GOULBURN-MURRAY WATER

Future of the Dethridge Meter

Final

May 2007

Hydro Environmental

EXECUTIVE SUMMARY

BACKGROUND

As part of the decision making process in deciding whether to continue with the Dethridge meter and if not what meter should be used to replace them, Thiess Services was engaged to use its Remote Electronic Verification System to test a range of flow meter types in the field for accuracy.

Throughout this report a positive error (+) means the meter over records (i.e. delivers less water than is shown on its display and a negative error (-) means the meter under records (i.e. the customer receives more water than is recorded).

PROJECT OBJECTIVES

Thiess has completed its report in draft form and Hydro Environmental has been engaged by Goulburn-Murray Water (G-MW) to:

i) review and understand the implications of the Thiess Services Report titled "Insitu Flow Verification Report on Irrigation Structures - Goulburn Murray Water"

ii) provide recommendations based on conclusions drawn from the Thiess Services Report

iii) gain an understanding of Water Provider Industry's perspective on the future metering and the future of the Dethridge meter

iv) provide recommendations regarding the future use of the Dethridge meter by G-MW.

The report is also to include some discussion on the performance of meters other than the Dethridge meter, such meters could include the FlumeGate™ and Magnetic flow meters and their respective capabilities to comply with the proposed National Metering Standards.

METHODOLOGY

To achieve the four key project objectives Hydro Environmental:

i) Reviewed the Thiess Services' (March 2007) report titled "Insitu Flow Verification Report on Irrigation Structures - Goulburn Murray Water", and specifically the methodology followed to undertake the verification

ii) Reviewed additional reports relevant to metering accuracy and the metering accuracy of the Dethridge meter

iii) Reviewed and understood the methodology followed by Thiess Services to undertake the metering accuracy analysis

iv) Provided recommendations regarding the methodology to undertake the in-situ verification of metering accuracy and analysis

v) Analysed the results included in the Thiess Services Report and drew conclusions where possible

vi) Consulted with key stakeholders in the water metering industry, such as rural water authorities, Manly Hydraulics Laboratory, Department of Environment and Water Resources and National Measurement Institute to gain an understanding of their perspective on the future metering for the irrigation industry and the future of the Dethridge meter

vii) Briefly reviewed the performance of meters other than the Dethridge meter, including meters such as FlumeGate™, MagFlow and Doppler meters, and their respective capabilities of complying with the national metering standards

viii) Discussed the suitability of alternative meters

ix) Prepared recommendations regarding the future use of the Dethridge meter by G-MW.

CONCLUSIONS

Based on the content of this report the following general conclusions have been drawn:

Field Testing Results

i) The Thiess field testing and report shows;

a. the REVS unit measures accurately and the level of uncertainty is between 0.5% and 0.6% for this series of tests

b. subject to conclusion (ii) the accuracy and process used by Thiess are appropriate

c. the Dethridge meter errors are significant (-1 % to -24 %) and favour G-MW customers

d. Dethridge meter errors are caused by a range of factors many of which cannot be controlled or influenced by G-MW. The REVS tests clearly showed that the errors increased with the increase in the clearance between the drum and the emplacement (Test 2 at each site)

e. the G-MW MagFlow meters tested measure accuracies between -2.3 % and +3.3 % which is within the desired level of accuracy

f. the MagFlow meter installed by a landowner on his property under recorded by about 10 %

g. the FlumeGate™ meters fitted with the new software and tested by Thiess produced accuracies within ± 3.5 % which is within the required level of accuracy.

ii) The Thiess test and analysis methodology associated with their portable field test unit (REVS) is sound for testing meters using constant or near constant flow. It is suggested that in future:

a. the leakage from the pondage test be measured over night and used to adjust the results

b. where possible the REVS data logger record and the analysis be based on volume delivered rather than flow rate (this will allow variable flows to be analysed with minimal error)

iii) The Thiess field testing was based on a small sample which may have been biased due to the ease of access or the maintenance regime of the G-MW Area Manager operating the meters. If the Dethridge meter is to be used in the longer term, or if the extent of measurement error is to be better quantified, it would therefore be appropriate to test a larger random sample of Dethridge meters in each of the Irrigation Areas.. For the same reason further testing of FlumeGate™ meters would also be appropriate.

iv) Some of the Thiess field tests showed significant variation in results and should have been repeated so that they could be verified. Future testing should be designed to better suit the proposed forensic analysis by, for example, holding all but one variable constant and conducting repeated tests

Meeting National Standards

v) There are a significant number of factors which will lead to it being difficult, time consuming and costly to bring the Dethridge meter to a standard such that it will meet the proposed National Metering Standards

Future of the Dethridge Meter for G-MW

vi) Most other eastern State Water Providers, have decided not to use the Dethridge meter in the longer term most having short term replacement program to remove Dethridge meters from their supply systems

vii) The opportunity to obtain Australian Government funding for meter upgrading will be increased if a meter other than the Dethridge meter is used

viii) Government funding under the NWI or the National Water Plan for meter upgrading are likely to be short lived. If G-MW decides not to continue with the Dethridge meter it should consider strategically what are the best steps to take to secure some of this funding

ix) The MagFlow meter should be the easiest meter for which the manufacture can gain Pattern Approval however because the accuracy of the meter will be impacted by the pit design Pattern approval may need to be obtained for the combination of the two.

KEY FINDINGS AND RECOMMENDATIONS

A. The following key findings should be noted:

A1. The results in the Thiess report on in-situ testing of meters are generally as expected with the Dethridge meter significantly under recording by an average of 10 % based on the small sample

A2. Based on current knowledge, the Dethridge meter is unlikely to meet the proposed requirements of the National Metering Standard

A3. Australian Government funding is unlikely to be available to assist with upgrading Dethridge meters to meet the new National Metering Standard

A4. Most irrigation water providers in Australia are not planning on using Dethridge meters in the longer term

A5. The small sample Doppler type meters tested did not perform well and the MagFlow and FlumeGate™ meters performed well as part of these tests. The latter two meters met the proposed National Standards for accuracy however A larger sample size of each of the meters is however required to verify this conclusion

B. It is recommended that:

B1. further in-situ field testing be undertaken to verify the accuracy of a broader sample of Dethridge meters in various G-MW Irrigation Areas

B2. further in-situ field testing be undertaken to verify the accuracy of FlumeGate™ meters under a normal maintenance regime

B3. future test methodology and analysis be modified and undertaken as indicted in this report

B4. G-MW not pursue the long term use of the Dethridge meter unless the requirements of the National Metering standards are relaxed

B5. G-MW consider strategically what are the best steps to take to secure funding for its meter upgrade/replacement program.

