

# Goulburn-Murray Water

*“Commercial in Confidence”*

## In-situ Testing of Dethridge Meter Accuracy in the Goulburn-Murray Irrigation District

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Hydro Environmental  


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# Table of Contents

## Acknowledgements

<b>Executive Summary</b>	<b>1</b>
E1. Project Objectives	1
E2. Key Findings	1
E3. Background	1
E4. Methodology	2
E5. Results	2
E6. Recommendations	4
<b>1. Project Objectives</b>	<b>5</b>
<b>2. Background</b>	<b>5</b>
<b>2.1. General</b>	<b>5</b>
<b>2.2. Test Specific</b>	<b>6</b>
<b>2.3. Error Reporting</b>	<b>6</b>
2.3.1. Meter Error	6
2.3.2. Correct Delivery Volume	6
2.3.3. Error Convention	6
2.3.4. Uncertainty in Measured Volume	7
<b>2.4. In-situ Meter Testing - Test Methodology</b>	<b>7</b>
2.4.1. General Processes for These Tests	7
2.4.2. Specific Processes for These Tests	8
<b>2.5. Accuracy Verification of In-situ Measurement Verification Rigs (IMVR)</b>	<b>8</b>
2.5.1. Electronic Verification	8
2.5.2. Flow Verification	8
2.5.3. Recommended Best Practice	8
2.5.4. Thiess Services – Remote Electronic Verification System (REVS)	9
2.5.4.1. Siemens Verification Test Report (dry testing)	9
2.5.4.2. Manly Hydraulics Report (wet testing)	9
2.5.5. AWMA Water Control Solutions – MagRig	9
2.5.5.1. Electronic Verification (dry testing)	9
2.5.5.2. Manly Hydraulics Report (wet testing)	10
2.5.6. Corrected Delivery Volume Calculations Check	10
<b>2.6. In-situ Meter Selection</b>	<b>10</b>
2.6.1. Dethridge Meter Sizes	10
2.6.2. Sources of LMO Measurement Error	12
2.6.3. Dethridge Meter Pendant Counter Accuracy	13
<b>3. In-situ Dethridge Meter Test Results</b>	<b>16</b>
<b>3.1. Analysis of LMO Results</b>	<b>16</b>
3.1.1. 2007 In-situ Testing Results for LMO – All Data (High, Normal & Low Flow)	16
3.1.2. 2008 In-situ Testing Results for LMO – All Data (High, Normal & Low Flow)	17
3.1.3. 2009 In-situ Testing Results for LMO – All Data (High, Normal & Low Flow)	18
3.1.4. Testing Contractor Comparison	19
3.1.5. Combined In-situ Testing Results for LMO - Normal Ordered Flow Data	21
3.1.5.1. Spread of LMO Measurement Error	21
3.1.5.2. Flow vs. Measurement Error	22
3.1.5.3. Tailwater Depth vs. Measurement Error	23
3.1.5.4. Supply Depth vs. Measurement Error	24
3.1.5.5. Bottom Clearance vs. Measurement Error	25
3.1.5.6. Maintained vs. Unmaintained LMO Measurement Error	26
<b>3.2. Analysis of DLMO Results</b>	<b>27</b>
<b>3.3. Analysis of SMO Results</b>	<b>28</b>

<b>3.4. Portability of the Results</b>	<b>29</b>
<b>3.5. Combined In-situ Volumetric Error and Billing Measurement Error</b>	<b>30</b>
<b>3.6. Mathematical Model</b>	<b>31</b>
<b>4. Findings</b>	<b>32</b>
<b>5. Key Findings</b>	<b>33</b>
<b>6. Recommendations</b>	<b>34</b>
<b>Appendix 1 – Large Meter Outlet (LMO) In-situ Testing Results</b>	<b>35</b>
<b>Appendix 2 – Dethridge Long Meter Outlet (DLMO) In-situ Testing Results</b>	<b>40</b>
<b>Appendix 3 –Small Long Meter Outlet (SMO) In-situ Testing Results</b>	<b>41</b>
<b>Appendix 4 – Outliers - Large Meter Outlet (LMO) In-situ Testing Results</b>	<b>41</b>
<b>Appendix 4 – Outliers - Large Meter Outlet (LMO) In-situ Testing Results</b>	<b>42</b>

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## Executive Summary

### E1. Project Objectives

The objectives of this project were to:

- i) review and assess all in-situ field flow measurement error verification data for a sample of Dethridge meter service points provided by Thiess Services and AWMA Water Control Solutions since 2007.
- ii) provide a report outlining the tested flow measurement accuracy of a range of different size Dethridge meter outlets tested in 2007, 2008 and 2009 across six Goulburn-Murray Irrigation District (GMID) Irrigation Areas.

### E2. Key Findings

The following key findings should be noted:

- i. Based on the in-situ test results on 95 LMO service points;
  - a. The mean LMO measurement error (excluding pendant counter error) across the GMID could be between -6.96% and -4.56% with a mean of -5.76%.
  - b. The mean LMO measurement error (excluding pendant counter error) for unmaintained LMOs across the GMID could be between -7.45% and -4.85% with a mean of -6.15%.
  - c. Including the inherent inaccuracy of the pendant counter, the mean LMO measurement error across the GMID could be between -7.41% and -4.83% with a mean of -6.12%.
  - d. LMO measurement within the GMID is non-compliant meters within the GMID based on the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time.

**Point a. and b. are the mean (volumetric) in-situ result as tested and calculated by each contractor with applied confidence limits determined by an extrapolation in order to represent the whole GMID LMO error. Whereas point c. includes the mean volumetric error (in-situ error as tested and calculated by each contractor) and the mean billing measurement error (pendant counter error) with applied extrapolation in order to represent the whole GMID.**

- ii. Based on the in-situ testing results, the DLMO and SMO, are also non-compliant meters within the GMID based on the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time.

### E3. Background

Accurate metering of water delivered to customers is essential for good water management and customer billing. It is therefore imperative that water authorities have an accurate and comprehensive knowledge of the amount of water each customer is using, for the purposes

of billing and to assist in understanding the water balance in the Goulburn-Murray Water (G-MW) delivery systems.

The implementation of the National Metering Standards results in the requirement for all non-compliant meters to be replaced or upgraded with Pattern Approved meters within the GMID. There are over 20,000 non-compliant meters currently used within the GMID.

Due to the significant requirements of the National Metering Standards, the State Government stipulated within the Northern Victoria Irrigation Renewal Project (NVIRP), and other modernisation projects that the program of works should include replacement of inaccurate and non-compliant meters to both assist G-MW in implementation of the National Standards and ensure the benefits of a modernised system are fully realised.

As part of the GMID modernisation process, it is expected that all Dethridge meters will be replaced over a period of time.

For G-MW's in-situ Dethridge meter accuracy testing program, undertaken between 2007 to 2009, the Thiess Services 'Remote Electronic Verification System' (REVS) as well as the AWMA Water Control Solutions 'MagRig' (MagRig) were used. Both of these testing units are large, portable, independently certified, In-situ Measurement Verification Rigs (IMVR) which are used to collect flow data on the measurement accuracy of a number of Dethridge meters across the GMID.

This report is based on the in-situ error measurement analysis of 95 Large Meter Outlets (LMO), 11 Small Meter Outlets (SMO) and 6 Dethridge Long Meter Outlets (DLMO) tested as part of the G-MW Dethridge meter testing program across six GMID Irrigation Areas.

#### **E4. Methodology**

The REVS unit (2007 – 2009) and the MagRig (2009) were used to undertake the in-situ testing of a sample of Dethridge meters across the GMID.

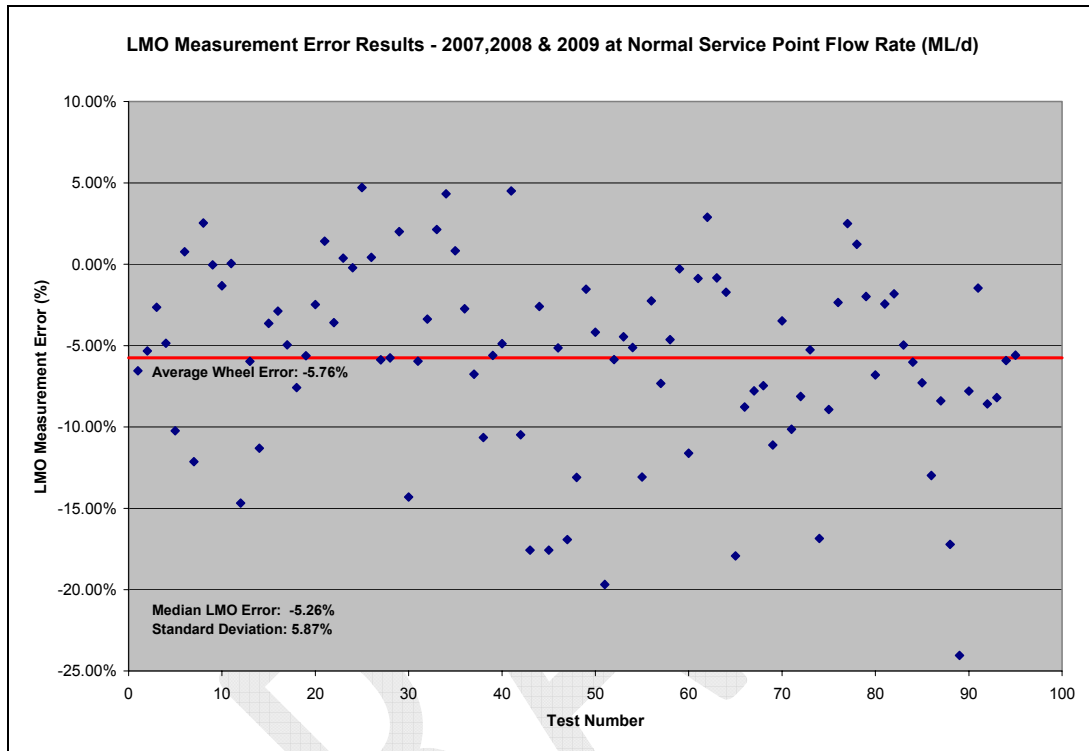
At each site at least three flow rates were tested using the IMVRs. These flow rates represented the approximate normal customer ordered flow rate at that service point as well as a lower and higher flow rate. The test conditions were chosen to enable the measurement accuracy to be assessed under the normal operating conditions at that site as well as to gain an understanding of the expected performance of the meter in that operating environment under higher and lower flow conditions.

Hydro Environmental undertook the assessment of the in-situ flow data after reviewing the corrected delivery volume calculations and analysis workbooks for each contractor.

#### **E5. Results**

G-MW is primarily interested in the accuracy of the LMO (the most widely used irrigation meter in the GMID) at their normal operating flow. As such, the main conclusions drawn in this report are based on the analysis of measurement error results from 95 LMOs tested at their normal operating flow. Brief conclusions are also drawn as to the in-situ accuracy of the SMO and DLMO from the small sample of service points that were tested.

**Figure E1** provides a graphical representation of the spread of LMO measurement error at their normal operating flow across the GMID. This graph shows the large scatter of accuracy which ranges between -24.05% to 4.72% with a mean of -5.76%. Variables such as bottom clearance, tailwater depth, supply depth, maintenance issues and flow rate have been assessed against measurement error for the same sample of data and are discussed in detail in the report to help explain the high level of variability in the results.



**Figure E1: Spread of GMID LMO Measurement Error (%)**

**Table E1** provides a summary of the in-situ error measurement results for the three Dethridge meter types in operation across the GMID as well as the combined volumetric and billing accuracy. The mean measurement error for the LMO was determined from normal operating flow tests, while the mean measurement error for the sample of SMOs and DLMOs were determined using the three flow test results due to the limited data available.

It can be noted that on average, none of the Dethridge meter models complied with the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time. Despite the SMO and DLMO mean measurement errors being below 5%, two standard deviations away from the mean in both cases, caused the 95% confidence width to fall outside of the  $\pm 5\%$  specification. Furthermore, the extrapolation uncertainty is independent from the standard deviation and should be considered separately. For example, the standard deviation applies only to the variance in the errors of the meters tested, whereas the extrapolation uncertainty is used when applying the mean measurement error to the entire GMID population.

Table E1: GMID Dethridge Meter Accuracy Results.

In-situ Error (Volumetric only)						
Meter Type	Sample Size	Mean Measurement Error (%)	Standard Deviation (%)	Mean Systematic Uncertainty (%)	95% Confidence Limits based on St <sup>d</sup> (%)	95% Confidence Limits based on Extrapolation (%)
LMO	95	-5.76	5.87	± 0.50	-17.50 to 5.98	-6.96 to -4.56
SMO	11	-0.43	8.37	± 0.50	-16.90 to 16.04	-5.53 to 4.67
DLMO	6	-0.63	4.37	± 0.50	-9.37 to 8.11	-4.33 to 3.07
Pendant Counter Error & In-situ Error (Billing and Volumetric Error combined)						
LMO	95 <sup>⓪</sup>	-6.12	6.47	N/A	-12.59 to 0.35	-7.41 to -4.83

Note: (i) Refer to Section 3.5 for explanation on combined sample population.

## E6. Recommendations

It is recommended that:

- i. G-MW adopts the recommended best practice for verifying the accuracy of IMVR meters as outlined in **Section 2.5.3** whereby G-MW request bi-annual electronic calibration (dry test) certificates and flow testing (wet test) certificates every two years to verify test system recording accuracy.
- ii. If G-MW continue to undertake in-situ meter testing, G-MW continue to use the REVS and MagRig IMVRs as independent audit tools and compliance measure for determining the accuracy on a range of irrigation meters in the field.
- iii. G-MW compares the LMO in-situ testing results with the LMO mathematical modelling results and if necessary recalibrate the model to ensure the use of this method of determining meter error is a simple accurate low cost alternative to in-situ testing.
- iv. G-MW conduct in-situ testing on a small number of LMO Dethridge meters using both AWMA Water Control Solutions and Thiess Services IMVR in order to verify the assumption that both systems measure to the same level of accuracy.

# Review of Dethridge Meter Accuracy

## 1. Project Objectives

The objectives of this project were to:

- iii) review and assess all in-situ field flow measurement error verification data for a sample of Dethridge meter service points provided by Thiess Services and AWMA Water Control Solutions since 2007.
- iv) provide a report outlining the tested flow measurement accuracy of a range of different size Dethridge meter outlets tested in 2007, 2008 and 2009 across six GMID Irrigation Areas.

## 2. Background

### 2.1. General

Accurate metering of water delivered to customers is essential for good water management and accurate billing. It is an imperative that water authorities have an accurate and comprehensive knowledge of the amount of water each customer is using for billing purposes, and to assist in understanding the water balance in the G-MW delivery systems.

The implementation of the National Metering Standards results in the requirement for all non-compliant meters to be replaced or upgraded with Pattern Approved meters within the GMID. There are over 20,000 non-compliant meters currently used within the GMID. The new National Standards potentially provide significant water savings benefits for G-MW, however there are many issues faced in order to comply with the impending standards. These issues include;

- i) a lack of Pattern Approved meters
- ii) cost implications associated with the purchase and installation of new pattern approved meters
- iii) cost implications associated with the ongoing measurement compliance maintenance and testing activities
- iv) skills shortage and retention of technically proficient staff to install and maintain new meters
- v) the risks associated with adopting new technology and adapting to technological changes
- vi) public perception and irrigators resilience to change.

Due to the significant requirements of the National Metering Standards, the State Government stipulated within the Northern Victoria Irrigation Renewal Project (NVIRP), and other modernisation projects that the program of works should include replacement of inaccurate and non-compliant meters to both assist G-MW in implementation of the standards and ensure the benefits of a modernised system are fully realised.

As part of the GMID modernisation process, it is expected that all Dethridge Meters will be replaced over a period of time.

## 2.2. Test Specific

For G-MWs Dethridge Meter testing program from 2007 to 2009 the Thiess Services 'Remote Electronic Verification System' (REVS) as well as the AWMA Water Control Solutions 'MagRig' (MagRig) was used. Both of these testing units are large, portable, independently certified In-situ Measurement Verification Rigs (IMVR) which were used to collect flow data on the measurement accuracy of a number of Dethridge meters across the GMID. G-MW used the Thiess Services REVS Unit for the 2007, 2008 and part of the 2009 testing, and used the AWMA Water Control Solutions MagRig for part of the 2009 testing.

This report is based on in-situ Dethridge meter flow data collected and analysed by Thiess Services and AWMA Water Control Solutions.

## 2.3. Error Reporting

### 2.3.1. Meter Error

The National Measurement Institute metering standard specifies that meter error should be expressed as a percentage, and is equal to:

$$\text{Meter Error} = (V_i - V_a) / V_a \times 100 \quad - 1$$

Where:

$V_a$  = Actual volume, (i.e. the total volume of water passing through the water meter in any given time interval). This is the volume measured by the electromagnetic meters on the IMVR.

$V_i$  = Indicated volume, (i.e. the volume of water indicated by the meter on the tested device (Dethridge Meter) in an in-situ test).

