# Comparison of current Australian Standard with updated ISO standard

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| Current Australian Standard | AS 3778.4.1 | Measurement of water flow in open channels<br>Part 4: Measurement using flow gauging structures<br>Method 4.1: Thin-plate weirs |
| Updated ISO Standard | ISO 1438 | Hydrometry – Open channel flow measurement using thin-plate weirs |

## High-level comment on differences

The updated ISO Standard is substantially different in many sections to the current Australian Standard.

Whilst some sections are identical or similar (i.e. only minor updates and changes to content), there are however, several substantial differences between the documents which are summarised as follows:

- The updated ISO includes an increased required approach length (double the aged standard) but includes provisions for installing flow straighteners and/or baffles to modify approach conditions suitably. It also includes a new Annex (Annex A) which provides a mechanism for factoring the coefficient of discharge when the approach length is not suitable. Similarly, it also includes a new Annex (Annex B) which provides design and installation requirements for flow straighteners.
- The updated ISO standard includes provision for the option of measuring the downstream head to determine flow in drowned conditions for rectangular full width (b/B = 1.) thin plate weirs.
    - The updated ISO includes standards for downstream head measurement location (7.3.2)
    - Mechanisms for determining the drowned flow correction factor for the coefficient of discharge and its application in the modified Rehbock flow discharge equation for full width weirs (9.7.2)
    - Limitations for operation in the drowned flow range (9.7.2)
- The updated ISO standard provides considerable additional information on Uncertainties in flow measurement and aligns the Standard with the *Guide to the expression of uncertainty in measurement (GUM)* and *ISO/TS 25377*. The changes include the following:
    - AS3778.4.2 expresses measurement uncertainty of the discharge coefficient at the 95% confidence interval (equivalent to two standard deviations). The updated ISO expresses the discharge coefficient as standard uncertainty in accordance with *GUM* as one standard deviation.
    - Inclusion of a new Annex (Annex C – Introduction to measurement uncertainty)
    - Inclusion of a new Annex (Annex D – Sample measurement performance for use in hydrometric worked examples)
    - Substantial rework of Section 11– Uncertainties in flow measurement
        - The revised section of uncertainties in flow measurement aligns the Standard with Standard Uncertainty equivalent to one standard deviation.

- This revised section, and the accompanying worked example in Section 12 provides considerable additional detail on measurement uncertainty and aligns it with standard uncertainty (one standard deviation).
- It should be noted that the updated ISO standard still includes Section 10.7 – Accuracy of discharge coefficients – Triangular-notch weirs which contains information that is contradictory to the uncertainty principles presented in the revised version of Section 11. This section still makes reference to 95% confidence interval (equivalent to two standard deviations) however the uncertainty principles in Section 11 are in accordance with standard uncertainty for hydrometry (one standard deviation). I suspect that this was an error in the revision of ISO1438 and Section 10.7 should be removed in the same way that Section 9.8 (Accuracy of discharge coefficient – Rectangular weirs) was removed.

## Reviewer recommendation

I recommend that the technical committee

- *accept the updated ISO in full to replace current AS*

(This recommendation was reached following further discussion with Working Group members)

In future ISO review processes, as the opportunity arises, recommend updating or removing Section 10.7 as it contains the old standard for uncertainty estimation (95% confidence interval).

| *options* |
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| • *accept the updated ISO in full to replace current AS (simplest option!)* |
| • *reject the updated ISO and withdraw the current AS (in cases where the update is not appropriate for Australian practice)* |
| • *reject the updated ISO and re-confirm the current AS without change (an alternative option in cases where the update is not appropriate for Australian practice)* |
| • *further work required to adapt the ISO for an updated AS (non-preferred option, exceptional cases only)* |

## Detailed summary of differences

The table below outlines in more detail a summary of the differences between the current Australian Standard under review and the relevant updated ISO standard and includes reviewer comment where relevant.