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Acknowledgements

This report has been prepared by Hydro Environmental and is based on data provided by Goulburn-Murray Water and Thiess Services.

The authors thank Ross Plunkett and Bill Heslop of Goulburn-Murray Water and Leon Tepper and Nurullah Ozbey of Thiess Services for their assistance in providing data and explanations as required.

1. Project Objectives

Hydro Environmental has been engaged by Goulburn-Murray Water (G-MW) to:

1. review and understand the implications of the Thiess Services Report titled *"Insitu Flow Verification Report on Irrigation Structures - Goulburn Murray Water"*
2. provide recommendations based on conclusions drawn from the Thiess Services Report
3. gain an understanding of Water Provider Industry's perspective on the future metering and the future of the Dethridge meter
4. provide recommendations regarding the future use of the Dethridge meter by G-MW.

In preparing this report Hydro Environmental has referred to other testing of the Dethridge meter as well as other irrigation water meters. Consequently the report also includes some discussion on the performance of meters other than the Dethridge meter. These meters include the FlumeGate™ and Magnetic flow meters and their respective capabilities of complying with the proposed National Metering Standards.

2. Background

2.1. In-situ Field Testing of Irrigation Water Flow Meters

Goulburn-Murray Water (G-MW) has traditionally used Dethridge meters to control and record the volume of water delivered to its customers. For many years there have been concerns over functionality of these meters and how they will meet the future needs of the irrigation industry with its increased emphasis on improved water resources management and the associated need for accurate measurement.

With the change in water availability and mobility, G-MW is also embarking upon a supply system modernisation / rationalisation program. This reconfiguration program may lead to global supply system upgrading. This upgrading may include customer meter replacement or rationalisation whereby the number of customer supply points is significantly reduced.

The Australian Government's focus on the need for improved water management, together with the pending introduction of a National Meteorological and Technical requirements for non urban water meters have also lead G-MW to question whether the Dethridge meter will meet its metering requirements in the foreseeable future. These proposed changes have lead to the need for G-MW to question whether it should continue to install Dethridge meters as its standard meter for measuring the volume of water delivered to its irrigation customers.

Utility Services, a consortium of water industry services providers, has developed a portable meter to enable field testing of in-situ irrigation water flow meters. Thiess Services used this portable meter to test 12 Dethridge meters and 16 other G-MW meters for in-situ accuracy.

2.2. G-MW Irrigation Water Measurement Meters

G-MW has some 21,660 irrigation supply points within its irrigation Districts. Approximately 92% of these customer supply points are metered with 91% of the meters being Dethridge meters. **Table 1** shows the approximate distribution of the various types of meters supplying irrigation water across the Irrigation Areas of G-MW. The closed conduit meters used for metered diversions directly from streams have not been included in these numbers.

Table 1: Distribution of Meter types across G-MW

District	Dethridge	MagFlow	Ultrasonic	FlumeGate™	Other meters
Murray Valley	2,723	14	5	0	318
Shepparton	2,160	43	1	0	9
Central Goulburn	5,003	74	22	131	118
Rochester/Campaspe	2,233	34	15	0	50
Pyramid Boort	2,205	11	3	1	36
Torrumbarry	3,573	57	5	0	504
Pumped Districts	270	257	0	0	172
Total	**18,167**	**490**	**51**	**132**	**1,207**

ANCID 2005/2006 Benchmarking Report and G-MW Assets Register

2.3. National Water Initiative and National Measurement Regulations

On the 25 June 2004 the Council of Australian Governments (COAG) approved and signed the *Intergovernmental Agreement on the National Water Initiative* (NWI) with the aim of ensuring the productivity and efficiency of Australia's water use is continually improved into the future. In signing this agreement the Parties agreed to in the first 5 years of the Agreement develop:

i) a national meter specification;
ii) national meter standards specifying the installation of meters in conjunction with the meter specification; and
iii) national standards for ancillary data collection systems associated with meters.

Trade measurement in Australia is controlled by complementary Commonwealth and State laws. The Commonwealth law is the National Measurement Act and the State and Territory law is the Uniform Trade Measurement Legislation (UTML). Although the Commonwealth has constitutional responsibility for weights and measures, it has not enacted trade measurement legislation. Currently this responsibility remains with the State and Territory governments through their respective UTML.

The objectives of the National Measurement Act are to establish an Australian national system of measurement based on the International System of Units (SI units) and standards of measurement of physical quantities, to provide for the uniform use of those units and standards of measurement throughout Australia, and to co-ordinate the operation of the national system of measurement.

The national standard covers the requirements for Pattern, or type, approval and initial verification of production units, prior to them being placed into service.

At the present time, section VA of the National Measurement covers electricity, water and gas meters but, because the necessary infrastructure was not in place when this section VA was added to the Act, Regulation 87 was added to exempt electricity, water and gas meters from the requirements of the act in the short term. As the infrastructure is put in place, this exemption will be progressively lifted. On July 1, 2004 the exemption for small water meters (urban) was lifted.

For irrigation meters the first step is to develop a Standard with which these meters must comply. The next step is for meters to be approved to that standard (i.e. Pattern Approval must be obtained). When this is completed steps can be taken to lift the exemption for irrigation meters under National Measurement Act. From that point in time forward it will be an offence under the National Measurement Act to use a meter for trade if it has not been Pattern Approved and verified. Each meter must be verified to confirm that it functions in accordance with the approved pattern and operates within the maximum permissible errors. At the time of the lifting of the exemption to the National Measurement Act; all installed meters will remain exempt until such time as they are replaced or required substantial maintenance. A definition of "substantial maintenance" has not been developed to date.

The production of these metering standards and specifications is well advanced with the documents expected to be finalised by the end of 2007. The securing of pattern approval and verification of particular meters to comply with the National Measurement Regulations is expected to take up to a further two years with the exemption expected to be lifted in about 2010.

The Australian Government National Measurement Institute's publications titled "*Meteorological and Technical Requirements for Meters Intended for Metering of Non –Urban Water in Open Channels and partially filled Pipes (NMI M 10B-1)"* and *"Meteorological and Technical Requirements for Meters Intended for Metering of Non –Urban Water in Full Flowing Pipes (NMI M 10A-1)",* which have been prepared in close consultation with the water providers and meter manufacturer industries, are available in draft form and are expected to be finalised shortly.