### 2.3.2. Correct Delivery Volume

In determining the corrected delivery volume the indicated volume ( $V_i$ ) must be adjusted by a correction factor. For example  $V_i$  may be taken over any given time period – such as an irrigation season. Equation 2 shows this relationship.

$$\text{Corrected Delivery} = \text{Correction Factor (CF)} \times V_i \quad - 2$$

Meter error, in the form required by the National Standard (equation 1), should not be multiplied by the indicated delivery volume ( $V_i$ ) to estimate the corrected delivery. The meter correction factor can be derived from the meter error (equation 3).

$$\text{Correction Factor} = V_a / V_i = 1 / \{(\text{Meter Error}/100) + 1\} \quad - 3$$

### 2.3.3. Error Convention

To be consistent with the National Metering Standard, throughout this report a positive error (+) means the meter over records (i.e. the indicated display is more than the actual volume delivered) and a negative error (-) means the meter under records (i.e. the customer receives more water than is recorded).

### 2.3.4. Uncertainty in Measured Volume

Through the in-situ testing process, a systematic uncertainty of the measured volume passing through the IMVR is calculated and must be applied to each test result. Although the uncertainty depends on the flow rate and the length of the analysis period for the in-situ test, for both the Thiess Services REVS unit and the AWMA Water Control Solutions MagRig, this systematic uncertainty is typically in the order of  $\pm 0.50\%$ .

## 2.4. In-situ Meter Testing - Test Methodology

### 2.4.1. General Processes for These Tests

The REVS unit and the MagRig were used to undertake the in-situ testing of a sample of Dethridge meters across the GMID.

In-situ field verification of Dethridge meters was undertaken in accordance with the following steps and was the same for the REVS unit and the MagRig:

- i) the customer's irrigation channel (farm channel) was temporarily blocked with an impermeable barrier to form a coffer dam downstream of the service point meter to be tested
- ii) the IMVR was positioned at the site and leveled in an optimal position to allow the IMVR discharge to either enter the customer's farm channel downstream of the coffer dam, or discharge back into the irrigation supply channel
- iii) once testing had begun, the IMVR unit pumped water through an electromagnetic flow meter (selected for size on the basis of the flow) before being discharged either back into the supply channel or downstream into the customer's farm channel
- iv) a water level sensor in the coffer dam and software were used to alter the discharge rate through the variable speed pumps such that a near constant water level is maintained downstream of the meter being tested
- v) Dethridge meter wheel revolutions, supply depth, flow rate and tailwater levels were monitored and recorded throughout the test period
- vi) seepage rates and evaporation from the coffer dam were also measured/estimated for the test period.

The in-situ flow verification range capability on the REVS is between 1 ML/d and 15 ML/d. Flows ranging from 0 - 5.5 ML/d pass through the 150 mm diameter electromagnetic flow meter and flows ranging from 5 - 15 ML/d pass through the 300 mm diameter electromagnetic flow meter on the REVS<sup>1</sup>.

The in-situ flow verification range capability on the MagRig is between 1 ML/d and 30 ML/d. Flows ranging from 0 - 6 ML/d pass through the 150 mm diameter electromagnetic flow meter and flows ranging from 3 - 12 ML/d pass through each of the two 200 mm diameter electromagnetic flow meters on the MagRig. A unique feature of the MagRig is that it is multiple pump operation enabled, hence the large 30 ML/d flow capability.

<sup>1</sup> Factsheet: G-MW's 2007/08 Irrigation Meter Testing Program

The time period for each test is chosen such that there is sufficient data from which to choose a 60 minute flow analysis period which has a near constant flow. This 60 minute analysis period is adequate to reduce the test analysis uncertainty to a reasonable level of about  $\pm 0.50\%$  for the flow rates being tested.

#### **2.4.2. Specific Processes for These Tests**

At each service point tested (site) at least three flow rates were tested using the IMVRs. These flow rates represented the approximate normal customer ordered flow rate at that service point as well as a lower and higher flow rate. The test conditions were chosen to enable the measurement accuracy to be assessed under the normal operating conditions at that site as well as to gain an understanding of the expected performance of the meter in that operating environment under higher and lower flow rates.

### **2.5. Accuracy Verification of In-situ Measurement Verification Rigs (IMVR)**

#### **2.5.1. Electronic Verification**

Dry testing of IMVR meters is a test on the electronic detection components of the meter which includes the coils, sensors and transmitters. This is an electronic simulation that compares the electronic footprint at the time of commissioning with the current footprint. The test does not involve testing the meter under actual flow conditions. Electronic (Dry) testing of the meter detects any changes in the meter's sensor and transmitter functions that may be caused by structural alterations, corrosion or hardware failures. The cost of electronic verification is around \$1,000 per test.

#### **2.5.2. Flow Verification**

Wet testing of IMVR meters is a test to confirm their accuracy under laboratory conditions. For the test the whole IMVR is taken to an accredited laboratory, the volumes measured by the IMVR are compared to volumes that are passed through the testing facility that are measured by meters that are calibrated in an accredited laboratory by the National Association of Testing Authorities (NATA) which is Australia's national laboratory accreditation authority. Manly Hydraulic Laboratory (MHL) is one such accredited laboratory. The cost of re-verifying the accuracy of an IMVR through flow testing is around \$10,000.

The IMVR dry testing only checks the performance of the electronic components of the meter whereas the wet testing is more comprehensive and checks the accuracy of the whole IMVR system.

#### **2.5.3. Recommended Best Practice**

As IMVRs are used to verify the accuracy of meters which are most commonly used for billing purposes, it is important that the accuracy of the meters on the IMVRs are established and periodically verified.

As determined through extensive research that was undertaken by RJ Keller & Associates in conjunction with Hydro Environmental, the following accuracy certification schedule is recommended.

- Electronic (dry) verification (electronic) at a minimum of six month intervals (if the results indicate complete stability over four consecutive measurements, then this recommendation can be relaxed and electronic verification can be undertaken at 12 month intervals).
- Flow (wet) verification should be carried out at a minimum of two yearly intervals.

#### **2.5.4. Thies Services – Remote Electronic Verification System (REVS)**

##### **2.5.4.1. Siemens Verification Test Report (dry testing)**

Laboratory verification of the individual 150 mm and 300 mm diameter electromagnetic flow meters specifications was conducted in October 2006 before the REVS was built to ensure that they were electronically within the design specifications.

In November 2007 Siemens electronically re-verified both the individual 150 mm and the 300 mm electromagnetic flow meters used by the REVS and found that both meters were within calibration and specifications.

Test certificates were provided for both tests and these certificated a satisfactory result with the test parameters being within 2 % of their original value.

Following the 2009 Dethridge meter testing, electronic verification of the accuracy of the REVS meters was undertaken in May 2009, Hydro Environmental was advised that the meters were still within calibration.

##### **2.5.4.2. Manly Hydraulics Report (wet testing)**

Laboratory testing of the REVS unit developed by Thies Services, was conducted by the NSW Department of Commerce Manly Hydraulics in order to verify the accuracy of irrigation meters installed in open channels. These initial tests were conducted in October 2006.

The tests conducted, compared the REVS 150 mm and 300 mm diameter electromagnetic flow meters with Manly Hydraulics MagMaster and concluded that correction factors had to be applied to the 300 mm electromagnetic measurements to ensure the reported results are accurate. All reported results from the REVS used those correction factors.

In January 2008 the REVS was retested by Manly Hydraulics. These tests confirmed that both meters used by the REVS recorded results which are within the upper and lower limits of the expected volume ranges at 95 % confidence levels. There have been no further wet tests to verify that the REVS calibration factors have not changed.

#### **2.5.5. AWMA Water Control Solutions – MagRig**

##### **2.5.5.1. Electronic Verification (dry testing)**

No electronic verification (dry testing) has been undertaken on the MagRig meters either at or following commissioning to ensure they remain within design tolerances. It is expected that prior to any further testing, electronic verification of these meters will be undertaken.

### **2.5.5.2. Manly Hydraulics Report (wet testing)**

Laboratory testing of the IMVR developed by AWMA Water Control Solutions was conducted by the NSW Department of Commerce Manly Hydraulics in order to verify the accuracy of irrigation meters installed in open channels. These initial tests were conducted in February 2009.

The tests conducted, compared the MagRigs single 150 mm and two 200 mm diameter electromagnetic flow meters with Manly Hydraulics MagMaster. The testing concluded that correction factors had to be applied to the 150 mm and both of the 200 mm electromagnetic flow meter measurements to ensure the reported results are accurate. All reported results from the MagRig used those correction factors. For dual pump operation, each correction factor is applied to the measured volume through each electromagnetic flow meter then added to determine the total volume for that time period.

### **2.5.6. Corrected Delivery Volume Calculations Check**

Hydro Environmental checked the analysis workbooks for about 10% of the tests undertaken by each of Thiess Services and AWMA Water Control Solutions.

The main objective of the review was to determine whether the corrected delivery volume calculation processes used by each contractor were consistent and compliant with the National Measurement Institute Metering Standards as shown in **Section 2.3**. Hydro Environmental can conclude that the corrected delivery volume calculations used by each contractor are consistent and compliant with the National Measurement Institute Metering Standard.

## **2.6. In-situ Meter Selection**

### **2.6.1. Dethridge Meter Sizes**

Field testing of the Dethridge meter has been undertaken by G-MW in six Irrigation Areas across the GMID, namely Central Goulburn, Pyramid-Boort, Rochester-Campaspe, Murray Valley, Torrumbarry and Shepparton (over three periods of testing). These tests were conducted in January 2007, September 2007 – February 2008 and February – April 2009.

The Dethridge meter which is a positive displacement meter and has been used by most major irrigation water providers in Australia, was invented in Australia in 1910 by John Dethridge, the commissioner of the Victorian State Rivers and Water Supply Commission at the time<sup>2</sup>.

Up until recently the Dethridge meter has been in widespread use with over 40,000 meters installed throughout Australia where they were being used by all major providers of irrigation water<sup>3</sup>.

Although the design of the Dethridge meter varies slightly from State to State, the general design and dimensions of the wheel have remained unchanged for more than 90 years. The Dethridge meter is both a meter and a flow control device with the Victorian version of the

<sup>2</sup> Future of the Dethridge Wheel, Hydro Environmental (2007)

<sup>3</sup> Future of the Dethridge Wheel, Hydro Environmental (2007)

design having an upstream gate with which to control flow and flared downstream sidewalls to minimise downstream impedances to flow and minimise tailwater depths<sup>4</sup>.

There are three models of the Dethridge meter used by G-MW with each having a different range of acceptable flows, recording accuracy and head loss to ensure the command component of level of service is not compromised. These meters and their minimum associated flow rates are:

- i) Small Dethridge Meter (SMO) at least 1.6 ML/d
- ii) Large (Standard) Dethridge Meter (LMO) at least 3 ML/d
- iii) Dethridge-Long Meter (DLMO) at least 3 ML/d.

It should be noted that each LMO is designed to operate with 75 mm of head loss at 10 ML/d. Flows above 10 ML/d (e.g. 12 ML/d) would require more available head.

**Table 1** lists the proportion and distribution of each type of Dethridge meter across the GMID. When referring to total Dethridge meter populations within this report the figures presented in **Table 1** will be rounded to the nearest ten for ease of reading.

**Table 1: Distribution of Dethridge Meter types across G-MW.**

Irrigation Area	Total Number of Meters in the GMID			
	LMOs	DLMOs	SMOs	Total Meters
Central Goulburn	3,728	71	1,245	5,044
Pyramid-Boort	2,009	79	114	2,202
Murray Valley	1,685	17	1,008	2,710
Shepparton	1,372	19	735	2,126
Rochester	1,590	46	355	1,991
Torrumbarry	2,821	91	635	3,547
<b>TOTAL</b>	<b>13,205</b>	<b>323</b>	<b>4,092</b>	<b>17,620</b>

Poulton, D 2008, pers.comm., 21 April

Note: These figures are indicative only and may not represent the present population and/or configuration of Dethridge meters across the GMID.

Over the three testing periods, a sample of each meter size was tested to verify its in-field accuracy. The most commonly used Dethridge meter in the GMID, as shown in **Table 1**, is the LMO. Of the meters tested and included in the analysis in this report, there were;

- 95 LMOs tested
- 11 SMOs tested, and
- 6 DLMOs tested.

**Table 2** provides a summary of the meters tested across each Irrigation Area in each testing period.

<sup>4</sup> Future of the Dethridge Wheel, Hydro Environmental (2007)

Table 2: Summary of Dethridge Meters tested across the GMID.

Irrigation Area	Testing Year	Dethridge Meter Type			Total
		SMO	LMO	DLMO	
Central Goulburn	2007	0	10	0	10
	2008	2	15	1	18
	2009	2	9	0	11
Murray Valley	2007	0	0	0	0
	2008	1	5	0	6
	2009	3	6	1	10
Shepparton	2007	0	0	0	0
	2008	0	4	0	4
	2009	1	5	0	6
Rochester	2007	0	0	0	0
	2008	0	5	0	5
	2009	0	7	1	8
Pyramid-Boort	2007	0	0	0	0
	2008	0	6	0	6
	2009	0	7	1	8
Torrumbarry	2007	0	0	0	0
	2008	0	8	1	9
	2009	2	8	1	11
<b>Total</b>		<b>11</b>	<b>95</b>	<b>6</b>	<b>112</b>

Note: Total excludes two LMOs that were omitted from the analysis due to abnormal test conditions.

### 2.6.2. Sources of LMO Measurement Error

As indicated through Sections 3.1 – 3.3 there is a large variation in the accuracy of the Dethridge meters tested indicating that there are a number of different physical and environmental factors which may affect measurement accuracy. If the Dethridge meter, and in particular the eight finned steel drum, is incorrectly installed or damaged, or the bearings wear such that design clearances are not maintained, serious inaccuracies can result.

A more comprehensive list of factors which affect the measurement accuracy of the Dethridge meter include:

- i) tolerances on the drum manufacture (fin length differences, drum roundness etc.)
- ii) tolerances on the concrete emplacement manufacture
- iii) whether the drum is in the centre of the emplacement
- iv) whether the sump in the emplacement and the tip of the drum fins do not have the same pivot point
- v) damage to the downstream sill of the emplacement
- vi) variations in clearances between the fins and the emplacement
- vii) obstructions to the rotation of the drum
- viii) amount of wear on the bearings
- ix) flow rate of the water passing through the meter
- x) elevation and flatness of the floor of the emplacement

- xi) construction tolerances or uneven wear of emplacement
- xii) upstream water level
- xiii) downstream water level
- xiv) fluctuations in channel water levels
- xv) the degree to which the emplacement door is sealed under no flow
- xvi) obstructions in the approach waterway to the meter
- xvii) the amount the door is opened (velocity under the door)
- xviii) wind direction and velocity.

Inaccurate pendant counter measurement can also result in inaccurate billing records versus water that is actually delivered.

### **2.6.3. Dethridge Meter Pendant Counter Accuracy**

A pendant counter or more specifically a pendant actuated sealed cyclometer, is riveted to the wheel cylinder on Dethridge meters and rotates to totalise the volume. Each pendant counter is designed such that one revolution activates the same incremental increase in volume. Each sized Dethridge meter has a different volume rating per revolution. The pendant counter also has a ratchet mechanism which prevents winding back if the wheel is rotated in the wrong direction.

As part of the in-situ Dethridge meter testing programme, G-MW thought it appropriate to conduct a series of tests to determine the accuracy of the Dethridge meter pendant counter. The pendant counters used in the analysis were removed from decommissioned wheels in the Central Goulburn Irrigation Area as part of the modernisation process.