*Column 1: Identifies the number and name of the section in the current Australian Standard*

*Column 2: Classification of the change for that section. Classified as either:*

- ***No change** (green shading) – The updated ISO is the same as the current Australian Standard.*
- ***Minor change** (blue shading) – Changes that have minimal impact on the outcome, including*
  - *minor format, style or heading changes*
  - *minor additions, removals or changes to a few words or clauses*
  - *addition or exclusion of more detailed explanation*
  - *very minor changes to steps or processes.*
- ***Significant change** (orange shading) – Changes that have a moderate to major impact on the outcome, such as*
  - *Changes to requirements*
  - *Significant changes to calculations, steps or processes.*

*Column 3: More detail to describe the change, and comment from the reviewer (enough detail for the consideration of AHA and WaMSTeC members in their review).*

*Text colour is used in this column as follows:*

- *Black text – More detailed explanation of the changes and reviewer comment. Specific reviewer comment on the changes highlighted in yellow.*
- *Blue text – reference to information included in the updated ISO that is not in the current Australian Standard*
- *Red text – reference to information included in the current Australian Standard that is not in the updated ISO.*

| Section (AS section number) | Classification of change AS to ISO | More detail and comment on changes in the updated ISO |
|---|---|---|
| 1. Scope and field of application | Significant change | Title changed to “Scope”. Updated standard limits this section to purely defining the scope and removes references to technical aspects of the application of Thin-plate weirs. |
| 2. References | Minor change | Title changed to “Normative references” and reference to ISO 4373 (Measurement of liquid flow in open channels – Water level measuring devices). |
| 3. Definitions | Minor change | Title changed to “Terms and definitions”. Minor wording changes and included references to external websites. Recommend that these be included in the References section if suitable. |
| 4. Units of Measurement | Significant change | This section has been removed in the updated standard and replaced with “Symbols and abbreviated terms”. The aged standard does not contain a section on nomenclature. |
| 5. Principle | Minor change | Inclusion of reference to drowned flow which is not covered in the aged standard. All other content identical. |
| 6. Installation<br>6.1 General | No change | Title and content identical. |
| 6.2 Selection of site | No change | Title and content identical. |
| 6.3 Installation conditions<br>6.3.1 General | No change | Title and content identical. |
| 6.3.2 Weir | No Change | Title and content identical |

| Section (AS section number) | Classification of change AS to ISO | More detail and comment on changes in the updated ISO |
|---|---|---|
| 6.3.3 Approach channel | Significant change | Minor wording changes. Specifications for the acceptable approach channel length have been updated from [redacted] times the width of the nappe to [redacted] times the width of the nappe.<br>A reference to a new Annex (Annex A) has been included to provide guidance on flow measurement in small tanks where the approach channel is shorter than 10 times the width of the nappe.<br>A reference to a new Annex (Annex B) has been included to specify installation of flow straighteners.<br>The updated standard also specifies restrictions on maximum measured head and the implication of flow straightener installation on reducing approach channel length.<br>Formatting change to Figure 1. |
| 6.3.4 Downstream channel | Significant change | Inclusion of additional information relating to drowned flow operation.<br>All other content similar with minor wording changes. |
| 7. Measurement of head<br>7.1 Head measuring devices | No Change | Title and content identical |
| 7.2 Stilling well | Minor change | Title changed to “Stilling or float well” in updated standard. Minor wording changes but meaning identical. |
| 7.3 Head measurement section | Significant change | Section 7.3 in the updated ISO has been split into two sections:<br>7.3.1 Upstream head measurement<br>7.3.2 Downstream head measurement<br>Section 7.3.1 is very similar to content in Section 7.3 of the aged standard, however additional information is provided for adjustment to the coefficient of discharge to account for frictional effects on the upstream channel. A new table (Table 1) is also provided which outlines correction factors to account for frictional effects based on *l/h* and *h/p*.<br>Section 7.3.2 provides specifications for measurement of water level downstream of the weir for measurement of flow in drowned conditions. |