In these draft documents any meters used for billing purposes should have an accuracy range of ± 2.5% during the initial verification (laboratory) and ± 5% for further field testing. To comply with the requirements of these guidelines, the meters must, amongst other things:

- reliably and consistently measure within the limits specified above
- be tamper proof
- meet Occupation Health and Safety standards
- be durable in at least one of the three environmental classes specified
- be corrosion proof
- be ultraviolet light resistant
- performance must not be temperature dependent
- be fail safe and retain data
- only be installed in the manner for which they have Pattern approval
- operate within its Pattern approved operating range.

Under the current arrangements the Department of Consumer Affairs Victoria (CAV) administers the Trade Measurements Act and Fair Trading Act in Victoria. Under the current legislative and regulatory arrangement, once the Standards and Technical Guidelines have been developed and Patterns registered at a National level with the Australian Government National Measurement Institute, it will be the responsibility of CAV to enforce the Pattern requirements of each meter at a State level in Victoria under operating conditions. However it is understood that CoAG has recommended that responsibility for all National Trade Measurement Legislation be transferred to the Australian Government by 2010.

2.4. National Water Plan

In conjunction with the NWI, the Australian Government's "National Plan for Water Security" (2007) has been developed which will look at modernising both farm and delivery system irrigation infrastructure in the Murray-Darling Basin by adopting *"more water meters to improve measurement"*. All States apart from Victoria have agreed to the Plan and once the Plan is agreed by all States the Australian Government is expected to provide $125 million to up-grade bulk off-takes and $225 million to upgrade customer supply points to meet national metering standards. These funds will facilitate irrigation water providers such as G-MW to upgrade their meters to meet the new National standards.

3. Methodology

To achieve the four key project objectives included in Section 1, the following methodology was applied by Hydro Environmental:

i) Review Thiess Services' (March 2007) report titled "Insitu Flow Verification Report on Irrigation Structures - Goulburn Murray Water", and specifically the methodology followed to undertake the verification

ii) Review additional reports relevant to metering accuracy and the metering accuracy of the Dethridge meter

iii) Review and understand the methodology followed by Thiess Services to undertake the metering accuracy analysis including the Uncertainty Analysis

iv) If appropriate, provide recommendations regarding the methodology to undertake the in-situ verification of metering accuracy and analysis

v) Analyse the results included in the Thiess Services Report and draw conclusions, where possible

vi) Consult with key stakeholders in the water metering industry, such as rural water authorities, Manly Hydraulics Laboratory, Department of Environment and Water Resources and National Measurement Institute to gain an understanding of their perspective on the future metering for the irrigation industry and the future of the Dethridge meter

vii) Briefly review the performance of meters other than the Dethridge meter, including meters such as FlumeGate™, MagFlow and Doppler meters, and their respective capabilities of complying with the national metering standards

viii) Discuss the suitability of alternative meters

ix) Prepare a report and recommendations regarding the future use of the Dethridge meter by G-MW.

4. Analysis and Discussion

4.1. Error Convention

Throughout this report a positive error (+) means the meter over records (i.e. delivers less water than is shown on its display and a negative error (-) means the meter under records (i.e. the customer receives more water than is recorded).

4.2. Meter Types

There are four generic types of meter used to measure irrigation water supplies in Australia. A general description of these is as follows.

4.2.1. Dethridge Meter

The Dethridge meter (DMO) 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. Up until recently the Dethridge meter has had widespread use with over 40,000 meters installed throughout Australia when they were being used by all major providers of irrigation water.

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 design having an upstream gate with which to control flow and flared downstream sidewalls to minimise downstream impedances to flow.

The Dethridge meter measures and records the volume of water delivered reasonably accurate in the laboratory provided:

- clearances and settings of the wheel relative to the concrete emplacement are within tolerance
- the upstream and downstream water levels are within acceptable limits
- flow rates are limited to between 3 ML/d and 10 ML/d
- water is not allowed to jet under the upstream control gate into the vanes on the wheel.

When G-MW channel water levels fluctuate significantly, or the flow rate through the meter is outside the range 3 to 10 ML/d, measurement accuracy decreases. Additionally, if the Dethridge meter, and in particular the 8 finned drum, is incorrectly installed, or the bearings wear such that design clearances are not maintained, serious inaccuracies can result. (http://www.ancid.org.au/ktf/, May, 2007).

There are three models of the Dethridge meter used by G-MW with each having a different preferred flow, namely:

i)	Small Dethridge meter	1.6 ML to 5 ML
ii)	Standard Dethridge meter	3 ML to 10 ML
iii)	Dethridge-Long meter	3 ML to 20 ML.

Each meter is designed to operate with 75 mm of head loss at its maximum flow rate.

4.2.2. Magnetic Flow Meter

The Magnetic Flow meter is a volumetric flow meter based on Faraday's Law of Magnetic Induction. As water flows through the pipe it acts as a conductor, inducing a voltage which is proportional to the average flow velocity, the higher the flow rate, the higher the voltage (http://www.tycoflowcontrol.com.au, May, 2007). A variety of Magnetic Flow meters exist within Australia and are becoming a cost effective good alternative replacement to Dethridge meters.

Over 2,200 Magnetic Flow meters have been in use across Australia by Irrigation Water Providers since the turn of the century and are generally used for the metering of the supply of irrigation water (http://www.ancid.org.au/ktf/, May, 2007). They are available in flanged, end of pipe and sandwich (flangeless) design and may be powered by solar panels.

The benefits of these in-pipe meters are that they demonstrate a high degree of accuracy (< ± 0.5%), feature no moving parts, increase command due to reduced head loss, have a wider flow range (0.5 ML/day to 300 ML/day using different diameter meters bodies), have little Occupational Health and Safety (OH&S) risk and reduce maintenance costs compared to the Dethridge meter. Best accuracies are achieved when velocities are greater than 1 m/s.

Measurement accuracy can be affected if manufacturer's specifications are not followed during installation and calibration, or if silt deposits in the pipe or meter housing. However, the potential for these errors to occur are being reduced as new designs are developed.

There are many configuration of the MagFlow meter, however the version favoured by G-MW is the version installed on the end of a either a 450 mm diameter pipe (0.5-14 ML/d) or 600 mm diameter pipe (1-18 ML/d) with an entry and exit pit on the pipe. G-MW refer to the 450mm design as "MANN outlet". The control gate can be installed at either the upstream or downstream pit but the pipe must remain full at all times if accurate measurement is to occur.