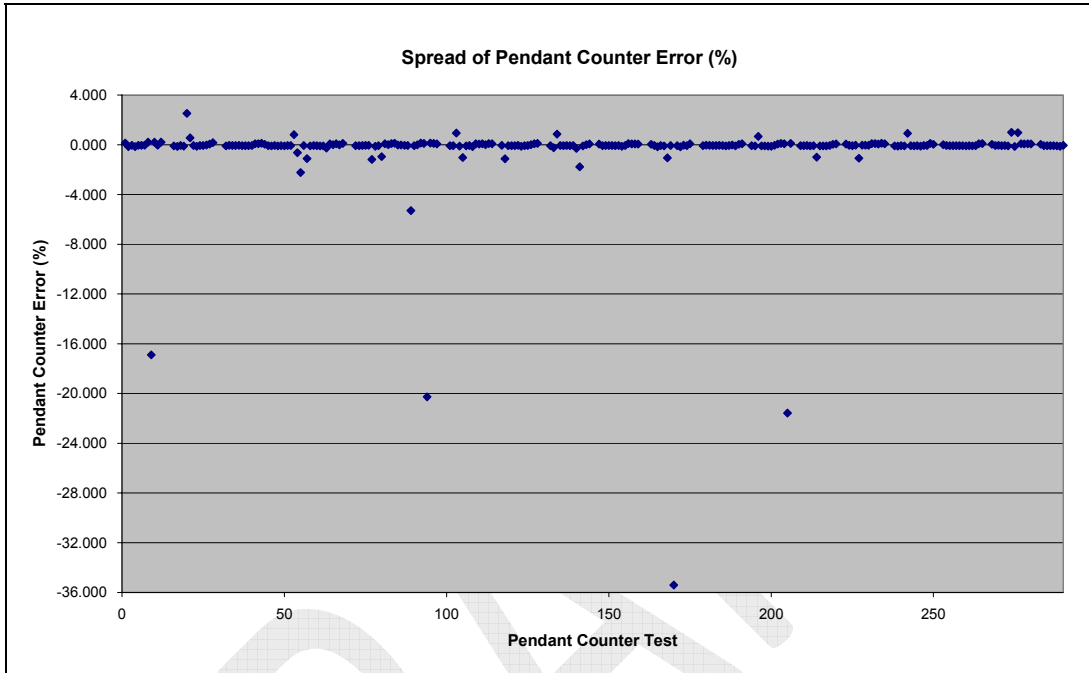
The testing procedure which was designed and conducted by G-MW, involved the use of a mechanical test rig that was made of a modified PVC tube which rotates at a near constant speed by a geared electric motor. Two pulse counters were fixed onto the outside of the PVC tube of the test rig which are attached to a manual counter and electronic data logger. Both units were setup to log each revolution of the test rig for a given period of time. For a detailed explanation of test uncertainties and calculations refer to G-MW (2009).<sup>5</sup>

As part of the accuracy testing, 288 pendant counters were tested (83 SMO, 197 LMO and 8 DLMO). Of the 288 pendant counters tested 5 completely failed while 7 were found to record intermittently. As G-MW has a system of checking and monitoring any faulty pendant counters, the 5 that failed completely, one pendant counter that had an error of -74% and one pendant counter that had an error of 207% were removed from the analysis as these results were anomalous and would have been picked up as part of G-MW's field checking system. However, because of the relatively small volumes of miss-measurement there is no way of checking for intermittent failure in the field under the current system, the six remaining pendant counters that showed an intermittent failure with an error of below 50% were retained in the analysis.

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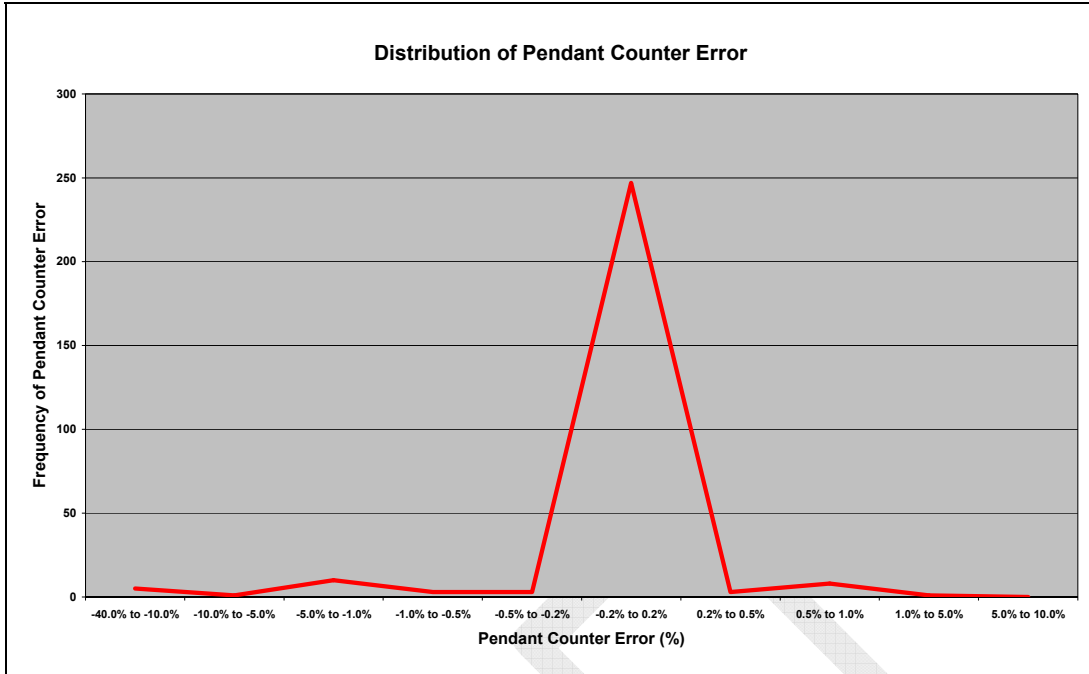
<sup>5</sup> Dethridge Meter Pendant Counter Accuracy Testing Report May 2009, #2658408.

The results presented in **Figure 1** and **Figure 2** comprises the three Dethridge meter (LMO, DLMO and SMO) pendant counters that are used and operating in the GMID. **Figure 1** shows the spread of G-MW pendant counter accuracy excluding outliers that would have been identified as part of G-MW's field checking system. With the exception of a small sample of pendant counters, the sample of 281 pendant counters included in the analysis had an average measurement error of -0.45% and a standard deviation of 3.02%.



**Figure 1: Spread of G-MW Pendant Counter Accuracy.**

**Figure 2** shows the distribution of pendant counter error which provides a visual representation of where the vast majority of the results fall. Of the 281 pendant counters included in the analysis 247 measured between -0.20% and 0.20%, which is a total of 88% of all pendant counters tested.



**Figure 2: Distribution of G-MW Pendant Counter Accuracy.**

Based on the pendant counter testing undertaken by G-MW it can be concluded that on average G-MW pendant counters under record (in favour of the G-MW customer) by approximately -0.45% with a standard deviation of 3.02%. A small proportion (2.4%) of Dethridge meter pendant counters are prone to complete failure. However, as long as a field checking system is in place, the pendant counter, for use as a customer billing tool is considered robust and accurate.

At the conclusion of testing, G-MW conducted a further test on 13 new pendant counters to determine if the result was similar to the sample removed from the field. This sample had an average measurement error of -0.02% and a standard deviation of 0.08%.

**Table 3** provides a summary on the accuracy of the three different samples of used Dethridge meter pendant counters tested by G-MW.

**Table 3: Summary of Dethridge meter Pendant Counter Accuracy.**

Pendant Counter Model	Number of Pendant Counters Tested and Analysed	Mean Measurement Error (%)	Standard Deviation of Errors (%)
SMO	81	-0.72%	3.76%
LMO	192	-0.36%	2.72%
DLMO	8	0.05%	0.04%

### 3. In-situ Dethridge Meter Test Results

#### 3.1. Analysis of LMO Results

The LMO is the most widely used irrigation meter for customer service points in the GMID (around 13,000 installed and operational). Sections 3.1.1 to 3.1.5.6 of the report present the analysis on the accuracy of G-MW LMOs tested from the 17 January 2007 to 5 May 2009. The complete set of LMO results (excluding outliers) is presented in **Appendix 1**.

A brief mention of the results from SMO and DLMO service points tested over the same period is provided in **Section 3.2** and **Section 3.3** respectively.

The results presented in **Section 3.1** to **Section 3.3** show that some Dethridge meters operate under extreme conditions, meaning that key design parameters of the Dethridge meter are not always upheld due to a lack of maintenance and/or environmental conditions during an irrigation event. However, these results were not excluded as outliers because G-MW have indicated that it is not uncommon for such operating conditions to occur across the GMID.

In this report an outlier is recognised as an anomalous result due to *exceptional circumstances*. For example, in one case, abnormally windy conditions retarded the rotation of the wheel for the test; as such the result was omitted from the analysis. There was a total of two outliers which are listed in **Appendix 4** along with the reason for their omission from the analysis.

**Table 4** provides a summary of LMOs tested by each contractor in each Irrigation Area.

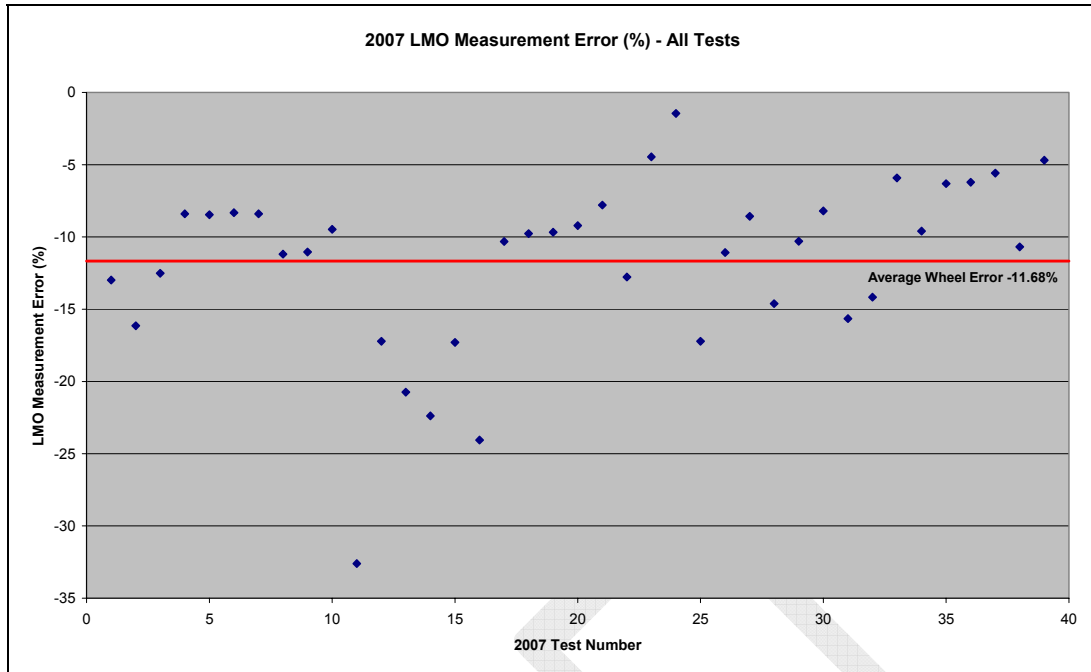
Table 4: Contractor LMO Testing Summary.

Irrigation Area	2007	2008	2009		Total
	Thiess Services	Thiess Services	Thiess Services	AWMA	
Central Goulburn	10	15	9	0	34
Murray Valley	0	5	6	0	11
Shepparton	0	4	5	0	9
Rochester	0	5	0	7	12
Pyramid-Boort	0	6	0	7	13
Torrumbarry	0	8	0	8	16
<b>Total</b>	10	43	20	22	95

#### 3.1.1. 2007 In-situ Testing Results for LMO – All Data (High, Normal & Low Flow)

In-situ testing was undertaken by Thiess Services in the Central Goulburn Irrigation Area between 17 January and 6 February 2007 on 10 LMOs. The results analysed in this section include the high, normal and low flow data. **Figure 3** shows the spread of LMO measurement results from the 2007 testing.

Flow rates for the 10 LMOs tested in 2007 varied from 2.97 ML/d to 11.30 ML/d, with one of the 37 flow tests being below the minimum flow recommended for the LMO (at least 3ML/d). The results of the 2007 in-situ Dethridge meter testing are presented graphically in **Figure 3**.



**Figure 3: 2007 LMO Accuracy Results – All Tests.**

These results exclude two anomalous test results. These were also excluded in previous reporting (Hydro Environmental, 2008).<sup>6</sup>

**Figure 3** shows a large scatter within the results which highlights the highly variable nature of Dethridge meter accuracy that is influenced by many of the factors listed in **Section 2.6.2**.

The average measurement error for the tests analysed from 2007 was -11.68% (under recording in favour of the G-MW customer) with a standard deviation of 6.02% and an average flow of approximately 7.2 ML/d.

Variables such as supply depth, tailwater depth, bottom clearance and maintenance issues have been assessed as part of the combined analysis (2007, 2008 & 2009 Dethridge meter results). These are discussed in detail in **Section 3.1.5** and may partially explain the variability encountered when analysing Dethridge meter accuracy.

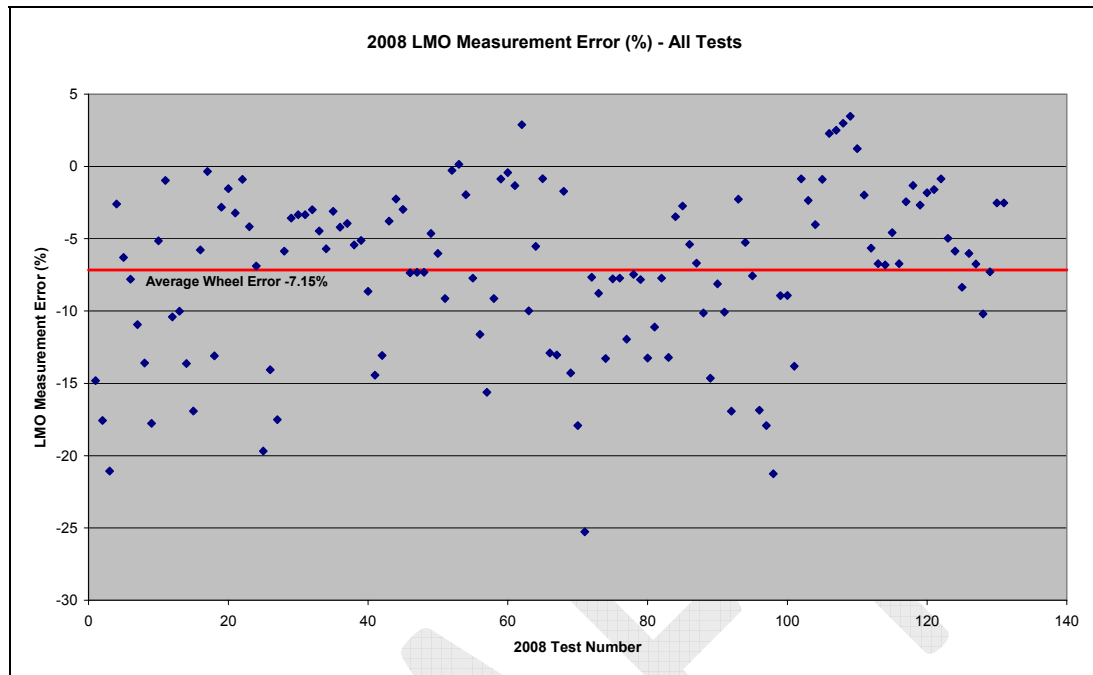
### 3.1.2. 2008 In-situ Testing Results for LMO – All Data (High, Normal & Low Flow)

In-situ testing was undertaken by Thiess Services in the Central Goulburn, Rochester, Pyramid-Boort, Shepparton, Murray Valley and Torrumbarry Irrigation Areas between 27 September 2007 and 21 February 2008 on 43 LMOs. The results analysed in this section include the high, normal and low flow data for all service points tested. **Figure 4** shows the spread of LMO measurement results from the 2008 testing.

Flow rates for the 43 LMOs tested in 2008 varied from 2.20 ML/d to 14.57 ML/d, with four of the 123 flow tests being below the minimum flow recommended for the LMO (at least

<sup>6</sup> In-situ REVS Testing of Large Dethridge Meter Outlets in the GMID, Hydro Environmental 2008.

3 ML/d). The results of the 2008 in-situ Dethridge meter testing are presented graphically in **Figure 4**.



**Figure 4: 2008 LMO Accuracy Results – All Tests.**

**Figure 4** shows the LMO measurement error for a range of LMOs tested across the GMID in 2008. As was the case in the 2007 results, there is a large scatter within the results which highlights the inherent highly variable nature of Dethridge meter accuracy that is influenced by many of the factors listed in **Section 2.6.2**.

The average measurement error for the tests analysed from 2008 was -7.15% (under recording in favour of the G-MW customer) with a standard deviation of 5.76% and an average flow of approximately 6.7 ML/d.

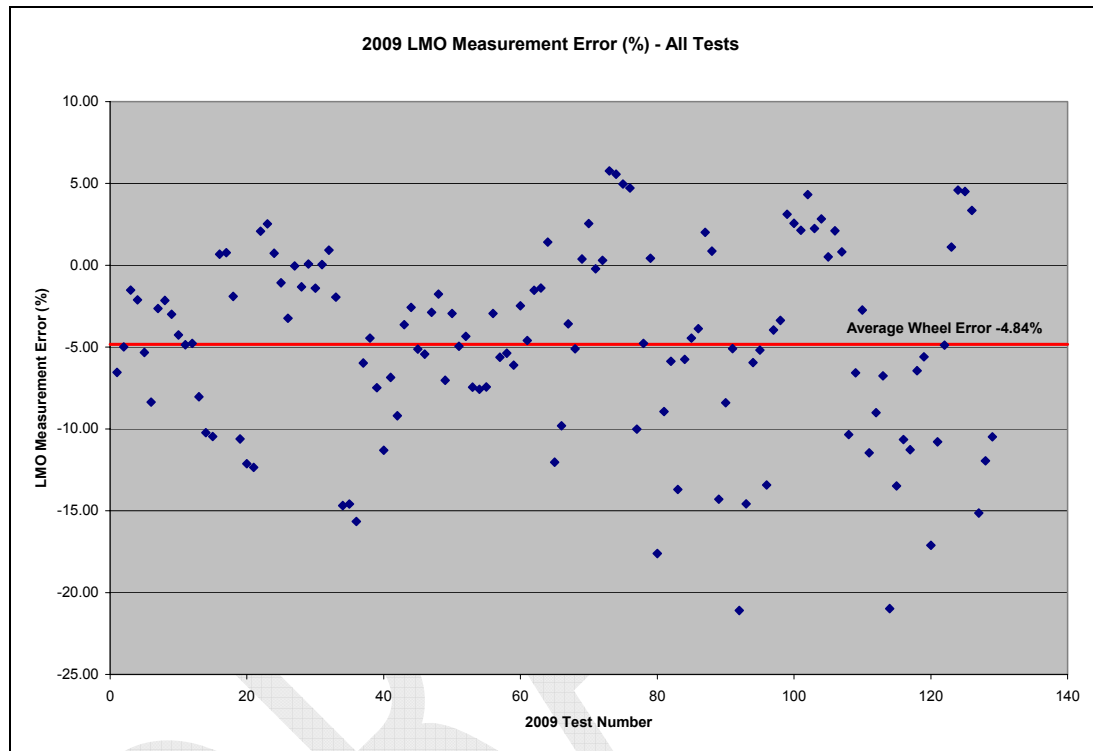
Variables such as supply depth, tailwater depth, bottom clearance and maintenance issues have been assessed as part of the combined analysis (2007, 2008 & 2009 Dethridge meter results). These are discussed in detail in **Section 3.1.5** and may partially explain the variability encountered when analysing Dethridge meter accuracy.