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| 7.4 Head-gauge datum (gauge zero) | No change | Title and content identical |
| 8. Maintenance | Minor change | Majority of content identical.<br>Inclusion of maintenance requirements for flow straighteners. |
| 9. Rectangular thin-plate weir<br>9.1 Types | Significant change | Text of section identical, however Figure 2 has been updated to change the acceptable location of head measurement. The aged standard required head to me measured in a section [redacted] times $h_{max}$ behind the crest, whereas the updated standard specifies the head measurement section as [redacted] times $h_{max}$ from the crest. |
| 9.2 Specifications for the standard weir | No change | Title and content identical |
| 9.3 Specifications for installation | No change | Title and content identical |
| 9.4 Specifications for head measurement | Minor change | This section formerly consisted of two sections:<br>9.4.1 – General which made specifications for head measurement by reference to Section 7.1, 7.2 and 7.3<br>9.4.2 – Determination of gauge zero.<br>In the updated standard, Section 9.4.1 has been removed, as it purely references other sections of the same document and is therefore unnecessary.<br>It has been replaced by Section 9.4 Determination of gauge zero.<br>The content of this section is identical to Section 9.4.2 of the aged standard, with the figures being refreshed graphically. |
| 9.5 Discharge formulae - General | Significant change | Inclusion of reference to a third category of discharge formula – non-modular discharge formula for full-width weirs.<br>Removal of reference to symbols used in formulae, as they are now located in Section 4 of the updated standard. |

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| 9.6 Formulae for the basic weir form (all values of *b/B*)<br>9.6.1 Kindsvater-Carter formula | Minor change | Minor change to symbols used in formula. $C_e$ has been changed to $C_d$. |
| 9.6.1.1 Evaluation of $C_e$, $k_b$ and $k_h$ | Minor change | Section number in updated Standard has been changed to Section 9.6.2.<br>Minor changes to symbols used in formulae. $C_e$ has been changed to $C_d$. Remaining content identical. |
| 9.6.1.2 Formulae for $C_e$ | Minor change | Section number in updated Standard has been changed to Section 9.6.3.<br>Minor changes to symbols used in formulae. $C_e$ has been changed to $C_d$. Remaining content identical. |
| 9.6.1.3 Practical limitations on *h/p*, *h*, *b* and *p* | Minor change | Section number in updated Standard has been changed to Section 9.6.4.<br>Content identical. |
| 9.6.2 SIA formula | Significant change | The Swiss SIA (Société des Ingénieurs et Architectes Suisses) formula has been removed from the updated standard. Comment: This is a reasonable removal as the Kindsvater-Carter equation is simpler to apply and there are no significant accuracy benefits to using the SIA equation. |
| 9.7 Formulae for full-width weirs (*b/B* = 1.0) | Significant change | Removal of content in this heading section which purely references other sections and does not provide additional information/value. |
| 9.7.1 Rehbock formula (1929) | Significant change | Title changed to “Modular flow discharge formula” in updated standard.<br>Minor changes to symbols used in formulae. $C_e$ has been changed to $C_d$.<br>Notable changes to practical limitations:<br>*h/p* shall not be greater than [redacted]. (was [redacted] in aged standard)<br>*h* shall be between [redacted] and [redacted]m (was [redacted] and [redacted]m in aged standard)<br>*p* shall be between [redacted] and [redacted] m (was less than [redacted]m)<br>Provision is also made for determining Cd when [redacted] with a mechanism for determining effective head ($h_e$) and the practical limitations of this scenario. |

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| 9.7.2 IMFT formula | Significant change | The IMFT (Institut de Mecanique des Fluides de Toulouse) formula for full-width weirs has been removed from the updated standard. |
| New inclusion | Significant change | Inclusion of new section – Section 9.7.2 Non-modular flow discharge formula.<br>This section provides a method for determining the drowned flow reduction factor *f* under various conditions, and its method of application in the Rehbock equation. |
| 9.8 Accuracy of discharge coefficient – Rectangular weirs | Significant change | This section has been removed from the updated standard, as it is superseded by information contained in the revised Section 11 (Accuracy of discharge measurements). |
| 10. Triangular thin-plate weir<br>10.1 Specifications for the standard weir | No change | Title and content identical. |
| 10.2 Specifications for the installation | No change | Title and content identical. |
| 10.3 Specifications for head measurement<br>10.3.1 General | No change | Title and content identical. |
| 10.3.2 Determination of the notch angle | No change | Title and content identical. |
| 10.3.3 Determination of gauge zero | Minor change | Minor formatting changes. Content identical. |
| 10.4 Discharge formulae - General | Minor change | Removal of reference to symbols used in formulae, as they are now located in Section 4 of the updated standard. All other content identical. |
| 10.5 Formula for all notch angles between π/9 and 5π/9 radians ($20^o$ - $100^o$) | Minor change | Content from this section has been moved to 10.5.1 – Kindsvater-Shen formula.<br>Minor change to symbols used in formula. $C_e$ has been changed to $C_d$.<br>All other content identical with minor formatting updates. |