4.2.3. Doppler Flow Meter

The Doppler Flow meter was first used by irrigation water providers at pump stations in 1987. Over 450 meters have since been installed across Australia and are used at pumping stations, for monitoring and more recently for irrigation supply to farms (http://www.ancid.org.au/ktf/, May, 2007).

The Doppler Flow meter (or Ultrasonic meter) is also a volumetric flow meter which measures the instantaneous and total water flow in channels and pipelines. The basic principle of operation employs the frequency shift (Doppler Effect) of an ultrasonic signal when it is reflected by suspended particles in motion (http://www.omega.com, May, 2007). In G-MW's installations these meters are installed in-pipe, however, clamp-on Doppler Flow meters are also available. Doppler Flow meters have an extremely wide flow range (0.5 ML/day to 6,000 ML/day), are robust and require minimal maintenance. They can measure bi-directional flow and are easy to install. As with the Magnetic Flow meter, the Doppler Flow meter does not pose an OH&S risk. They may be powered by solar panels. Their accuracy is subject to design and the effectiveness of G-MW's installation and in-situ field calibration process.

The accuracy of the Doppler Flow meter can be affected should power supply not be maintained, electronic components suffer damage (e.g. lighting damage), or the meter is not installed or calibrated to manufacturer's specifications.

4.2.4. FlumeGate™ Meter

FlumeGate™ meters are a control and measuring device and comprise a downward pivoting radial gate with sensors to measure the upstream, water level, the down stream water level and the position of the gate. A mathematical algorithm then uses each of these position measurements to calculate the flow rate thence the volume passed. The standard FlumeGate™ size adopted by G-MW is the 1050-674 which is 1050 mm wide. To measure accurately there must be at least a 40 mm drop in water level over the gate. Flows able to be passed and measured accurately are in the range 3 ML to 20 ML.

4.3. In-situ Verification Meter Accuracy Test

Thiess Services was engaged by G-MW to undertake field verification of the accuracy of various water measuring devices, including:

i) 12 large Dethridge meters (all in the Central Goulburn Area)

ii) 7 FlumeGate™ meters (all in the Central Goulburn Area)

iii) 7 MagFlow meter

iv) 2 Doppler meters.

4.3.1. REVS Testing Unit

Thiess Services undertook in-situ verification of the accuracy of the abovementioned meters using a portable test unit referred to as “REVS”, an acronym from Remote Electronic Verification System. The REVS unit is a trailer mounted mobile hydraulic metering device, that was designed by Thiess Services and built by Utility Services specifically for in-situ verification of the accuracy of various flow metering devices used in the rural water industry.

Water is pumped to a header tank on the trailer mounted REVS unit, where it is gravity fed through one of two electromagnetic flow meters before being discharged either back to the supply channel or downstream to the customer. Software is used to alter the discharge rate through the variable speed pumps to maintain the water level at a near constant level downstream of the meters being tested. A photo showing the REVS unit in operation is included as **Figure 1**.

Figure 1: REVS Testing Unit in operation

4.3.2. REVS Testing Unit Accuracy Verification and Calibration

Prior to undertaking in-situ analyses, the REVS unit was calibrated and verified for accuracy at the Manly Hydraulics Laboratory. The REVS unit includes two electromagnetic flow meters:

i) 150 mm diameter electromagnetic flow meter (flow range 0 – 5.5 ML/day)

ii) 300 mm diameter electromagnetic flow meter (flow range 5 – 16 ML/day).

The Manly Hydraulics calibration report indicated that no calibration was required for the 150 mm diameter electromagnetic flow meter, and recommended a flow dependent calibration factor be applied to the 300 mm diameter electromagnetic flow meter. In accordance with the calibration report, Manly Hydraulics verified that these meters were within an accuracy of better that ± 1 %.

In addition to verification of accuracy of the REVS unit at the Manly Hydraulics Laboratory, in-situ verification of the accuracy of the Goulburn Weir flow measuring site was undertaken. The Goulburn weir site is the Rubicon / G-MW meter testing facility and is serviced by two certified master meters (one 450mm and one 150 mm). Comparison between the REVS unit and the Goulburn Weir certified electromagnetic meter showed that all four test results were within ± 1% of each other, giving additional confidence in the accuracy of the REVS unit.

4.3.3. In-situ Accuracy Verification Methodology

A critique of the methodology to undertake in-situ verification of the accuracy of various flow metering devices tested for G-MW is presented in **Table 2**. The table outlines the procedure undertaken by Thiess, the precautions undertaken by Thiess to minimize/account for the error and a qualitative critique by Hydro Environmental of the process used by Thiess.

Generally the methodology applied by Thiess was considered to be satisfactory, however, a number of specific procedures could have been improved. These included:

i) Using logged MagFlow meter volume data (approximately 1 min intervals) rather than the logged flow rate as used by Thiess, to calculate volume measured by the REVS unit during testing of MagFlow and Doppler meters. Whilst the methodology applied by Thiess is correct and there is no difference in volumes calculated via the two methodologies, it is recommended that a standard methodology of using logged volume data rather than flow rates to avoid confusion and error when calculating volumes measured by other meters, such as FlumeGate™ meters particularly where flows are variable within the calculation time interval

ii) Using logged FlumeGate™ volume data (approximately 1 min intervals) to calculate volume measured by the FlumeGate™ meter during the testing period rather than the logged flow rate to calculate volume as used by Thiess. FlumeGate™ volume does not equal FlumeGate™ flow rate multiplied interval period. FlumeGate™ volume is logged at coarser intervals than flow is logged in the REVS unit. It is therefore recommended that actual (not interpolated) FlumeGate™ logged volume data is used, which are spread over at least an hour long duration with consistent flows

iii) Using logged MagFlow meter and Doppler meter flow volume (1 min intervals) rather than logged flow rate as used by Thiess to calculate volume. This may be incorrect if flow rate varies during the polling interval, it is therefore recommended that logged volume data used.

iv) FlumeGate™ volume data is provided by G-MW to three decimal places (round to the kilolitre), which can result in an error of 0.40 % for an hour long test at a flow rate of 3 ML/day. It is recommended that FlumeGate™ data be provided to six decimal places (round to the litre).