### 3.1.3. 2009 In-situ Testing Results for LMO – All Data (High, Normal & Low Flow)

In-situ testing was undertaken by Thiess Services and AWMA Water Control Solutions across six Irrigation Areas within the GMID. Thiess Services conducted in-situ testing in the Central Goulburn, Murray Valley and Shepparton Irrigation Areas whereas AWMA Water Control Solutions conducted in-situ testing in the Rochester, Pyramid-Boort, and Torrumbarry Irrigation Areas. All testing took place between 19 February and 5 May 2009 on 42 LMOs (20 tested by Thiess Services, 22 tested by AWMA Water Control Solutions). There was no overlap in the service points tested by Thiess Services and AWMA Water

Control Solutions. The results analysed in this section include the high, normal and low flow data. **Figure 5** shows the spread of LMO measurement error results from the 2009 testing.

Flow rates for the 42 LMOs tested in 2009 varied from 2.79 ML/d to 14.36 ML/d, with ten of the 128 flow tests being below the minimum flow recommended for the LMO (at least 3 ML/d). The results of the 2009 in-situ Dethridge meter testing are presented graphically in **Figure 5**.



**Figure 5: 2009 LMO Accuracy Results – All Tests.**

**Figure 5** shows the LMO measurement error for a range of LMOs tested across the GMID in 2009. As was the case with the 2007 and 2008 testing there is a large scatter within the results which highlights the highly variable nature of Dethridge meter accuracy that is influenced by all of the factors listed in **Section 2.6.2**.

The average measurement error for the tests analysed from 2009 was -4.84% (under recording in favour of the G-MW customer) with a standard deviation of 5.81% and an average flow of approximately 6.62 ML/d.

Variables such as supply depth, tailwater depth, bottom clearance and maintenance issues have been assessed as part of the combined analysis (2007, 2008 & 2009 Dethridge meter results). These are discussed in detail in **Section 3.1.5** and may partially explain the variability encountered when analysing Dethridge meter accuracy.

#### 3.1.4. Testing Contractor Comparison

In 2007 and 2008 all testing of G-MW Dethridge meters was undertaken by Thiess Services. In 2009 two contractors were engaged by G-MW to test 54 Dethridge meters across the GMID. Of the 54 G-MW service points tested, 42 of these were LMOs. As mentioned in

**Section 3.1.3**, 22 LMOs were tested by AWMA Water Control Solutions and 20 LMOs were tested by Thiess Services.

Although the IMVR designs are different, the setup and procedures of both contractors are fundamentally the same. The graph shown in **Figure 6** shows the spread of LMO measurement error as tested and calculated by both contractors for different service points in six different Irrigation Areas across the GMID. Ideally, some overlap of tested meters should have occurred, however no overlap was designed into the G-MW testing programme.



**Figure 6: Comparison of Contractor LMO Accuracy Results for 2009 Testing.**

The average measurement error for the tests undertaken by each contractor was nearly identical. The average measurement error as measured and calculated by AWMA Water Control Solutions was -4.80%, and the average measurement error as measured and calculated by Thiess Services was -4.88%.

The spread of results from each contractor is however markedly different; the Thiess Services results have a standard deviation of 4.21% whereas the AWMA Water Control Solutions spread of results have a standard deviation of 6.97%. Although the mean LMO error is very close for each contractor, the spread of results is most likely due to a number of variables associated with the characteristics of the Dethridge meters tested. These variables include fin bottom clearance, supply depth, tailwater depth, flow rate and the condition of the wheel and concrete emplacement. However, as no overlap of Irrigation Area, and hence no overlap of service point testing was achieved, a direct comparison of the relative test rig accuracy could not be made.

It is likely that the broader spread of results achieved by AWMA Water Control Solutions is due to different LMO maintenance schedules and wheel tolerance limits across Irrigation Area boundaries.

**Table 5** shows a comparison of each of the test results as measured and calculated by each Contractor. Assuming that the populations of Dethridge meters tested by each contractor are the same, the comparison of mean errors can be made. The mean error between each group of Contractor tests differs by only 0.08%, which is well within the typical measurement uncertainty of  $\pm 0.50\%$  calculated for each IMVR test. It is therefore reasonable to conclude that the results for each IMVR will be the same for a given LMO and that each IMVR measures flows within the average systematic uncertainty of  $\pm 0.50\%$  for each IMVR test undertaken on G-MW Dethridge meters in 2009.

**Table 5: 2009 LMO Contractor Result Comparison.**

	Thiess Services	AWMA Water Control Solutions	Combined
Number of LMOs Tested	20	22	42
Mean Error (%)	-4.88%	-4.80%	-4.84%
Typical Systematic Uncertainty in IMVR Result (%) for a 60 minutes test	$\pm 0.50\%$	$\pm 0.50\%$	$\pm 0.50\%$
Standard Deviation of Errors (%)	4.21%	6.97%	5.59%

### 3.1.5. Combined In-situ Testing Results for LMO - Normal Ordered Flow Data

As G-MW is primarily interested in water savings potential, it requires the accuracy of the LMO as near as possible to their normal operating flow and conditions, **Sections 3.1.5.1 to 3.1.5.6** refer only to LMO data (excluding outliers) obtained from the in-situ tests between 2007 and 2009 that were undertaken at or closest to the service point normal flow rate enjoyed by the respective customers.

#### 3.1.5.1. Spread of LMO Measurement Error

**Figure 7** shows the spread of LMO measurement error for all LMOs tested at their normal operating flow. The average LMO measurement error is -5.76% with a standard deviation of 5.87%.

The error and operating conditions at each site varied significantly with each of the key parameters detailed for each service point in **Appendix 1** and the range summarised in **Table 6**.

Table 6: Summary of average IMVR test conditions for LMOs at the normal operating flow.

Test Parameter	Units	Average	Median	Actual Range	Design	Indicative change resulting from 1 unit change in test parameter on measurement error
Flow Rate	ML/d	7.93	8.14	2.2 to 14.6	> 3	+ 0.3% per ML increase
Tailwater Depth	mm	159	158	2 to 340	180	-0.04% per mm increase
Supply Depth	mm	426	405	307 to 687	380	-0.02% per mm increase
Bottom Clearance	mm	8.5	8	3 to 30	6	-0.56% per mm increase
Overall Error	%	-5.76	-5.26	-24.05 to 4.72		
Unmaintained Error	%	-6.15	-5.46	-24.05 to 4.72		
Maintained Error	%	-3.36	-2.73	-11.31 to 4.33		

Each of the key variables namely bottom clearance, tailwater depth, supply depth, maintenance issues and flow rate have been assessed against measurement error for the same sample of data and are discussed in detail in the following sections to help explain the high level of variability in the results.

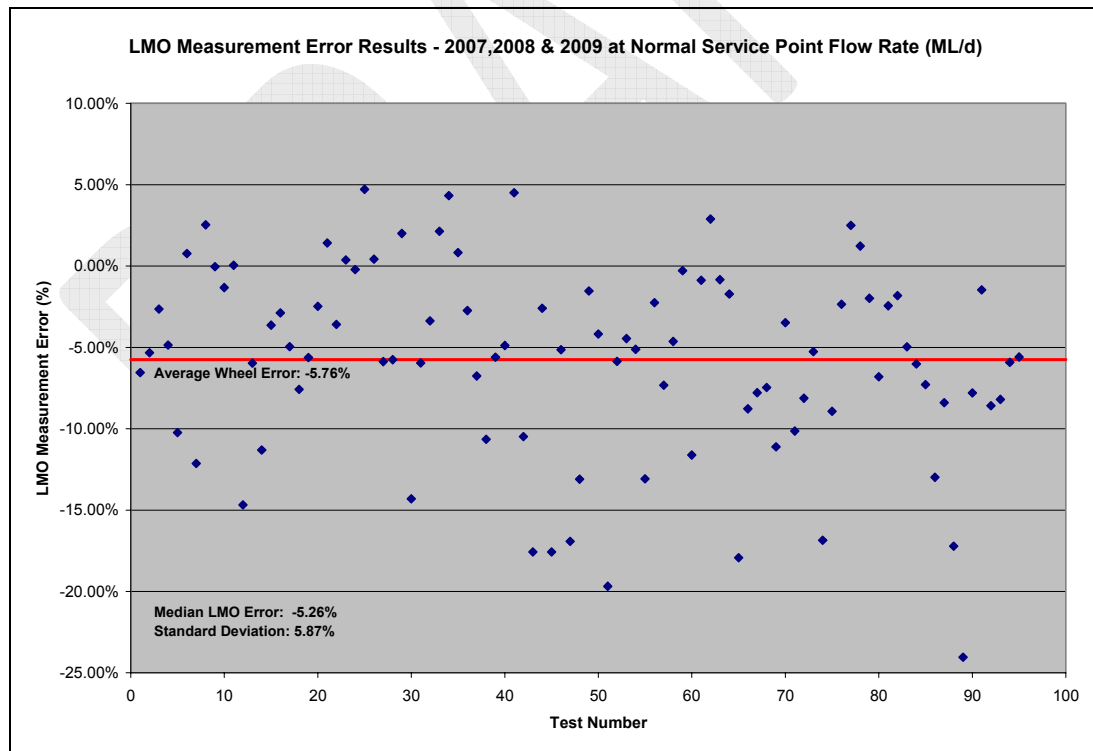


Figure 7: GMID LMO measurement error (%) spread.

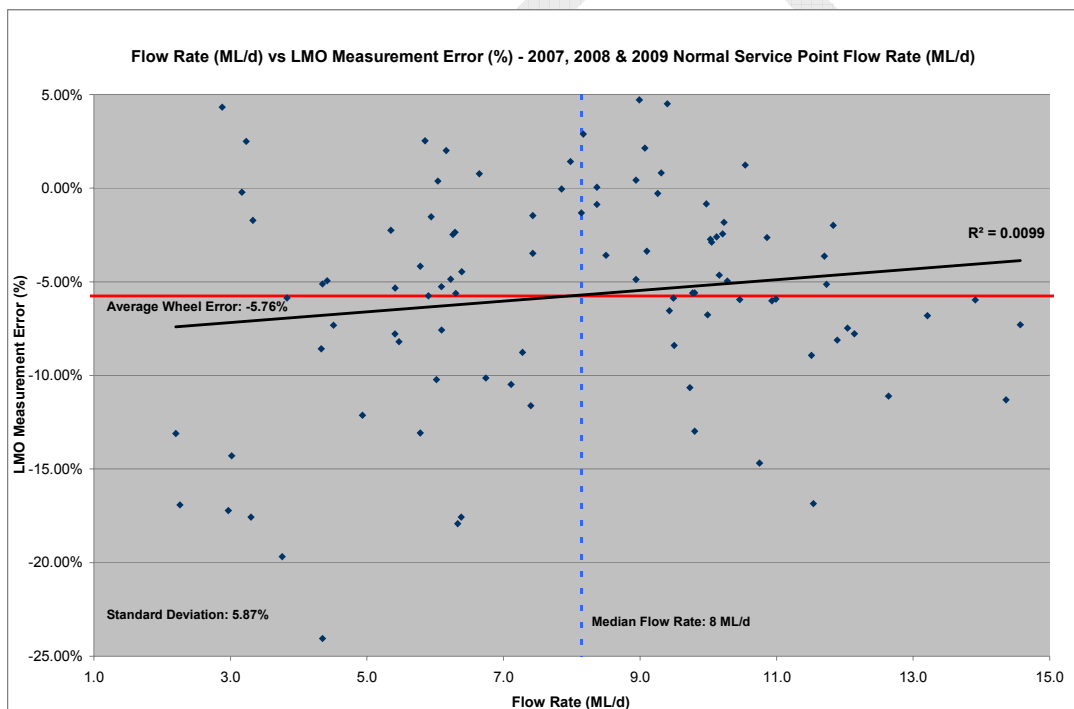
3.1.5.2. Flow vs. Measurement Error

G-MW required at least one flow rate tested for each service point to be the same or similar to that normally ordered by each customer. Although the recommended minimum flow for

the LMO is 3 ML/d, the range of flows tested and analysed in this report for tested LMOs ranged from 2.20 ML/d to 14.57 ML/d. Flow rates below the recommended minimum flow have been retained in the analysis in this report because they are representative of the service points normal operating conditions.

**Figure 8** shows the LMO measurement error for a range of flow rates across the six Irrigation Areas. The median flow rate tested was 8.14 ML/d. The high variability in the results show that a relationship between LMO measurement error (%) and flow rate (ML/d) is virtually non-existent with an R<sup>2</sup> value of less than 1%. (The R<sup>2</sup> value, or the coefficient of determination indicates the strength of fit between two variables by calculating the variation in one value that occurs in proportion to variations in another value. In this case, flow rate vs. measurement error, where less than 1% of the variability in the LMO measurement error can be explained by the different flow rates used for the in-situ tests).

However, overall these results indicate that on average LMO measurement error changes by + 0.3% for every ML change in flow.



**Figure 8: GMID LMO measurement error (%) vs. Flow Rate (ML/d).**

### 3.1.5.3. Tailwater Depth vs. Measurement Error

The range of tailwater depths in which testing was conducted for LMOs in the GMID is shown graphically in **Figure 9**. The average tailwater depth was 159 mm compared with the 180 mm allowed before the flow condition is considered drowned under a standard supply depth of 380 mm.. The high variability in the results shows that the relationship between LMO measurement error (%) and tailwater depth (mm) is very weak with an R<sup>2</sup> value of approximately 24%. Tests with a tailwater level below 180 mm recorded an average measurement error of -4.33%, whilst those tests with tailwater depths greater than 180 mm had an average measurement error of -9.26%.

Overall these results indicate that LMO measurement changes by -0.04% for each mm increase in tailwater depth.

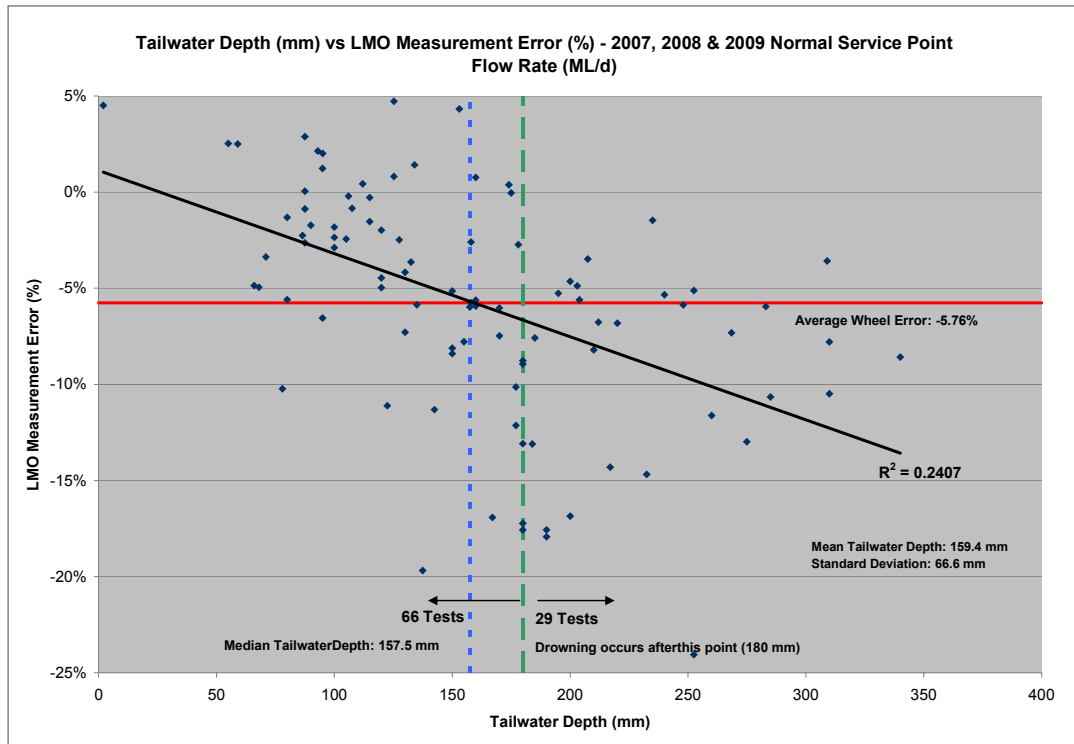


Figure 9: GMID LMO measurement error (%) vs. Tailwater Depth (mm).