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| 10.5.1 Evaluation of $C$ and $k_h$ | Minor change | Section number corresponds to 10.5.2 in updated standard.<br>Minor change to symbols used in formula. $C_e$ has been changed to $C_d$.<br>All other content identical with minor formatting updates. |
| 10.5.2 Practical limitations on $\alpha$, $h/p$, $p/B$, $h$ and $p$ | Minor change | Removal of the limitations specified for $p/B$.<br>All other limitations identical. |
| 10.6 Formula for specific notch angles | No change | Title and content identical. |
| 10.7 Accuracy of discharge coefficients – triangular-notch weirs | No change | Title and content identical.<br>Note that while the title and content of this section is identical to the aged standard, I suspect it is included in the updated standard in error as it is contradicted by the revised uncertainty methods presented in the updated Section 11.<br>This section should be removed from the updated standard in the same way that Section 9.8 was removed, as it is superseded by Section 11. |

| Section (AS section number) | Classification of change AS to ISO | More detail and comment on changes in the updated ISO |
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| 11. Accuracy of discharge measurements | Significant change | Title changed to Uncertainties of flow measurement.<br>The changes in this section are numerous and significant. The updated standard aligns the Standard with the *Guide to the expression of uncertainty in measurement (GUM)* and *ISO/TS 25377*. The changes include the following:<br>• AS3778.4.2 expresses measurement uncertainty of the discharge coefficient at the [redacted] confidence interval (equivalent to two standard deviations). The updated ISO expresses the discharge coefficient as standard uncertainty in accordance with *GUM* as one standard deviation.<br>• Substantial rework of all subsections in this section to align with standard uncertainty. Removal of term “error” in preference to “uncertainty”<br>  ○ The revised section of uncertainties in flow measurement aligns the Standard with Standard Uncertainty equivalent to one standard deviation.<br>  ○ This revised section, and the accompanying worked example in Section 10 provides considerable additional detail on measurement uncertainty and aligns it with standard uncertainty (one standard deviation).<br>  ○ The equation for modular flow measurement uncertainty has been updated from [redacted] to reflect one standard deviation<br>  ○ An additional equation for uncertainty in drowned flow conditions is presented.<br>The multiple sub-sections of this section have been modified considerably and as-such, cannot be directly compared. However the updated standard brings it in-line with ISO25377 – Hydrometry uncertainty guidance. It is therefore recommended that all changes to this section be adopted in their entirety |

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| 12. Example | Significant change | This section and all sub-sections are considerably different to the example presented in the aged standard as the approach to uncertainty determination has changed considerably.<br>As such, if the changes proposed to Section 9 are to be implemented, it is also recommended that all changes to this section be adopted in their entirety. |
| New inclusion – Annex A | Significant change | Inclusion of a new Annex (Annex A) which provides information relating to using small weir tanks for flow measurement.<br>This Annex is referenced in Section 6.3.3 of the updated standard and provides a method for estimating the coefficient of discharge when the approach channel is shorter than 10 times the width of the nappe. |
| New inclusion – Annex B | Significant change | Inclusion of a new Annex (Annex B) which provides information relating to the design and installation of a flow straightener.<br>This Annex is referenced in Section 6.3.3 of the updated standard and provides a method for straightening the flow in a shortened approach channel. |
| New inclusion – Annex C | Significant change | Inclusion of a new Annex (Annex C – Introduction to measurement uncertainty)<br>A detailed informative Annex relating to the updated methods for determining measurement uncertainty.<br>This Annex is referenced extensively in the revised version of Section 11 - Uncertainties in flow measurement. |
| New inclusion – Annex D | Significant change | Inclusion of a new Annex (Annex D – Sample measurement performance for use in hydrometric worked examples)<br>A supplementary document referenced extensively in the revised version of Section 12 – Example. |
| Table 1 | Minor change | Table 1 from the aged standard has been relocated to Annex E |

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