4.3.4. Uncertainty in Results

All measurements have errors even after all known calibrations and corrections have been applied. Uncertainty is a measure of the range within which the true value of the result may be expected

The uncertainty of the results from the REVS for this series of tests undertaken and analysed by Thiess were calculated in accordance with the International Organisation of Standardisation (ISO) and, as published by the associated ISO Guideline titled "Guide to the Expression of Uncertainty in Measurement (GUM)". GUM is a key document used by National Measurement Institutes as the basis of evaluating the uncertainty in the output of a REVS and is the same as that used by the Manly Hydraulics Laboratory when determining their uncertainty in measurement.

The uncertainty of the REVS measurement data is generally in the range of ± 0.5-0.6 % of the results reported with the higher uncertainties being associated with the lower volume tests and/ or the greater error range in the measurement of the water level downstream of the meter being tested.

Table 2: In-situ Verification of Flow Meter Accuracy Methodology Critique

ID	Thiess Services		Hydro Environmental
	Procedure	Error Minimisation	Critique
	Potential Minor Volumetric Errors		
1.	• Pooling water downstream of the meter being tested to create a sump for pumping	• Lining the pooled area where possible, and wetting up prior to test where lining not possible	• Satisfactory
2.	• Estimating difference in pool volume	• Measuring pool dimensions • Using evaporation data • Measuring pool depth prior to and following test	• Satisfactory
3.	• Estimating difference in REVS unit header tank volume	• Measuring tank dimensions • Measuring tank depth prior to and following test	• Satisfactory
4.	• Accounting for evaporation from pool downstream of the meter being tested	• Calculating evaporation losses and determining losses to be insignificant	• Satisfactory
5.	• Accounting for seepage from pool downstream of the meter being tested	• Lining with impervious membrane, where possible • Otherwise, filled pool and let sit overnight, and observed no drop in pool depth • Assumed seepage losses to be negligible	• Satisfactory for this test but could be improved by the seepage rates being measured before the test could be used to make this more accurate • In the future the length of channel directly downstream of meter should be setup for in-situ testing and seepage rate determined before Thiess is involved (i.e. clay lined channel with downstream bank and gate to pool downstream of channel)
	Test Period		
6.	• Testing period	• Testing period of 1 hour	• Satisfactory, provided 1 hour of coincident data is used. This may require mare than 1 hour of testing
7.	• Collecting data during period of near constant flow rates	• Commencing test once a near constant flow rate is achieved and maintaining this flow rate for the test duration	• Satisfactory
8.	• Verifying accuracy for a range of flow rates	• Undertaking tests for flow rates of approximately 3, 7 & 12 ML/day	• Satisfactory

Cont.

ID	Thiess Services		Hydro Environmental
	Procedure	**Error Minimisation**	**Critique**
9.	• Multiple time frame analysis within the test period	• Determined error for each timeframe and compared the differences with the calculated error uncertainty	• Satisfactory
	Time Synchronisation		
10.	• Time synchronisation for testing Dethridge, MagFlow and Doppler meters	• A single data logger was used to log data from the REVS unit and meter being tested	• Satisfactory
11.	• Time synchronisation for testing of FlumeGate™ meters	• REVS unit data logger was synchronised with field FlumeGate™ meter time	• Satisfactory • Rubicon indicated that there may be a time lag of up to 1 second • Thiess field staff indicated that at times the time lag appeared to be up to 4 – 5 seconds
	REVS unit Volume Measurement		
12.	• Calculating volume measured by the REVS unit during testing of MagFlow and Doppler meters	• Using logged MagFlow meter flow rate data (approximately 1 min intervals) to calculate volume • Interpolating calculated volume, where required	• Satisfactory for this test but could be improved • Volume may be incorrect if flow rate varies during the polling interval • Logged volume data should be used
13.	• Calculating volume measured by the REVS unit during testing of Dethridge and FlumeGate™ meters	• Using logged MagFlow meter volume data (approximately 1 min intervals) • Interpolating logged volume data, where required	• Satisfactory
	Dethridge Meter Volume Measurement		
14.	• Calculating volume measured by Dethridge meters during tests	• Dividing a Dethridge meter revolution into 12 pulses • Using logging pulses to calculate flow rate	• Satisfactory

Cont.

<table>
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<tr><th>Procedure</th><th>Error Minimisation</th><th>Critique</th></tr>
<tr><td></td><td colspan="3">FlumeGate™ Meter Volume Measurement</td></tr>
<tr><td>15.</td><td>• Calculating volume measured by FlumeGate™ meters during tests</td><td>• Using logged FlumeGate™ meter flow rate data (approximately 1 min intervals) to calculate volume
• Interpolating calculated volume, where required</td><td>• Not satisfactory
• FlumeGate™ volume ≠ FlumeGate™ flow rate x interval period
• FlumeGate™ volume is logged at coarser intervals than volume is logged in the REVS unit. It is therefore recommended that actual (not interpolated) FlumeGate™ logged volume data is used, which are spread over at least an hour long duration with consistent flows</td></tr>
<tr><td>16.</td><td>• Provision of FlumeGate™ data by G-MW</td><td>• Data was provided to three decimal places (rounded to the kilolitre)</td><td>• Not satisfactory
• This can result in a volume error of 0.40 % for an hour long test at a flow rate of 3 ML/day
• Better to provide data to six decimal places (rounded to the litre)</td></tr>
<tr><td>17.</td><td>• FlumeGate™ logging field data</td><td>• May be a time lag of up to one second</td><td>• Satisfactory
• Negligible error</td></tr>
<tr><td></td><td colspan="3">MagFlow and Doppler Meter Volume Measurement</td></tr>
<tr><td>18.</td><td>• Calculating volume measured by MagFlow and Doppler meters during tests</td><td>• Using logged MagFlow and Doppler meter flow rate data (1 min intervals) to calculate volume</td><td>• Satisfactory for this test but could be improved
• Volume may be incorrect if flow rate varies during the polling interval
• Logged volume data should be used</td></tr>
<tr><td></td><td colspan="3">Calculation Process Generally</td></tr>
<tr><td>19.</td><td>• Calculation of Uncertainty was confined to REVS</td><td>• uncertainty in the recorded data for the meter being tested than in REVS may be expected</td><td>• It would have been useful to extend this analysis to include the meter being tested</td></tr>
<tr><td>20.</td><td>• Calculating the error over different time intervals</td><td>• Using the logged flows calculating the volume difference between the REVS and the meter being tested for three different time intervals and checking the variation against the uncertainty</td><td>• Satisfactory for this test where flows are generally at a near constant rate
• In future should use volumes recorded and a period of at least 1 hour of data. Other intervals of time can be used as a check against the uncertainty expected.</td></tr>
</table>

4.4. In-situ Verification of Metering Accuracy Test Results

There were only a limited number of tests undertaken namely 45 Dethridge meter, 22 MagFlow meter, 27 FlumeGate™ and 6 Doppler meter tests. Due to limited non repetitive nature of the data set it has been difficult to undertake valid statistical analyses. Further testing is therefore recommended to verify the meter accuracy conclusions in this report. Based on the available data, where possible, conclusions have been drawn from the REVS results.