#### 3.1.5.4. Supply Depth vs. Measurement Error

The range of supply depths in which testing was conducted for LMOs in the GMID is illustrated in **Figure 10**. The average supply depth for the series of tests was 426 mm compared to the design supply depth of 380 mm. The high variability in the results shows that a relationship between LMO measurement error (%) and supply depth (mm) is essentially absent with an  $R^2$  value of approximately 5%. Supply depths greater than the recommended supply depth can have a negative result on the accuracy of the LMO. This can result in a change in measurement error of -0.02% per mm rise in level. If supply depth is better controlled by automation this could lead to an improvement of 0.2% for each reduction of 10 mm in channel water level where LMOs are retained.

Results presented in **Figure 10** show those tests undertaken with a supply depth of greater than the standard 380 mm had an average measurement error of -6.85% whilst tests undertaken with a supply depth below 380 mm had an average measurement error of -3.52%.

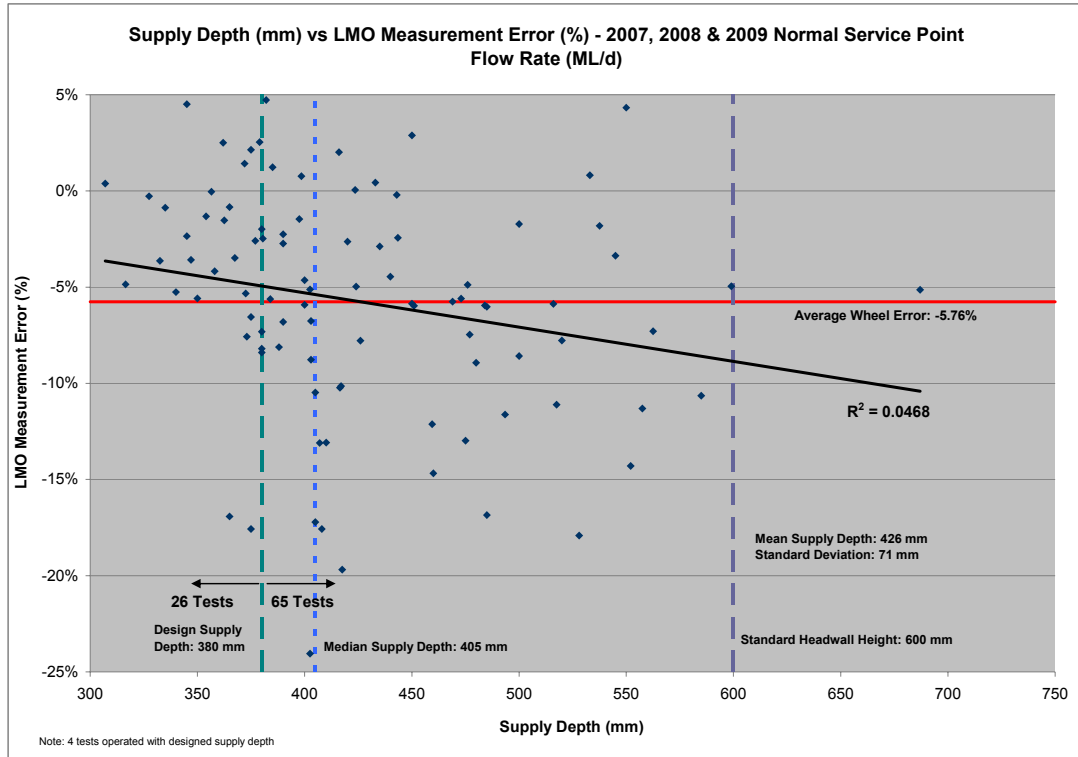


Figure 10: GMID LMO measurement error (%) vs. Supply Depth (mm).

**3.1.5.5. Bottom Clearance vs. Measurement Error**

The standard bottom clearance for a G-MW LMO is 6 mm. The range of average fin bottom clearances for the 95 sites reported varied between 3.0 mm and 30.0 mm with an overall average of 8.5 mm, 2.5 mm above the standard design bottom clearance. The LMO accuracy results are graphed against average fin bottom clearance in **Figure 11**.

The high variability in the results shows a weak relationship between LMO measurement error (%) and bottom clearance (mm) with an R<sup>2</sup> value of approximately 16%. The results indicate that LMO measurement error changes by -0.56% for each mm change in bottom clearance. However, the tests with an average bottom clearance less than 6 mm had an average measurement error of -2.48%, in comparison; the tests undertaken with an average bottom clearance above 6 mm had an average measurement error of -7.09%.

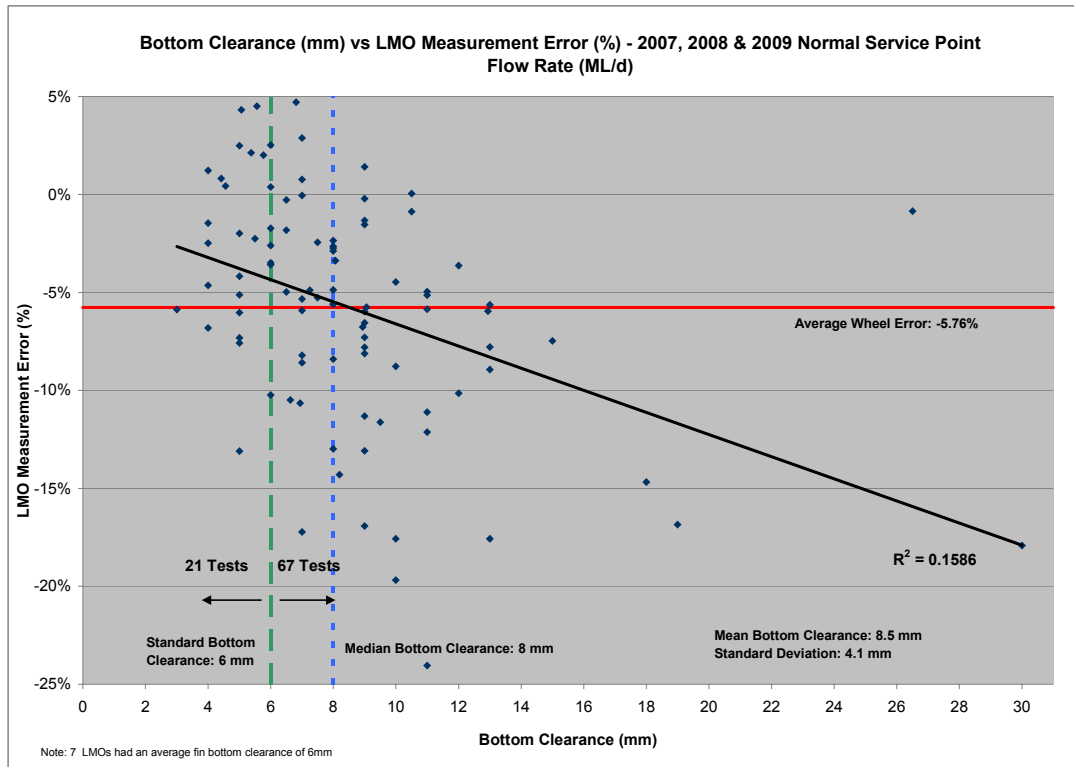


Figure 11: GMID LMO measurement error (%) vs. Bottom Clearance (mm).

### 3.1.5.6. Maintained vs. Unmaintained LMO Measurement Error

As part of its drought initiative to save water in the short term, G-MW has undertaken a targeted maintenance on Dethridge meters with recorded high annual use volumes since the start of the 2006/07 irrigation season. This maintenance program was in place across the majority of the Irrigation Areas in the GMID and targeted service points with usage over 100 ML/year. This involved measuring the tolerances of each service point for compliance against the standard operating designs for the Dethridge meter as well as checking any components that required replacement, such as new bearings etc. Due to the modernisation program which includes the replacement of Dethridge meters across the GMID with new National Standard compliant meters, the targeted maintenance program for Dethridge meters was wound back. Based on the proportion of maintained service points as indicated by the G-MW Irrigation Area Operations Managers, on average approximately 30% of Dethridge meters across the GMID have been rehabilitated since 2006/07.

The analysis includes 13 maintained LMOs and 82 unmaintained LMOs, 18 of which are assumed to be unmaintained. This is because they were part of the early phases of testing and without a maintenance status which lead to them being considered as unmaintained because it is assumed that G-MW would keep records of service point meters that had undergone rehabilitation. 13.6% of the service points included in the analysis have been rehabilitated; this is approximately 15% below the proportion of maintained Dethridge meters across the GMID.

As can be seen in **Figure 12**, the average LMO measurement error for maintained wheels is -3.36% and the average LMO measurement error for unmaintained wheels is -6.15%. Based

on this small sample of meters it can be concluded that on average, maintained LMOs measure more accurately than unmaintained LMOs by approximately 3%.

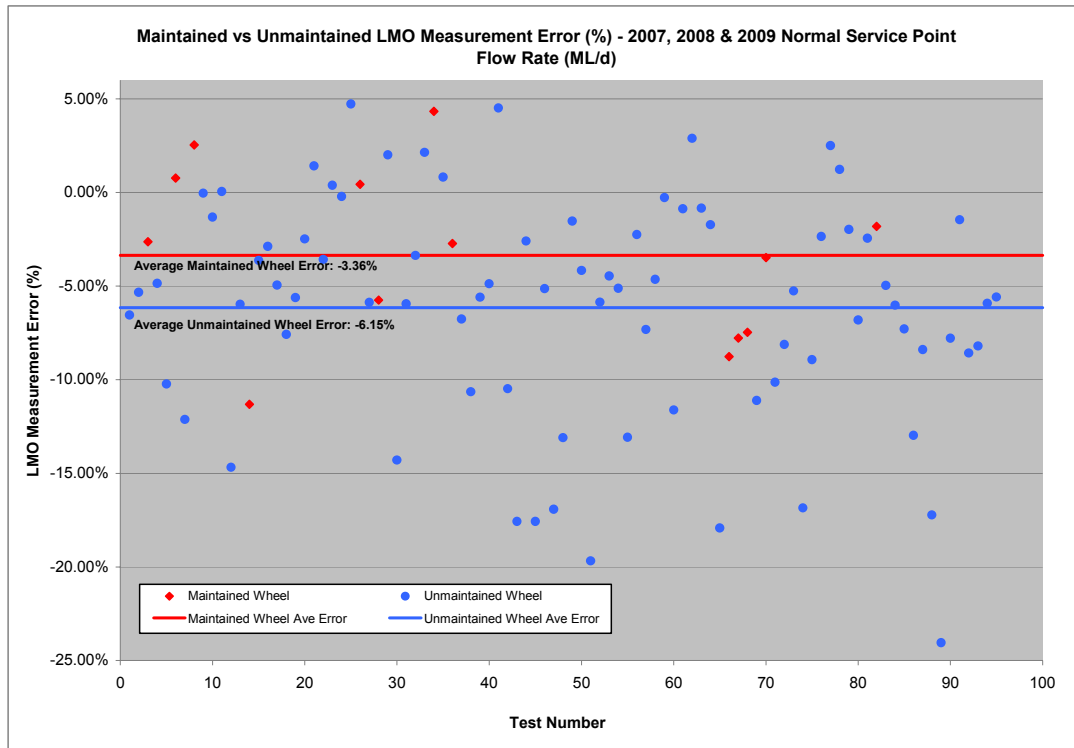


Figure 12: Maintained vs. Unmaintained LMO measurement error (%).

### 3.2. Analysis of DLMO Results

Six DLMOs were tested as part of the G-MW Dethridge meter testing programme in 2008 and 2009. Across all Irrigation Areas within the GMID 323 DLMOs are installed and operational. The sample of DLMOs tested represents 1.9% of the population.

As shown in **Figure 13** the range of DLMO measurement error was between -11.49% and 6.69% with an average of -0.63% and a standard deviation of 4.67%. With such a large standard deviation, the result at 95% confidence limits (two standard deviations away from the mean) is outside of the field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time. If required a larger sample of DLMOs should be tested to determine whether the standard deviation of DLMO measurement error is correct.

Based on the results from the analysis of six DLMOs, it can be concluded that on average DLMO measurement within the GMID is significantly more accurate than the LMOs but is still non compliant with the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time.

The complete set of DLMO results are presented in **Appendix 2**.

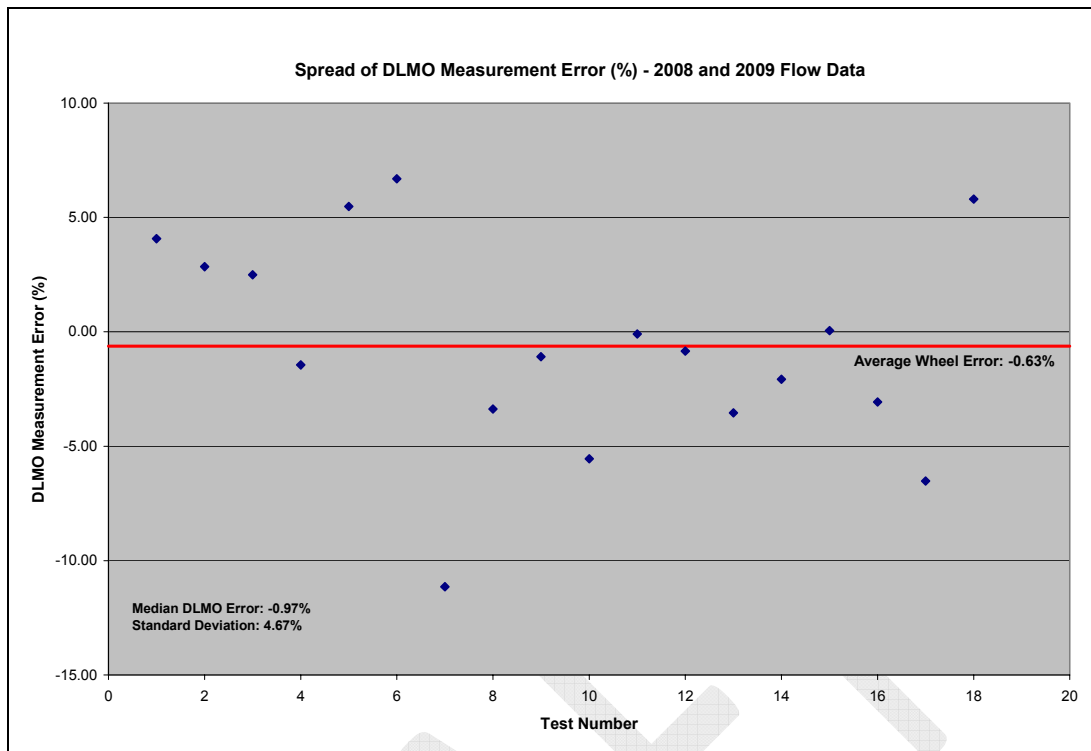


Figure 13: Spread of DLMO measurement error (%) results.

### 3.3. Analysis of SMO Results

11 SMOs were tested as part of the G-MW Dethridge meter testing programme in 2008 and 2009. Across all Irrigation Areas within the GMID 4,092 SMOs are installed and operational. The sample of SMOs tested represents 0.3% of the population.

As shown in **Figure 14** the range of SMO accuracy measurements was between -21.37% and 14.81% with an average of -0.43% and a standard deviation of 8.37%. With such a large standard deviation, the result at 68% confidence limits (one standard deviation away from the mean) and 95% confidence limits (two standard deviations away from the mean) is outside of the field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time. A larger sample of SMOs should be tested to determine whether the standard deviation of SMO measurement error is correct.

Based on the results from the analysis of 11 SMOs, it can be concluded that SMO measurement within the GMID is non compliant with the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time and that although the average measurement error for those meters tested was better than the LMO a similar spread of error was seen.

The complete set of SMO results are presented in **Appendix 3**.

