such rippling is not significant enough to affect hydraulic performance or pipe quality and is well within acceptable tolerances.

11. MAXIMUM ALLOWABLE RIPPLE HEIGHT

The clauses for Freedom from defects in Australian Standards have recognised the potential presence of rippling in PVC pipes for over 40 years. This feature was first included in the 1984 edition of AS 1260 for DWV pipes and in 1988 for pressure pipes to AS 1477.1. In both cases, the acceptance criteria were related back to the dimensional requirements of the relevant Standard. However, in the years since, PVC DWV pipes have moved to being specified on a performance basis in terms of their ring-stiffness. This has led to removal of wall thickness tolerances which had set a limit on rippling.

PVC pipe manufacturers have QA processes in which conformity to the Standard is demonstrated according to a sampling and test plan. Visual Inspection for Freedom from defects in accordance with Clause 2.4 of AS/NZS 1260 is conducted at a frequency of once per shift. Where visual inspection indicates high levels of rippling that may be of concern, the ripple height shall be measured and shall not exceed the following in Table 4:

Table 4 – Maximum Ripple Height (peak to valley)

DN	Maximum Ripple Height (peak to valley)
150	0.7mm
225	1.0mm
300	1.2mm

This maximum ripple height is based on the historical wall thickness tolerance for PVC SEH Class Sewer pipes and is included on the basis that pipes with these tolerances have successful long-term performance in sewerage reticulation applications in Australia. (ref: AS/NZS 1260 Part 1 – 1984).

12. CONCLUSION

Bore rippling is a normal and expected feature of PVC pipe manufacturing, resulting from the extrusion process. It is a well-recognised phenomenon acknowledged by Australian Standards, including AS/NZS 1260[1]. Minor wall thickness variations caused by rippling do not affect the pipe's structural strength or hydraulic performance.

Extensive field and laboratory testing—including real-world service evaluations and controlled hydraulic studies—confirm that bore ripples have no measurable impact on flow performance. Hydraulic coefficients remain well within design assumptions, with Manning's 'n' consistently validating the use of a conservative value of 0.009 for PVC sewer pipes, even at minimum design gradients.

Key takeaways from this technical review include:

Bore rippling is normal and expected
It is inherent to the extrusion process and varies slightly between manufacturers, with ripple amplitudes typically below 0.5 mm. These minor variations are aesthetic only and fall within accepted manufacturing tolerances.

No effect on structural or hydraulic performance
Pipes exhibiting rippling meet all applicable product standards for wall thickness, stiffness, pressure rating, and impact resistance. The internal surface remains smooth to the touch, and self-cleansing velocities are maintained.

Conservative assumptions in WSA 02 cover rippling effects
The *WSA 02 Gravity Sewerage Code* adopts deliberately conservative hydraulic parameters—such as a roughness height (k) of 1.5 mm or Manning's n = 0.0128—for design. These values incorporate a substantial safety margin that comfortably accounts for minor surface features like bore rippling, ensuring reliable performance even under shallow gradient conditions.

Water jetting is safe when done to Best Practice
When performed in line with PIPA's POP205 guideline, high-pressure water jet cleaning does not harm the internal pipe surface. PVC pipes remain resilient under such maintenance, with no degradation of bore or performance.

CCTV inspections can be misleading
Modern CCTV systems can exaggerate surface features due to lighting and camera angles. Bore rippling may appear more prominent than it is, leading to misclassification as a defect. Visual inspection alone is not a reliable basis for assessing pipe condition.

Measurement is not routinely required
Accurate ripple measurement requires destructive lab testing and is not practical or necessary for standard quality assurance. With all performance indicators met, visual assessment is sufficient monitoring.

Standards and QA systems are sufficient
Australian product standards and manufacturer QA protocols already ensure consistent compliance and performance. Ripples within these tolerances do not warrant concern.

In summary, bore rippling in PVC pipes is a benign manufacturing artefact with no bearing on the pipe's long-term functionality. It does not affect structural strength, hydraulic capacity, maintenance suitability, or service life. When installed and maintained in accordance with current standards and best practices, PVC pipes with bore rippling perform as intended and should not be treated as defective.

13. TECHNICAL REFERENCES

[1]AS/NZS 1254 PVC-U pipes and fittings for stormwater and surface water applications

[1]AS/NZS 1260 PVC-U pipes and fittings for drain, waste and vent applications

[1]AS/NZS 1477 PVC pipes and fittings for pressure applications

[1]AS/NZS 4441 Oriented PVC (PVC-O) pipes for pressure applications

1AS/NZS 4765 Modified PVC (PVC-M) pipes for pressure applications

[1]AS2200 Design charts for water supply and sewerage

[2]The Water Services Association of Australia (WSAA) WSA 02 Version 3.3: Gravity Sewerage Code of Australia

[3]Tables for the hydraulic design of pipes, sewers and channels, 6th Edition Volumes I & II, HR Wallingford and D.I.H Barr, 1994

[4]IWE *Manual of British Water Engineering Practice*

[5]Marriott, M.J. and Jayaratne, R. (2010) 'Hydraulic roughness - links between Manning's coefficient, Nikuradse's equivalent sand roughness and bed grain size' Proceedings of Advances in Computing and Technology, (AC&T) The School of Computing and Technology 5th Annual Conference, University of East London, pp. 27-32

[6]Bishop, Ronald R., "Hydraulic Characteristics of PVC Pipe in Sanitary Sewers (A Report of Field Measurements)" (1978). Reports. Paper 598

[7]Uni-Bell PVC Pipe Association, Utah Water research Laboratory, M.E. Simpson Co Inc., 'Hydraulic Testing of PVC Pipe Laboratory and Field Tests Confirm Flow Coefficients', June 2023

[8]POP205 – *Water Jet Cleaning of Plastics Pipes*

[9] Westlake Pipe & Fittings, Technical Bulletin, Minor Surface Dimples & Rippling of PVC Pipe, 2022

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