The limited data set and a lack of repetition in testing has made it difficult to exclude results that appear to be outliers which are caused by such things as unexplained instrument or human error. As a result, none of the data collected with the REVS has been excluded from the analyses undertaken.

4.4.1. Dethridge Meter Results

Testing of the Dethridge meters using REVS was generally undertaken by three tests on each meter, which included:

i) Test 1 - As found clearance, as measured at the nominated flow conditions

ii) Test 2 - An approximate clearance of 15 mm, at the nominated flow conditions

iii) Test 3 - Wheel reset to achieve as close as possible to the emplacement bottom (i.e. the 6 mm standard clearance) and undertaking any required maintenance (i.e. bearing replacement).

The flow rate for each site was about the same for each test on a particular site. Flow rates tested varied from the allowable minimum for the Dethridge meter of 3 ML/d up to 11 ML/d.
The results of the REVS Dethridge meter tests are tabulated in **Appendix B** and presented as graphs in **Figure 2** and **Figure 3**. The graphs show the Dethridge meter accuracy (%) (Dethridge meter volume / REVS volume) for various flow rates, and indicate the wheel clearance and gate opening range for each test. It is noted from **Figure 2** and **Figure 3** that there is a large scatter within the results, which highlights the highly variable nature of the Dethridge meter accuracy.

The results also exhibit a number of inconsistencies with changes in clearance not being reflected by expected corresponding changes in error. This detail can be seen in **Table B1** of **Appendix B** and is highlighted in **Table 3**.

Table 3: Consistency of Dethridge Meter Results

Outlet Number	Clearance	Error	Comment on Inconsistency
RN 283	11.0 mm	-17.5%	Increase in clearance does not lead to an increase in error.
	13.6 mm	-17.2%	
	14.0 mm	-20.2%	
RN 311	6.0 mm	-9.5%	Increase in clearance does not lead to an increase in error.
	7.5 mm	-8.4%	
	14.0 mm	-11.2%	
RN 312	8.0 mm	-17.3%	Different errors for the same clearance and disproportionate increase in error compared to increase in clearances.
	8.0 mm	-20.7%	
	16.0 mm	-22.4%	
RN 890	6 mm	-10.3%	Disproportionate increase in error compared to increase in clearances
	7 mm	-8.6%	
	12 mm	-14.6%	
RN 1049	6.5 mm	-8.2%	Disproportionate increase in error compared to increase in clearances
	7 mm	-14.2%	
	16.5 mm	-15.7%	

The results of other Dethridge meter testing as detailed in the various references in Section 7 of this report and summarised in **Table 4** Error! Reference source not found.show that high channel water levels and low flows lead to the highest errors. The magnitude of these errors is also significantly influenced by the clearance between the Dethridge meter drum and the side and base of the emplacement, the depth of water in the landowner's channel and the extent to which the Dethridge meter door is open (i.e. the velocity of flow under the door).

While there are limited data sets, the large number of variables that affect the Dethridge meter accuracy, together with the scatter and inconsistency in the data, make it difficult to undertake statistical analysis. However, the overall average results for the Dethridge meters were consistent with other findings in the industry. Some examples of corresponding findings are also shown in Error! Reference source not found.**Table 4.**