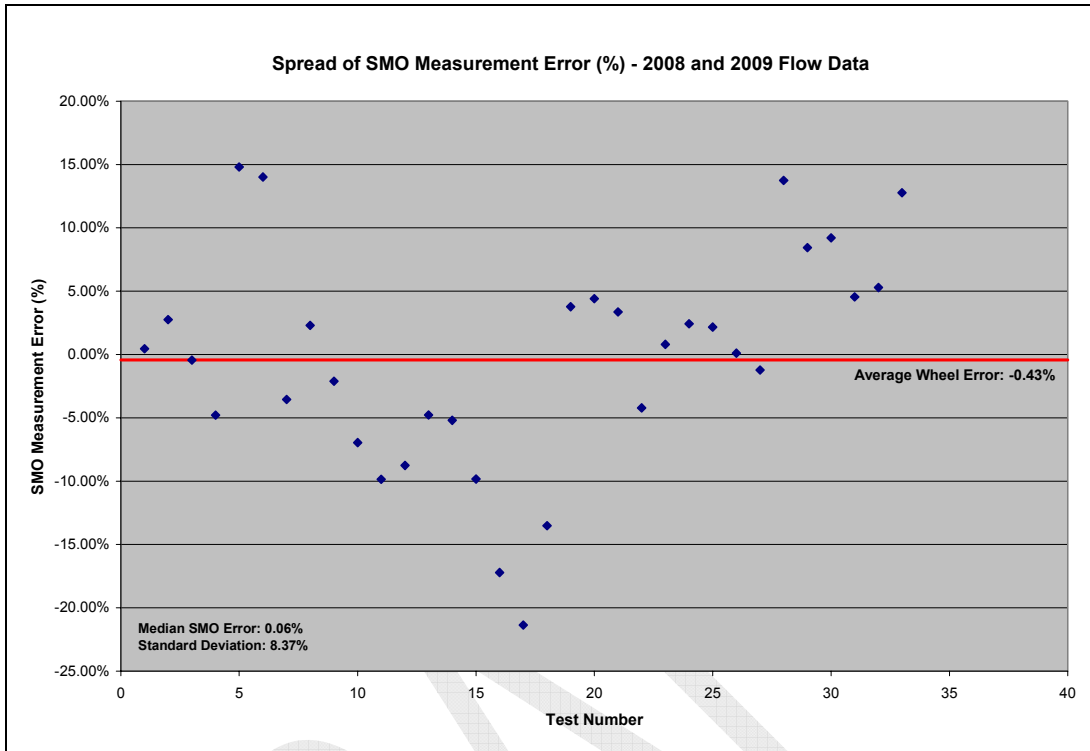


Figure 14: Spread of SMO measurement error (%) results.

### 3.4. Portability of the Results

In order to apply the mean measurement error to the entire population of Dethridge meters tested, an estimate of the 95% confidence interval width for the mean measurement error of each Dethridge meter population (LMO, DLMO and SMO) is required. This provides an indication of the variance in the measurement error results for Dethridge meters across the GMID.

In April 2008 G-MW engaged The University of Melbourne to develop an extrapolation methodology, this is shown below.

For the total GMID area a 95% confidence interval for the mean meter error of a sample of size  $n$  is given by:

$$\bar{x} \pm t_{n-1}(0.975) \frac{s}{\sqrt{n}} \sqrt{1 - \frac{n}{MP}}, \quad - 4$$

where  $\bar{x}$  is the mean meter error estimate from the sample of size  $n$ ,  $t_{n-1}(0.975)$  is the 0.975 quantile of the  $t$ -distribution with  $n-1$  degrees of freedom,  $s$  is the estimate of the standard deviation from the  $n$  observations and  $MP$  is the total population of Dethridge meters within the GMID. This means that the total width of the 95% confidence interval is given by:

$$2t_{n-1}(0.975) \frac{s}{\sqrt{n}} \sqrt{1 - \frac{n}{MP}} \quad - 5$$

The sample of 95 LMOs tested provides a confidence level of  $\pm 1.2\%$  when extrapolated to 13,205 meters across the GMID. The results for the SMO and DLMO provide a larger confidence interval width. This indicates that more SMOs and DLMOs should be tested if G-MW wishes to reduce the width of the confidence interval when extrapolating in-situ testing results for these meter types.

The width of the confidence interval for each Dethridge meter type based on their populations within the GMID is shown below in **Table 7**. The mean measurement error of -5.76% for the overall LMO, unmaintained LMO and maintained LMO is based on the measurement error at the normal operating flow, whereas the mean of -0.43% for the SMO and -0.63% for the DLMO is based on the mean of the results from the high normal and low flow measurement errors.

As mentioned in **Section 3.1.5.6**, the proportion of the LMO population treated as maintained for extrapolation purposes was 30%, approximately 4,000 service points across the GMID. Approximately 9,000 or 70% were treated as unmaintained.

**Table 7: Extrapolation intervals for Dethridge meters in the GMID.**

Meter Type	Meter Population (MP) in GMID	Sample of Pop <sup>n</sup> Tested (n)	95% confidence interval half width	95% confidence interval full width	95% Confidence interval width based on the mean from in-situ testing.		
					Lower	Mean	Upper
SMO	4,092 (0.3% tested)	11	5.1%	10.1%	-5.53%	<b>-0.43%</b>	4.67%
LMO (ii) (test sample)	13,205 (0.7% tested)	95	1.2%	2.3%	-6.96%	<b>-5.76%</b>	-4.56%
LMO (iii) (Unmaintained)	9,205 (0.9% tested)	82	1.3%	2.6%	-7.45%	<b>-6.15%</b>	-4.85%
LMO (iii) (Maintained)	4,000 (0.3% tested)	13	2.5%	5.1%	-5.86%	<b>-3.36%</b>	-0.86%
DLMO	323 (1.9% tested)	6	3.7%	7.4%	-4.33%	<b>-0.63%</b>	3.07%

Note: i. Lower and Upper interval widths based on rounded half width interval figures.  
 ii. Assuming the test sample is representative of the GMID average LMO condition.  
 iii. Assuming approximately 30% of LMOs in the GMID have been rehabilitated (Refer to Section 3.1.5.6).

### 3.5. Combined In-situ Volumetric Error and Billing Measurement Error

As mentioned in **Section 2.6.3** the Dethridge meter records the volume passing through the structure by using a pendant counter. To determine the full extent of potential water savings from the replacement of Dethridge meters across the GMID, the volumetric error (in-situ test result) and the billing measurement error (pendant counter error) must be combined. The addition of these two errors can be made as they are independent sources of error and should be considered as distinct from one another.

The mean measurement error from the 192 LMO pendant counters tested was -0.36% as shown in **Section 2.6.3** and the mean in-situ measurement error at the normal operating flow was -5.76% as shown in **Section 3.1.5.1**. The combined volumetric and billing measurement error for the test sample is therefore -6.12%.

In addition, the extrapolation methodology outlined in **Section 3.4** must also be applied to the combined result to determine the 95% confidence limits when the combined mean is extrapolated to 13,205 LMOs across the GMID. In order to do this, the standard deviations from both samples are combined. This is done by using the following equation:

$$\sqrt{(s_1)^2 + (s_2)^2} \quad - 6$$

Where  $S_1$  is the standard deviation calculated from the sample of in-situ error measurement results, and  $S_2$  is the standard deviation calculated from the sample of pendant counter error measurement results.

The number of each test population ( $MP$  in equation five in **Section 3.4**) must be known in order for the extrapolation calculation to be completed. As the two populations differed markedly, the lower of the two (95 in-situ tests vs. 192 pendant counter tests) sample populations (which is 95) was used when calculating the extrapolated uncertainty to ensure no bias was shown and a lower level of uncertainty reached as a consequence.

The combined volumetric and billing measurement errors provide a confidence level of  $\pm 1.29\%$  when extrapolated to 13,205 meters across the GMID. Therefore, with a mean of -6.12% an error of between -7.41% and -4.83% can be expected of LMO measurement error 95% of the time within the GMID.

### 3.6. Mathematical Model

As indicated in Hydro Environmental (2008)<sup>7</sup>, G-MW engaged the Statistical Consulting Centre at The University of Melbourne to provide advice on the form of a model to determine measurement error resulting from REVS testing undertaken at the Goulburn weir Dethridge meter test site in 2007.

The purpose of the mathematical model was to develop a more cost effective method of determining the accuracy of individual Dethridge meters in the field based on key site parameters such as bottom clearance, supply depth, flow rate etc. The reliability of the mathematical model to enable it to be confidently used as an audit tool for determining Dethridge meter accuracy across G-MW's entire metering fleet has been increased by undertaking more in-situ testing of Dethridge meters.

As such, it is recommended that G-MW compares the LMO in-situ testing results with the LMO mathematical modelling results and if necessary recalibrate the model to ensure the use of this method of determining meter error is a simple accurate low cost alternative to in-situ testing.

<sup>7</sup> In-situ REVS Testing of Large Dethridge meter outlets in the GMID, Hydro Environmental (2008)

## 4. Findings

The following findings should be noted:

- i) The accuracy with which the LMO measures the volume of water delivered is heavily dependent on its manufacturing tolerances, precision of installation and quality and consistency of maintenance, as well as the local environmental conditions when in operation. The results of this analysis can only be extrapolated to the entire GMID LMO population if, on average the characteristics of the untested meters are the same as the sample of 95 analysed in this report.
- ii) The mean measurement error of the 2007, 2008 and 2009 sample of LMOs tested differ considerably as follows:-
  - Mean measurement error (excluding pendant counter error) for LMOs tested (10) in 2007 is -11.68%
  - Mean measurement error (excluding pendant counter error) for LMOs tested (43) in 2008 is -7.15%
  - Mean measurement error (excluding pendant counter error) for LMOs tested (42) in 2009 is -4.84%

The difference in mean measurement error from the three samples of meters tested is primarily due to the difference in the characteristics of the test samples. For example, different tailwater levels, tested flow rates and the maintenance status of tested wheels. Operating conditions across the GMID vary markedly and the test population was increased from 53 (2007 & 2008) to 95 (2007, 2008 & 2009) to ensure that a representative sample of GMID LMOs were tested. As such, in considering the 95 service points tested, the varying tolerances of the average service point and the operating conditions are assumed to be, on average, representative of the entire GMID LMO population.

- iii) The results from the 95 in-situ LMO tests across the GMID show that this sample of LMOs significantly under recorded the volume of water delivered by an average of between -5.26% and -6.26% with a mean of -5.76%. The mean accuracy and range of LMO measurement meant that the LMO was non-compliant with the National standard (i.e. with the field specification that an open channel meter measure accurately to within  $\pm 5\%$ , 95% of the time).
- iv) The LMOs tested comprised a mix of rehabilitated and un-rehabilitated service points. Excluding pendant counter error maintained LMOs under recorded by -3.36% whereas unmaintained LMOs under record by -6.15%, a difference in accuracy of nearly 3%.
- v) In order to extrapolate the mean measurement error of -5.76% to the 13,000 LMOs across the GMID, an uncertainty of  $\pm 1.2\%$  must be applied. It is reasonable to conclude that 95% of the time the mean LMO measurement error (excluding pendant counter error) across the GMID would fall between -6.96% and -4.56%

- (under recording). Similarly for the un-maintained LMOs the mean LMO measurement error across the GMID would fall between -7.45% and -4.85%.
- vi) DLMO measurement was also non-compliant (with the field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time) due to the large standard deviation of the sample tested. The mean measurement error of the sample of six DLMOs tested was under recording by - 0.63% with the level of under recording on average being less than the LMO.
  - vii) SMO measurement was non compliant (with the field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time) due to the large standard deviation of the sample tested. The mean measurement error of the sample of 11 SMOs tested was -0.43% (under recording) with the level of under recording being highly variable but on average less than the LMO.
  - viii) Based on the pendant counter accuracy testing undertaken by G-MW on used LMO pendant counters the mean accuracy was -0.36% (in favour of the G-MW customer). When extrapolated to the entire LMO GMID population an uncertainty of  $\pm 0.38\%$  must be applied, therefore the mean LMO pendant counter error across the GMID would fall between -0.74% and 0.02% 95% of the time.

## 5. Key Findings

The following key findings should be noted:

- i. Based on the in-situ test results on 95 LMO service points;
  - a. The mean LMO measurement error (excluding pendant counter error) across the GMID could be between -6.96% and -4.56% with a mean of -5.76%.
  - b. The mean LMO measurement error (excluding pendant counter error) for unmaintained LMOs across the GMID could be between -7.45% and -4.85% with a mean of -6.15%.
  - c. Including the inherent inaccuracy of the pendant counter, the mean LMO measurement error across the GMID could be between -7.41% and -4.83% with a mean of -6.12%.
  - d. LMO measurement within the GMID is non-compliant based on the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time.

**Point a. and b. are the mean (volumetric) in-situ result as tested and calculated by each contractor with applied confidence limits determined by an extrapolation in order to represent the whole GMID LMO error. Whereas point c. includes the mean volumetric error (in-situ error as tested and calculated by each contractor) and the mean billing measurement error (pendant counter error) with applied extrapolation in order to represent the whole GMID.**

- ii. Based on the in-situ testing results, the DLMO and SMO, are also non-compliant meters within the GMID based on the National Standard field specification that an open channel meter must remain within  $\pm 5\%$ , 95% of the time.

**Table 8** provides a summary of the GMID Dethridge meter accuracy results.

**Table 8: Summary of GMID Dethridge meter accuracy.**

In-situ Error (Volumetric only)						
Meter Type	Sample Size	Mean Measurement Error (%)	Standard Deviation (%)	Mean Systematic Uncertainty (%)	95% Confidence Limits based on $S_t^d$ (%)	95% Confidence Limits based on Extrapolation (%)
LMO	95	-5.76	5.87	$\pm 0.50$	-17.50 to 5.98	-6.96 to -4.56
SMO	11	-0.43	8.37	$\pm 0.50$	-16.90 to 16.04	-5.53 to 4.67
DLMO	6	-0.63	4.37	$\pm 0.50$	-9.37 to 8.11	-4.33 to 3.07
Pendant Counter Error & In-situ Error (Billing and Volumetric Error combined)						
LMO	95 <sup>①</sup>	-6.12%	6.47%	N/A	-12.59 to 0.35	-7.41 to -4.83

Note: (i) Refer to Section 3.5 for explanation on combined sample population.

## 6. Recommendations

It is recommended that:

- i. If G-MW continue to undertake in-situ meter testing, it continue to use the REVS and MagRig IMVRs as independent audit tools and compliance measure for determining the accuracy on a range of irrigation meters in the field.
- ii. G-MW adopts the recommended best practice for verifying the accuracy of IMVR meters as outlined in **Section 2.5.3** whereby G-MW request bi-annual electronic calibration (dry test) certificates and flow testing (wet test) certificates every two years to verify test system recording accuracy.
- iii. G-MW compares the LMO in-situ testing results with the LMO mathematical modelling results and if necessary recalibrate the model to ensure the use of this method of determining meter error is a simple accurate low cost alternative to in-situ testing.
- iv. In order to verify the assumption that both systems measure to the same level of accuracy, G-MW conduct in-situ testing on a small number of LMO Dethridge meters using the AWMA Water Control Solutions and Thiess Services IMVRs.