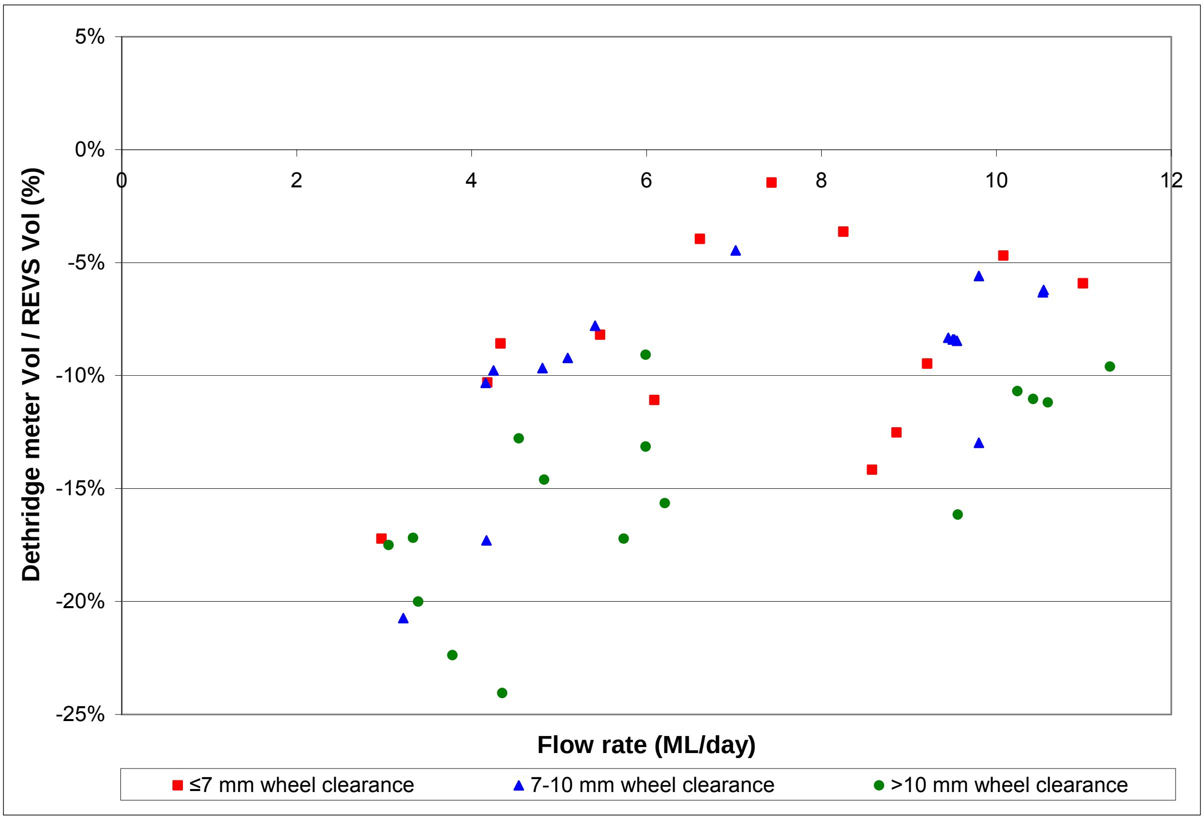

Figure 2: Dethridge Meter Accuracy Results – variable wheel clearances

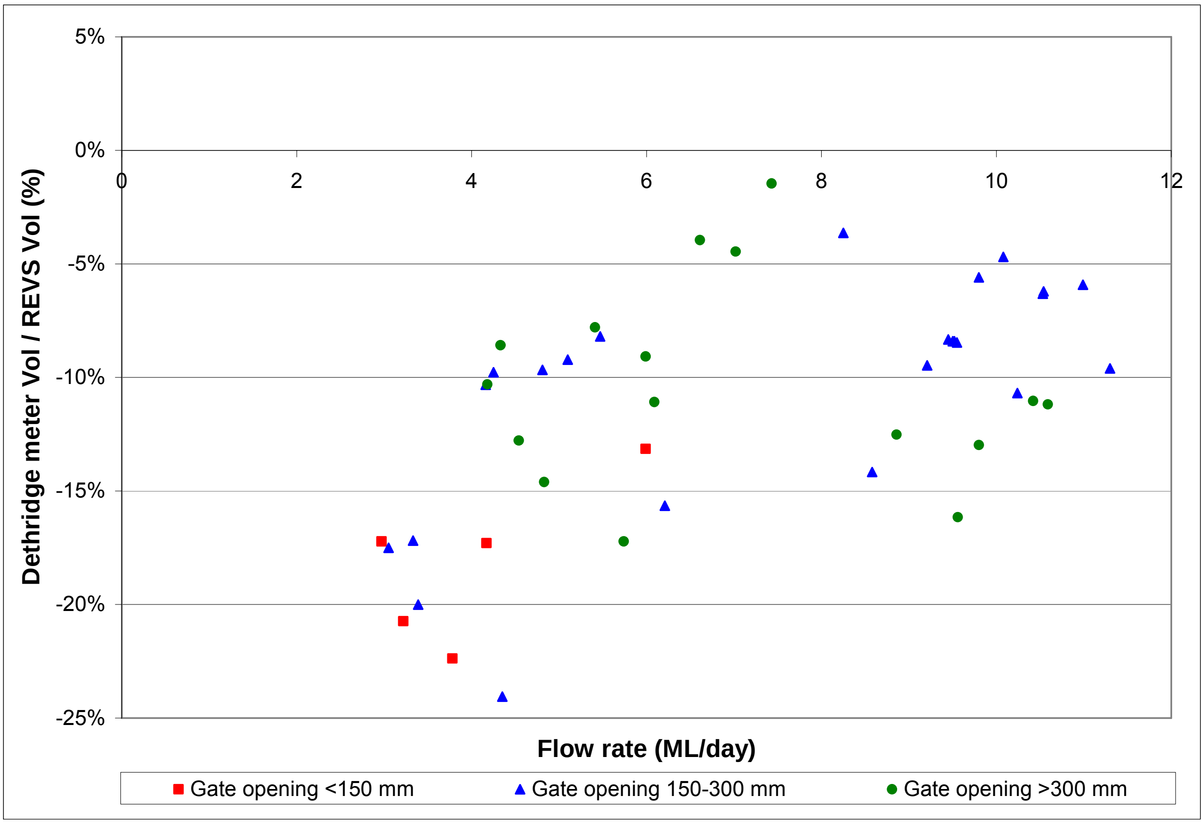

Figure 3: Dethridge Meter Accuracy Results – variable gate openings

Table 4: Other Supporting Dethridge Meter Testing

Indicative Reference Title	Section 7 reference	Specific Reference	Comment on Conclusion
G-MW - DSS Research Project - Goulburn Weir Testing	(iv)	Graphs and tables	Errors up to - 10 % for 6mm clearance and -20 % for 15 mm clearance with supply depth of 445 mm and low flows
G-MW - Dethridge Meter Error Algorithm development	(ii)	Graphs	Average error was – 5.4% based on drum clearance of 6 mm. If actual clearances are used results in error of -9.0%
RWC – Dethrideg meter testing at Werribee	(i)	Graph	Average error at 550 mm supply level is 9 % at low flows and up to 6.5% at high flows for a 6 mm drum clearances
SKM – Katandra Accuracy assessment	(xii)	Section F1.4.1 - Table 1-2	Errors in supply point volumes recorded varied from + 2% to - 30% with an average of – 11%.
Interviews with other Water Providers concerning their use of the Dethridge meter	Section 4.5 of this report and Appendix A	Appendix A	Murray Irrigation (since Nov 2007), Coleambally Irrigation, SunWater , Murrumbidgee Irrigation no longer install new Dethridge meters

An analysis comparing the difference in metering accuracy between the first and last test for each REVS test site has also been included as a graph in **Figure 4.**

Whilst the limited data set makes it difficult to undertake statistical analysis, the results graphed in **Figure 4** indicate that:

i) The first tests (as found clearance range 6mm -10.5mm) of Dethridge meters measured volume inaccuracies within a wide range of -24.1 % to -1.5 %, recording an average of -10.0 %

ii) The final tests (about 6mm) of Dethridge meters measured volume inaccuracies within a range of -17.3 % to -4.5 %, recording an average of -9.9 %

iii) Resetting the wheel clearance to the desired gap (6 mm) resulted in little improvement in the overall and average accuracy of tested Dethridge meters.

Test 2 on each of the Dethridge meters was not separately analysed because the clearances were made artificially high at around 13 mm (twice that of a correctly placed drum). The degree of under measurement for Test 2 was expected to always be greater than that of tests 1 and 3 with actual errors being up to -22%.

The range of uncertainty in these results is generally in the between ± 0.5% and ±0.6%.