## Appendix 1 – Large Meter Outlet (LMO) In-situ Testing Results

Test Year	Test Outlet	Test date	Testing Contractor	Normal flow rate	Recently Rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected Flow Rate	Reported meter error ((1-(822/actual rating))	Litres Per Revolution	Test Comments.
							Left side	Right side	Bottom (Av)								
2009 Data	█	19/2/2009	Thiess Services.	8	N	1.1	15	10	9	375	285/295	95	220	9.43	-6.55	880	Weeds u/s of door forced through door when opened.
										377/380	228/240	80/85	119	6.55	-4.99	865	
										380	215/220	72/78	60	3.97	-1.52	835	
	█	20/2/2009	Thiess Services.	6	N	1.1	5	10	7	328/340	328/340	180/185	Removed	9.11	-2.11	840	
										365/380	360	240	278	5.41	-5.33	868	
										365/368	340/348	240/250	108	3.07	-8.36	897	
	█	24/2/2009	Thiess Services.	10	Y	1.1	3	12	8	415/425	230	85/90	152	10.86	-2.64	844	Small leakage detected from the pools
										400/410	160/170	55/58	62	5.58	-2.15	840	
										405/411	158/165	40/42	35	3.55	-2.99	847	
	█	25/2/2009	Thiess Services.	6	N	1.1	10	14	8	305/312	265/275	78	305	8.89	-4.26	859	
										315/318	220/225	67/65	106	6.23	-4.86	864	
										315/320	200/210	50	58	3.77	-4.77	863	
█	26/2/2009	Thiess Services.	8	N	1.1	6	0	6	292/418	350/360	90/95	290	8.69	-8.03	894	water level in supply channel slowly rising through test. Mud at u/s door.	
									415/418	320/330	75/81	179	6.02	-10.23	916		
									417/420	270/275	48/55	52	3.19	-10.46	918		
█	4/03/2009	Thiess Services.	6	Y	1.1	6	15	7	397/405	260/275	165/170	175	10.57	0.68	816	Wheel stoped twice through the test period.	
									397/400	230/260	155/165		6.64	0.77	816		
									400	250/260	155/165	45	3.31	-1.90			
█	5/03/2009	Thiess Services.	5	N	1.1	3	12	11	455/462	290	170/175	115	7.67	-10.61	920	Seepage test not valid. Used RN368 data.	
									458/461	295/300	175/179	65	4.93	-12.13	936		
									459/460	295/300	176/177	41	3.03	-12.35	938		
█	6/03/2009	Thiess Services.	6	Y	1.1	5	13	6	377	70/85	65/75	92	8.82	2.08	805	Leakage from dam wall was found and blocked on arrival. Dirt washed away from the door.	
									378/380	40	55	54	5.85	2.53	802		
									389/393	90	35/38	25	3.08	0.74	816		
█	10/03/2009	Thiess Services.	8	N	1.1	4	15	7	350/355	350/355	185/192	Removed	6.15	-1.07	831		
									358/362	350/360	200/210	270	3.39	-3.24	850		
									355/358	355/358	175	Removed	7.85	-0.04	822		
█	11/03/2009	Thiess Services.	9	N	1.1	9	10	9	350/358	190	80	107	8.14	-1.32	833	Lowered the tail water and removed the gate for this test. D/S pool soaked before arrival. Seepage figures from RN1704B used.	
									362/370	170/175	63/68	76	6.38	0.08	821		
									370/375	158/162	43/45	35	3.22	-1.40	834		
2009 Data	█	16/3/2009	Thiess Services.	6-8	Y	1.1	7	15	10.5	abandoned						822	Small leakage through pool wall Small leakage through pool wall Small leakage through pool wall
										421/425	175	85/90	97	8.37	0.05	822	
										421/423	152/155	50/52	42	3.97	0.93	814	
	█	18/3/2009	Thiess Services.	10	N	1.1	10	12	18	420/422	230/235	95/100	160	11.81	-1.95	838	Small leakage through pool wall Pool was soaked before arrival.
										455/465	380	230/235	195	10.75	-14.68	963	
										474/475	280/290	200/202	106	7.62	-14.59	962	
	█	19/3/2009	Thiess Services.	12	N	1.1	11	7	9	470/471	270/280	175/179	46	4.00	-15.65	975	Pool was soaked before arrival.Small leakage from pool (included in calcs)
										450/452	370/380	155/160	328	13.91	-5.97	875	
										455/456	245/255	155	118	9.28	-4.45	860	
	█	23/3/2009	Thiess Services.	12	Y	1.1	16	6	9	451/454	265	160/162	44	4.24	-7.48	888	Silt removed from front door. Weed growth in front of door.
										555/560	350	140/145	223	14.36	-11.31	927	
										560/565	190	135	93	9.48	-6.85	883	
█	25/3/2009	Thiess Services.	12	N	1.1	14	8	12	569/570	225	125		5.00	-9.19	905	Pool was soaked before arrival. 0.2mm rain during the test. no rain during the test.	
									325/340	290	125/140	286	11.70	-3.63	853		
									328/331	235/240	120/125	150	8.66	-2.57	844		
█	7/04/2009	Thiess Services.	10	N	1.1	12	8	8	328/332	233/235	135/140	77	4.35	-5.12	866	0.7mm rain during the test. Pool was filled on arrival.	
									445/432	360/365	100	242	12.76	-5.43	869		
									435	210	100	132	10.05	-2.88	846		
█	30/03/2009	Thiess Services.	4	N	1.1	8	10	11	440/460	165/170	93	52	5.56	-1.76	837	Pool was soaked before arrival.	
									600/605	220/230	110/115	120	12.57	-7.02	884		
									602/605	150	90	60	8.02	-2.95	847		
█	6/04/2009	Thiess Services.	6	N	1.1	0	19	5	600/598	130	68	25	4.42	-4.95	865	small leakage through 300mm pipe. Pool dry on arrival. Pulse meter 1 disconnected from logger. Pulse meter 2 used.	
									380	290	100/110	267	10.92	-4.34	859		
									380	317	181	184	6.36	-7.45	888		
█	2/04/2009	Thiess Services.	6	N	1.1	6	10	13	373	320	185	184	6.09	-7.58	889	Pool dry on arrival.Silt movement in approach channel to outlet.	
									372	310	190	130	4.90	-7.43	888		
									320	320	125	220	8.93	-2.95	847		
█	3/04/2009	Thiess Services.	6	N	1.1	5	14	4	380/388	268/280	158/165	140	6.30	-5.62	871	Pool soaked before arrival.	
									390	275/280	165/170	88	6.32	-5.37	869		
									375	250/255	110/115	162	8.11	-6.10	827		
█									378/383	240/245	125/130	110	6.26	-2.48	843		
									388/393	255/250	130	51	3.87	-4.60	862		

Test Year	Test Outlet	Test date	Testing Contractor	Normal flow rate	Recently Rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected Flow Rate	Reported meter error ((1-(822/actual rating))	Litres Per Revolution	Test Comments.
							Left side	Right side	Bottom (Av)								
							mm	mm	mm								
2009 Data	█	30/4/2009	AWMA.	ML/d	N	1.1	10	4	9	382	152	258	3.07	-1.53	835	Pool soaked before arrival.	
						1.2				373	164	258	5.98	-1.39	834		
						1.3				372	134	354	7.98	1.42	810		
	█	29/4/2009	AWMA.	8-9	N	1.1	14	13	6	359	312	58	2.99	-12.03	934	Pool soaked before arrival.	
						1.2				359	315	175	6.02	-9.80	911		
						1.3				347	309	371	8.50	-3.58	853		
	█	4/5/2009	AWMA.	6-8	N	1.1	12	10	6	315	197	165	2.91	-5.10	866	Pool soaked before arrival.	
						1.2				307	174	285	6.04	0.38	819		
						1.3				308	127	285	9.07	2.56	801		
	█	23/4/2009	AWMA.	3-4	N	1.1	5	18	9	443	106	30	3.17	-0.21	823	Pool soaked before arrival.Bent fins on drum.	
						1.2				444	126	57	6.52	0.30	819		
						1.3				439	136	81	9.13	5.77	777		
█	21/4/2009	AWMA.	8	N	1.1	9	5	6.81	398	-90	37	3.09	5.57	778	Pool soaked before arrival. Free overfall.		
					1.2				397	-100	64	6.05	4.97	783			
					1.3				382	-110	114	8.99	4.72	785			
█	22/4/2009	AWMA.	10	Y	1.1	8	10	4.56	524	116	57	2.79	-10.02	913	Pool soaked before arrival. Bent fins.		
					1.2				431	115	115	5.91	-4.77	863			
					1.3				433	112	193	8.94	0.43	818			
█	5/5/2009	AWMA.	10	N	1.1	9	14	3	522	257	46	3.00	-17.61	997	Pool soaked before arrival. Bent fins		
					1.2				521	232	79	6.01	-8.94	903			
					1.3				516	248	126	9.49	-5.87	873			
█	1/4/2009	AWMA.	6-10	Y	1.1	14	8	9.06	470	155	38	3.04	-13.70	951	Pool soaked before arrival.		
					1.2				469	158	79	5.90	-5.75	872			
					1.3				475	150	146	9.85	-4.44	860			
█	6/4/2009	AWMA.	6	N	1.1	10	8	5.77	421	-177	39	3.10	-3.87	885	Pool soaked before arrival.Rust fins worn bearings , strong winds during the test.		
					1.2				416	-149	89	6.16	2.01	806			
					1.3				430	-136	137	9.03	0.87	815			
█	2/4/2009	AWMA.	3	N	1.1	10	10	8.2	552	217	48	3.02	-14.30	957	Pool dry on arrival		
					1.2				552	218	120	6.00	-8.40	897			
					1.3				553	219	185	10.13	-5.09	866			
█	8/4/2009	AWMA.	9-10	N	1.1	19	4	12.94	483	270	47	2.91	-21.10	1042	Pool soaked before arrival.		
					1.2				484	275	108	6.04	-14.58	962			
					1.3				484	283	286	10.46	-5.95	874			
█	8/4/2009	AWMA.	9-10	N	1.1	9	15	5.81	477	260	296	10.47	-5.18	867	Re-test after bottom fin clearance adjusted.		
					1.2				560	73	26	3.07	-13.43	949			
					1.3				558	67	62	6.18	-3.95	856			
█	3/4/2009	AWMA.	12	N	1.1	10	12	5.38	376	102	55	2.90	3.12	797	Pool soaked before arrival.bent fins slight scraping of fin. Strong winds during test.		
					1.2				376	98	103	6.04	2.57	801			
					1.3				375	93	158	9.07	2.14	805			
█	14/4/2009	AWMA.	3	Y	1.1	4	12	5.06	550	153	28	2.88	4.33	789	Pool soaked before arrival.		
					1.2				551	160	52	6.05	2.25	803			
					1.3				552	158	78	9.02	2.84	799			
█	10/3/2009	AWMA.	12	N	1.1	7	12	4.42	557	-180	25	2.99	0.52	818	Pool soaked before arrival.Bent fins		
					1.2				546	-180	55	6.10	2.11	805			
					1.3				533	-244	96	9.31	0.82	815			
█	16/3/2009	AWMA.	8-10	Y	1.1	3	13	8.00	376	183	70	2.97	-10.34	916	Pool soaked for 9 hrs before test.		
					1.2				376	167	156	6.03	-6.57	880			
					1.3				390	178	400	10.03	-2.73	845			
█	13/3/2009	AWMA.	8-10	N	1.1	4	15	8.94	410	237	64	3.12	-11.46	927	Pool soaked for 3 hrs before test.		
					1.2				400	248	282	6.22	-9.01	904			
					1.3				403	212	410	9.99	-6.76	882			
█	17/3/2009	AWMA.	10	N	1.1	14	8	6.94	576	275	70	2.85	-20.98	1039	Pool soaked for 2 hrs before test.		
					1.2				579	286	290	6.12	-13.48	949			
					1.3				585	285	405	9.73	-10.65	920			
█	17/4/2009	AWMA.	10-12	N	1.1	11	14	8.00	475	204	47	3.00	-11.27	926	Pool soaked before arrival.		
					1.2				475	205	83	6.05	-6.44	878			
					1.3				473	204	155	9.77	-5.60	871			
█	16/3/2009	AWMA.	MI/day	N	1.1	14	15	7.25	484	286	183	3.10	-17.11	992	Pool soaked before arrival.		
					1.2				477	237	260	6.09	-10.79	921			
					1.3				476	203	470	8.94	-4.88	864			
█	23/3/2009	AWMA.	8-10	N	1.1	13	12	5.56	316	82	54	2.84	1.11	813	Pool soaked before arrival.		
					1.2				354	76	72	5.21	4.59	786			
					1.3				345	2	137	9.40	4.51	786			
█	25/3/2009	AWMA.	MI/day	N	1.1	10	12	6.63	416	321	49	3.01	-15.14	967	Pool soaked before arrival.		
					1.2				404	314	128	6.09	-11.95	933			
					1.3				405	310	162	7.11	-10.48	920			

Test Year	Test Outlet.	Test date	Testing Contractor.	Normal flow rate	Recently Rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected Flow Rate	Reported meter error ((1-(822/actual rating))	Litres Per Revolution	Test Comments.
							Left side	Right side	Bottom (Av)								
2008 Data	█	13/02/2008	Thiess Services.	6	N	1.1	3	13	13	390	375	190	335	11.71	-14.82	965	
										408	280	180	100	6.38	-17.57	997	
										410	270	165	43	3.01	-21.07	1041	
	█	19/02/2008	Thiess Services.	8	N	1.1	12	4	6	377	300	158	255	10.12	-2.6	844	
										383	315	187	160	6.26	-6.29	877	
										380	300	186	52	3.25	-7.8	892	
	█	21/02/2008	Thiess Services.	3	N	1.1	5	13	10	355	305	180	302	10.77	-10.94	923	
										371	290	185	135	6.12	-13.59	951	
										375	290	190	65	3.30	-17.77	1000	
	█	16/01/2008	Thiess Services.	10	N	1.1	10	10	11	687	190	150	163	11.73	-5.14	867	
										700	198	180	108	7.89	-0.97	830	
										700	250	160	42	3.23	-10.4	917	
█	18/02/2008	Thiess Services.	2,3 or 4	N	1.1	11	10	9	413	330	208	274	11.16	-10.01	913		
									392/417	393	288	247	5.26	-13.63	952		
									365	260	167	33	2.26	-16.92	989		
█	15/01/2008	Thiess Services.	3	N	1.1	8	11	5	405	330	184	150	6.08	-5.77	872	Approach channel through Dethridge is restrictive	
									360	340	180	302	8.41	-0.35	825		
									407	300	184	35	2.20	-13.1	946		
█	3/10/2007	Thiess Services.	3.7	N	1.1	9	7	9	370	205	120/130	50	3.88	-2.82	846	Very windy / high seepage	
									365/360	200	115	80	5.94	-1.53	835		
									360/352	240	140/120	178	10.23	-3.22	849	order 3-7 ML/d	
█	17/01/2008	Thiess Services.	4 or 6	N	1.1	6	8	5	340	310	96	323	10.55	-0.89	829		
									358	280	130	104	5.78	-4.17	858		
									362	265	120	45	3.14	-6.88	883		
█	10/10/2007	Thiess Services.	6	N	1.1	8	12	10	415/420	#N/A	135/130	101	3.76	-19.68	1023	orders 6ML/d	
									420	#N/A	125/130	#N/A	6.31	-14.06	956		
									420	#N/A	130	150	9.42	-17.51	996		
█	9/10/2007	Thiess Services.	4	N	1.1	9	8	11	450	210/220	135	28	3.83	-5.86	873	orders 4ML/d	
									450	200	130	58	5.81	-3.57	852		
									450/445	200	130	101	9.02	-3.34	850		
█	14/02/2008	Thiess Services.	5	N	1.1	9	8	11	445	200	130	101	5.30	-3.34	850		
									360-420	350-380	120-125	314	10.09	-2.99	847		
									440	275	120	114	6.39	-4.46	860		
█	27/09/2007	Thiess Services.	5	N	1.1	10	5	5	400	400	200	out	10.55	-3.1	848		
									400/380	400	200/240	out	6.14	-4.2	858		
									400/380	400	200/235	out	6.49	-3.95	856	recalculated due to fluctuation in supply	
█	4/10/2007	Thiess Services.	6	N	1.3	10	5	5	390/415	400	245/280	out	4.25	-5.43	869	orders 5ML/d	
									390/415	400	255/250	out	4.35	-5.12	866	recalculated due to fluctuation in supply	
									405/410	210	75/80	50	4.24	-8.64	900		
█	20/11/2007	Thiess Services.	5	#N/A	1.3	8	8	9	410	320	175	65	3.99	-14.43	961		
									410	340	180	130	5.78	-13.08	946	Orders 6 ML/d	
									370/380	205	93/95	145	9.81	-3.78	854	Repeat test	
█	13/11/2007	Thiess Services.	5	N	1.3	9	7	5.5	385/395	160	86/87	65	5.35	-2.25	841	Orders 5 ml/d	
									391/396	165	80/90	84	6.92	-2.97	847		
									375/385	375/385	262/275	out	4.45	-7.36	887		
█	12/12/2007	Thiess Services.	10	N	1.3	10	12	5	375/385	375/385	262/275	out	4.48	-7.32	887		
									375/385	375/385	262/275	out	4.51	-7.32	887	orders 2-4 ML/d	
									400	330	200	167	10.16	-4.64	862		
█	7/12/2007	Thiess Services.	10	N	1.1	12	16	4	400/405	310	210/215	90	6.02	-6.02	875	Tips on some fins bent	
									405	305/310	205/210	41	2.98	-9.13	905		
									315/340	230/250	110/120	187	9.26	-0.28	824	wind assisting wheel	
█	7/11/2007	Thiess Services.	7	N	1.1	20	1	9.5	470/480	375	260/270	256	10.88	-7.72	891	bent fin, uneven side spacing	
									490/497	370/375	260	113	7.40	-11.62	930		
									502/500	340	260	30	3.17	-15.62	974		
█	6/12/2007	Thiess Services.	8	N	1.1	6	16	10.5	410/405	370/375	255/260	200	6.83	-9.13	905		
									330/340	210/215	85/90	137	8.37	-0.87	829	2 fins on wheel badly eroded	
									330/340	350/357	60/70	170	4.97	-0.42	825		
█	5/12/2007	Thiess Services.	8	N	1.3	6	16	10.5	355/363	150/160	50/55	38	3.13	-1.33	833		
									450	170/175	85/90	88	8.17	2.89	799		
									452/455	220/230	150	58	5.25	-9.98	913		
█	4/12/2007	Thiess Services.	10	N	1.1	11	11	26.5	360/370	280	105/110	243	9.97	-0.84	829		
									378/380	225	90/95	88	5.95	-12.9	944	dirt removed from gate	
									380/385	200/205	60/65	38	3.12	-13.04	945		

Test Year	Test Outlet	Test date	Testing Contractor	Normal flow rate	Recently Rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected Flow Rate	Reported meter error ((1-(822/actual rating))	Litres Per Revolution	Test Comments.									
							Left side	Right side	Bottom (Av)									mm	mm	mm	mm	ML/d	(% )	l/rev		
																									ML/d	Y/N
2008 Data	█	30/01/2008	Thiess Services.	6	N	1.1	17	10	6	485	250	130	134	11.27	#N/A	860										
																		1.2	500	175	107	55	6.26	#N/A	824	
																		1.3	500	180	90	28	3.33	-1.72	836	
	█	31/01/2008	Thiess Services.	6	N	1.1	8	8	~30	515	250	175	132	11.03	-14.28	959										
																			1.2	528	277	190	69	6.33	-17.92	1001
																			1.3	525	295	180	30	3.06	-25.27	1100
	█	7/02/2008	Thiess Services.	8	new bearings	2.1	3	10	10	406	330	170	290	11.57	-7.66	890										
																			2.2	403	290	180	123	7.28	-8.77	901
																			2.3	390	300	180	52	3.26	-13.28	948
	█	5/02/2008	Thiess Services.	10	Y	1.1	6	19	13	520	320	155	119	12.14	-7.78	891										
																			1.2	540	230	155	70	6.72	-7.73	891
																			1.3	495	253	144	37	3.28	-11.95	934
█	6/02/2008	Thiess Services.	10	new bearings	1.1	6	8	15	477	270	170	118	12.04	-7.47	888											
																		1.2	480	250	160	75	6.43	-7.82	892	
																		1.3	468	275	165	30	3.17	-13.25	948	
█	21/11/2007	Thiess Services.	14	#N/A	1.1	12	9	11	515/520	400	120/125	212	12.64	-11.11	925		shortened test result, but ok									
																		1.2	515/520	245/250	150/155	93	8.08	-7.73	891	
																		1.3	515/520	250	145	34	3.15	-13.21	947	
█	23/11/2007	Thiess Services.	#N/A	Y	1.1	7	9	6	365/370	#N/A	205/210	out	7.43	-3.48	852		gate removed during test									
																		1.2	360/365	#N/A	170/180	out	10.09	-2.73	845	
																		1.3	372/375	#N/A	243/247	out	4.52	-5.39	869	
█	8/02/2008	Thiess Services.	3 or 7 revs	#N/A	1.1	10	10	12	400	280	125	out	11.95	-6.69	881											
																		1.2	417	295	177	169	6.74	-10.14	915	
																		1.3	420	287	175	69	3.41	-14.64	963	
█	11/02/2008	Thiess Services.	12	N	1.1	12	11	9	388	320	150	294	11.89	-8.12	895											
																		1.2	410	340	190	210	8.58	-10.07	914	
																		1.3	418	305	185	43	3.12	-16.93	990	
█	22/01/2008	Thiess Services.	6	#N/A	1.1	11	10	7.5	337	270	145	236	10.05	-2.27	841											
																		1.2	340	315	195	227	6.09	-5.26	868	
																		1.3	335	273	177	94.2	3.07	-7.56	899	
█	23/01/2008	Thiess Services.	11	#N/A	1.1	12	17	19	485	450/440	200	276	11.54	-16.85	989											
																		1.2	508	355/360	225/220	113	6.28	-17.92	1001	
																		1.3	502/508	370/365	220	50	3.30	-21.25	1044	
█	23/01/2008	Thiess Services.	11	#N/A	1.1	10	13	13	480	250	180	144	11.51	-8.93	902.64											
																		1.2	493/488	250	185	70	6.55	-8.92	902.53	
																		1.3	488/483	250	185	35	3.50	-13.81	953.73	
█	24/01/2008	Thiess Services.	6	#N/A	1.1	6	9	8	322	317	100	307	8.84	-0.86	829.11											
																		1.2	345	260	100	130	6.29	-2.35	841.74	
																		1.3	343	230	72	51	3.34	-4.02	856.46	
█	20/02/2008	Thiess Services.	3	#N/A	1.1	6	12	5	355	288	100	260	10.32	-0.89	829											
																		1.2	380	215	87	89	6.04	2.28	804	
																		1.3	362	180	59	44	3.23	2.5	802	
█	16/10/2007	Thiess Services.	11	N	1.1	8	9	4	372/380	175/160	65	38	3.73	2.99	798		free fall at back of wheel									
																		1.2	400/382	170/175	70	72	6.06	3.47	794	
																		1.3	385	250	95	97	10.54	1.23	812	
█	17/10/2007	Thiess Services.	12	N	1.1	8	12	5	380	325	120	308	11.83	-1.98	839		culvert directly downstream of wheel									
																		1.2	400	305	180	122	6.13	-5.65	871	
																		1.3	400/402	295	190	75	3.89	-6.72	881	
█	18/10/2007	Thiess Services.	12	N	1.1	12	12	4	390	#N/A	220	224	13.21	-6.81	882		culvert directly downstream of wheel									
																		1.2	390	#N/A	200	76	6.30	-4.58	861	
																		1.3	390	#N/A	205	31	4.11	-6.73	881	
█	19/10/2007	Thiess Services.	11	N	1.1	19	9	7.5	442/445	230	105	132	10.21	-2.44	843		door with automatic control									
																		1.2	450/455	190	105	70	6.29	-1.31	833	
																		1.3	451/453	190	105	38	3.61	-2.67	845	
█	23/10/2007	Thiess Services.	11	Y	1.1	12	11	6.5	540/535	#N/A	100	118	10.23	-1.82	837											
																		1.2	540/545	220	65/80	55	6.18	-1.6	835	
																		1.3	540/547	210	55	30	3.72	-0.85	829	
█	24/10/2007	Thiess Services.	11	N	1.1	10	11	6.5	420/424	315	120	215	10.28	-4.97	865		Recommended test results									
																		1.2	420/432	260	95	101	6.75	-5.86	873	
																		1.3	432	250	90	52	4.06	-8.35	897	
█	31/10/2007	Thiess Services.	11	N	1.1	13	4	5	485	315	170	216	10.93	-6.02	875		fibrocere emplacement									
																		1.2	495	320	160	96	6.36	-6.75	882	
																		1.3	492/495	310	170	45	3.38	-10.19	915	
█	1/11/2007	Thiess Services.	14	N	1.1	10	10	9	560/565	315	130	290	14.57	-7.29	887		5 mm movement on bearing at high flow									
																		1.2	560/575	200	130	110	10.86	-2.53	843	
																		1.3	565	200	75	35	4.44	-2.53	843	

Test Year	Test Outlet	Test date	Testing Contractor	Normal flow rate	Recently Rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected Flow Rate	Reported meter error ((1-(822/actual rating))	Litres Per Revolution	Test Comments.
							Left side	Right side	Bottom (Av)								
2007 Data	18/01/2007	Thiess Services.	10	#N/A	1.0	#N/A	#N/A	8	475	open	275	out	9.80	-12.98	943		
						#N/A	#N/A	13	470	270	out	9.56	-16.15	979			
						#N/A	#N/A	7	480	open	265	out	8.86	-12.52	938	Bearings Replaced	
	17/01/2007	Thiess Services.	10	#N/A	1.0	#N/A	#N/A	8	380	330	150	280	9.50	-8.4	896		
						#N/A	#N/A	8	380	330	150	280	9.55	-8.46	897		
						#N/A	#N/A	8	380	330	150	280	9.45	-8.33	896		
						#N/A	#N/A	8	380	330	150	280	9.52	-8.4	896		
						#N/A	#N/A	14	375	open	170	out	10.59	-11.19	924		
						#N/A	#N/A	14	375	open	170	out	10.42	-11.04	923		
	23/01/2007	Thiess Services.	3	#N/A	1.0	#N/A	#N/A	7	405	325/330	180	75	4.14	-32.6	1218	Dethridge Pulse counter malfunction (-2 counts/rev)	
						#N/A	#N/A	7	405	330	180	50	2.97	-17.22	992		
						#N/A	#N/A	8	400	335	180	60	3.22	-20.74	1036		
6/02/2007	Thiess Services.			2.2	#N/A	#N/A	16	410/450	325	180	60	3.78	-22.38	1058			
					#N/A	#N/A	8	450	330	180	60	4.17	-17.3	993			
					#N/A	#N/A	11	397/408	380	255/250	180	4.35	-24.05	1081			
30/01/2007	Thiess Services.	4	#N/A	1.0	#N/A	#N/A	8	400	370-375	240/245	180	4.16	-10.32	915	Stones preventing continuous free turning of Dethridge Meter		
					#N/A	#N/A	8	400	370-375	240/245	180	4.25	-9.77	910			
					#N/A	#N/A	8	405	370-375	240/245	180	4.81	-9.67	909			
					#N/A	#N/A	8	410	380	245	180	5.10	-9.22	904			
					#N/A	#N/A	9	426	open	310	out	5.41	-7.79	890			
29/01/2007	Thiess Services.	5	#N/A	1.0	#N/A	#N/A	15	413	open	310	out	4.54	-12.78	941	D/S reg. gate opened near test end. Fins straightened		
					#N/A	#N/A	8	386	open	265/260	out	7.02	-4.46	859			
					#N/A	#N/A	4	395/400	open	235	out	7.43	-1.46	833	mean of 2 tests for algorithm		
22/01/2007	Thiess Services.	6	#N/A	2.0	#N/A	#N/A	13	385	open	235	out	5.74	-17.22	992			
					#N/A	#N/A	6	385	open	235	out	6.09	-11.08	923	Bearings replaced		
					#N/A	#N/A	7	500	495	340	310	4.33	-8.58	898			
24/01/2007	Thiess Services.	4	#N/A	2.0	#N/A	#N/A	13	495	495	340	350	4.83	-14.61	962			
					#N/A	#N/A	6	510	495	340	310	4.18	-10.3	915	Bearings replaced		
					#N/A	#N/A	7	380	355	210	290	5.47	-8.2	894			
1/02/2007	Thiess Services.	8	#N/A	2.0	#N/A	#N/A	17	370	360	210	245	6.21	-15.65	973			
					#N/A	#N/A	7	425/530	370/440	210/230	165	8.58	-14.17	957	Supply level rose significantly nearing end of test		
					#N/A	#N/A	7	400	310	160	240	10.99	-5.92	873			
19/01/2007	Thiess Services.	10	#N/A	2.0	#N/A	#N/A	14	390	310	170	250	11.30	-9.6	908			
					#N/A	#N/A	8	390	310	170	250	10.53	-6.31	876	Replaced Bearings		
					#N/A	#N/A	8	390	310	170	250	10.54	-6.21	875			
					#N/A	#N/A	8	350	200	80	155	9.80	-5.59	870	General conditions windy		
					#N/A	#N/A	17	350	190	80	155	10.24	-10.69	919			
31/01/2007	Thiess Services.	10	#N/A	3.0	#N/A	#N/A	7	350	200	80	155	10.08	-4.69	861	Dethridge Fins straightened. Replaced Bearings		

## Appendix 2 – Dethridge Long Meter Outlet (DLMO) In-situ Testing Results

Test Year	Test Outlet	Test date	Testing Contractor	Normal flow rate	Recently rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected flow rate	Reported meter error ((1-(822/actual rating))	Test rating	Test Comments
							Left side	Right side	Bottom (Av)								
2009 Data		26/3/2009	Thiess Services.	12	N	1.1	5	8	11	328/333	270/272	160/165	187	8.74	4.07	807	Pool was soaked before arrival.
						1.2			11	330/345	310/325	175/185	311	11.35	2.85	817	
						1.3			11	360/362	200	120	55	4.28	2.49	820	
		28/4/2009	AWMA.	14	N	1.1	8	3	5.08	487		220	47	4.00	-1.45	851.95	Pool soaked before arrival.
						1.2			5.08	488		232	92	8.10	5.48	796	
						1.3			5.08	486		233	159	13.98	6.69	787	
		31/3/2009	AWMA.	12	Y	1.1	4	6	5.58	506		335	54	3.06	-11.14	945	Pool soaked before arrival.
						1.2			5.58	484		326	120	7.07	-3.38	869	
						1.3			5.58	502		329	263	12.96	-1.09	849	
		26/3/2009	AWMA.	12-14	Y	1.1	4	5	5.00	391		224	49	3.96	-5.55	889	Pool soaked before arrival.
					1.2			5.00	390		224	108	8.01	-0.10	840		
					1.3			5.00	389		221	289	14.40	-0.84	847		
2008 Data		28/12/2007	Thiess Services.	8	N	1.1	5	4	18	400	300	147	252	#N/A	-3.54	#N/A	over measured
						1.2			18	400	210	180	107	#N/A	-2.08	#N/A	
						1.3			18	400	213	175	52	#N/A	0.05	#N/A	under measured
		26/10/2007	Thiess Services.	13	N	1.1	7	4	20.5	355	#N/A	102/105	211	13.49	-3.07	815	fairly good condition
						1.2			20.5	373/370	#N/A	118/122	96	8.13	-6.52	789	
					1.3			20.5	380	#N/A	130	33	3.11	5.80	892		



### Appendix 3 –Small Long Meter Outlet (SMO) In-situ Testing Results

Test Year	Test Outlet	Test date	Testing Contractor	Normal flow rate	Recently rehabilitated	Test Id	Fin Clearance. (mm)			Supply depth	Depth D/S of Gate	Tailwater depth (above rear sill)	Gate opening	Corrected Flow Rate	Reported meter error ((1-(822/actual rating)))	Test rating	Test Comments.
							Left side	Right side	Bottom (Av)								
2009 Data		17/2/2009	Thiess Services.	6	N	1.1	7	6	360/365	360/365	100/105	Removed	6.65	0.46%	350	Rear roller pressed into mudto concrete sill Mud u/s of gate was washed away gradually	
						1.2			340/350	150	95/98	70	3.77	2.75%	343		
						1.3			340/345	150	80/82	24	1.26	-0.44%	354		
		18/2/2009	Thiess Services.	6	N	1.1	16	4	9	312/315		81/88	138	6.40	-4.79%	370	
						1.2			9	318/321		54/58	48	3.55	14.81%	307	
						1.3			9	318/320		30/36	20	1.67	14.02%	309	
		24/3/2009	Thiess Services.	6	N	1.1	5	9	4	460	280/300	100	134	6.26	-3.54%	365	
						1.2			4	460/463	145/150	100/105	61	4.05	2.31%	344	
						1.3			4	455/460	175	105	34	2.24	-2.11%	360	Small leakage from pool.
		12/03/2009	Thiess Services.	6	N	1.1	6	11	7	450	420/425	205/210	450	6.08	-6.96%	378	Wheel stopped for 20 secs during test Test recalculated for shorter period.
						1.2			7	445/450	380/385	222/225	162	4.15	-9.85%	390	Seepage testform RN1704B used.
	2009 Data					1.3			7	440/442	338/340	230	50	1.99	-8.75%	386	
		17/3/2009	Thiess Services.	6	Y	1.1	11	5	14	379/380	105/115	50	29	2.18	-4.77%	370	Seepage data from MV6894 used. Pool wet on arrival.
						1.2			14	378/379	125/130	65/70	58	4.03	-5.19%	371	
						1.3			14	375/377	190	95	123	6.38	-9.83%	390	
		31/03/2009	Thiess Services.	2	N	1.1	6	9	12	415/432	328/335	238/240, 250	55	1.92	-17.21%	425	Pool dry on arrival.Culvert pipe was leaking.
						1.2			12	430/460	440/420	290/320	149	2.61	-21.37%	448	u/s W.L. dropped between test 2 and 3. Tail water level lowered.
						1.3			12	415/362	410/360	292/255	310	2.84	-13.52%	407	
		18/3/2009	AWMA.	5-6	N	1.1	11	9	7.06	384		-18	2	1.01	3.78%	339	Pool soaked for 2.5 hrs before test.
						1.2			7.06	387		-36	41	2.87	4.41%	337	
						1.3			7.06	376		-20	89	4.86	3.37%	340	
		20/3/2009	AWMA.	5-6	N	1.1	9	5	5.56	298		55	21	1.06	-4.21%	367	Pool soaked for 7.5 hrs before test.
2008 Data						1.2			5.56	296		47	62	3.10	0.81%	349	
					1.3			5.56	312		123	342	5.01	2.43%	343		
		5/10/2007	Thiess Services.	2	N	1.1	9	8	5	496	165/180	110	25	2.13	2.17%	#N/A	no orders
						1.2			5	490	160	115	35	2.86	0.11%	#N/A	
						1.3			5	460/465	170/175	110	74	5.46	-1.23%	#N/A	
		2/10/2007	Thiess Services.	4	N	1.1	6	7	14	360/370	260/240	180/165	45	2.25	13.75%	#N/A	
						1.2			14	375/360	245/235	175/160	85	4.10	8.44%	#N/A	
						1.3			14	360/355	280	175	135	5.37	9.21%	#N/A	
		29/01/2008	Thiess Services.	6	Y	1.1	6	5	8	457	270	135	135	6.11	4.54%	369	
						1.2			8	448	225	146	48	2.86	5.29%	372	
						1.3			8	432	233	135	20	1.40	12.78%	404	

### Appendix 4 – Outliers - Large Meter Outlet (LMO) In-situ Testing Results

Reference No.	Irrigation Area	Test date	Test Outlet	Test Id	Readings & Settings at Test Commencement						Test				
					Recently rehabilitated	Bottom Fin Clearance	U/S Supply depth	Depth D/S of Gate	Tailwater depth	Gate opening	Corrected Flow Rate	Result		Test comments	
					Y/N	mm	mm	mm	mm	mm	ML/day	% Under	% Over		L/Rev
1	CG	16-Jan-08	██████	1.1	N	12.5	711	110	150	128	11.61		13.07	872	Abnormally windy conditions assisting drum rotation, influencing the results for the first two tests. Higher approach velocity than generally anticipated.  Test results abnormal.
2	TIA	30-Oct-07	██████	1.1	N	8	445/435	#N/A	185	370	11.12	-13.44		950	Dethridge wheel fins damaged, bearings also worn (3 mm), one severely bent vane.  Excessive damage to the fins and vanes is uncommon.