Many of the results included in **Appendix B** and also shown in **Table 3** do not appear to be consistent or logical. However the accuracy of the Dethridge meter is influenced by many variables such as, upstream supply depth, depth downstream of gate and tail water depth. Many of these variables are interactive. This is demonstrated by the large variability in accuracy for changes in clear and gate opening. In the case of the Thiess tests due to the limited data set and lack of repeated tests under consistent conditions, analyses of these other variables has not been undertaken. Future testing should therefore be specifically targeted at one variable at a time to ensure the best analysis can occur.

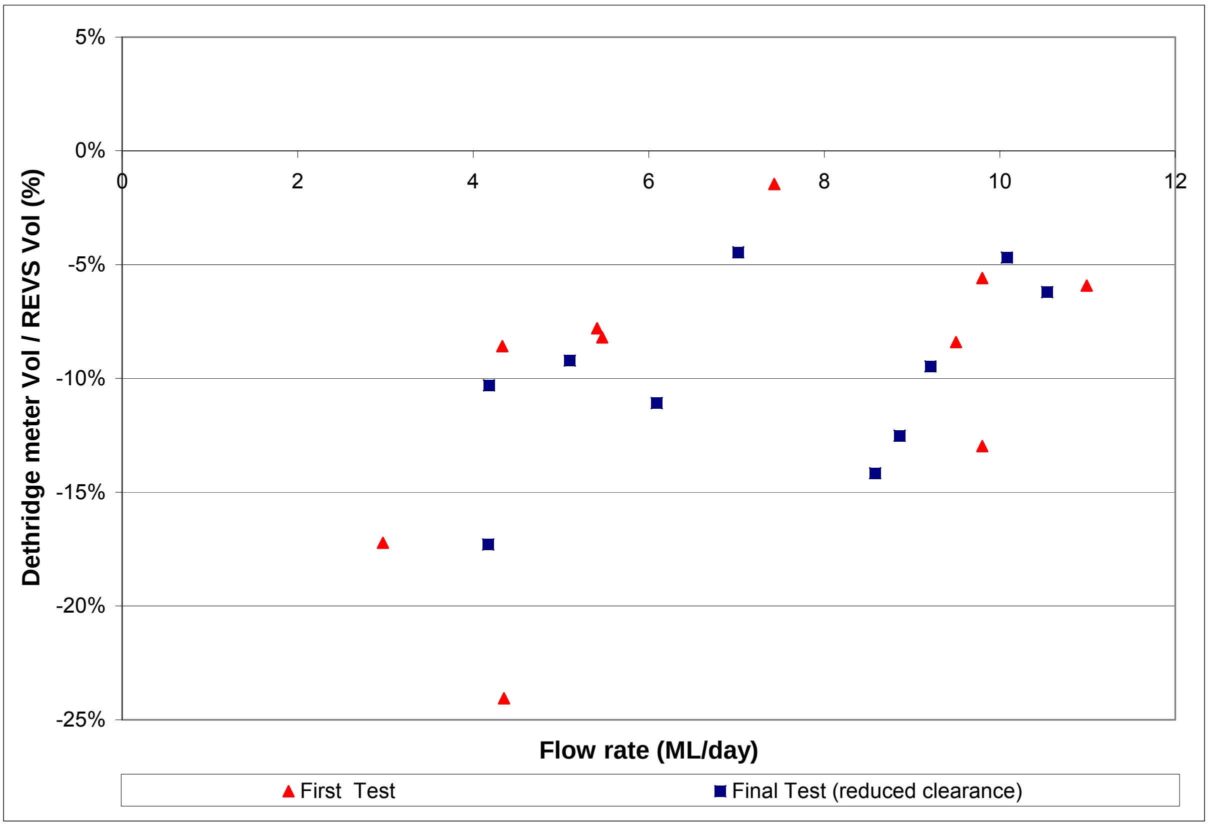

Figure 4: Comparison of Dethridge Meter Accuracy Results for First and Final Tests

REVS Conclusion

The findings from the REVS testing and other referenced testing of the Dethridge meter include:

i) All Dethridge meters under measured the volume of water delivered during the test period

ii) All G-MW Dethridge meters tested measured volume inaccuracies within a range of -24.1 % to -1.5 %, with an average of -10% which exceeds the tolerances of ± 5.0 % by a large amount

iii) Dethridge meters generally under measured more at lower flow rates

iv) There does not appear to be a significant correlation between wheel clearance and Dethridge meter inaccuracy from the REVS data due to other influences

v) Smaller gate openings result in decreased accuracy of the Dethridge meter. The extent of this inaccuracy is largely affected by the flow velocity, which is driven by the difference between the water level upstream and downstream of the gate

vi) Larger data sets with repeat testing and only one variable changed each time should be undertaken if more accurate error specification and quantification of error influences is wanted.

Other Conclusions

1. It is also understood that the Dethridge meters tested were partly selected on the basis of accessibility. Anecdotal evidence suggests that sites with good accessibility tend to have a higher degree of regular maintenance and therefore may not be representative of the G-MW general Dethridge meter population.

2. Maintenance regimes may also be different between G-MW operations Areas. It is noted that all of the Dethridge meters tested are located in the Central Goulburn Area. It is therefore possible that the sample selected was not representative of the population, and data may be skewed toward better maintained Dethridge meter outlets.

4.4.2. FlumeGate™ Meter Results

The results for the accuracy verification of seven FlumeGate™ meters, as determined by Thiess, are tabulated in **Appendix C** and are presented as a graph in **Figure 5**.

The graph shows the FlumeGate™ meter accuracy (%) (FlumeGate™ meter volume / REVS volume) for various flow rates. Whilst the limited data set makes it difficult to undertake statistical analysis, the following conclusions have been drawn from the results:

i) The FlumeGate™ meters tested always operated under free over fall conditions with a head loss greater than 40 mm and therefore are in the flow conditions that are able to be more accurately measured

ii) FlumeGate™ meters both under and over measured volume during the test period (i.e. there did not appear to be any systematic error)

iii) All FlumeGate™ meters tested with the new software (and possibly with sensors adjusted) measured volume inaccuracies within ± 3.5 %, which is within the tolerances of ± 5.0 % proposed for field meters in the proposed National Standard

iv) FlumeGate™ meters appeared to be less accurate at lower flow rates

v) The new software installed during the test period together with any sensor adjustments undertaken at the same time significantly improved the accuracy of the FlumeGate™.

It should be noted that the FlumeGate™ meters tested had their software upgraded either during or immediately before the testing. At the same time the sensor settings may also have been adjusted to offset any naturally occurring drift. The test undertaken by Thiess may therefore not be an accurate reflection of what could be expected under the normal maintenance regime.

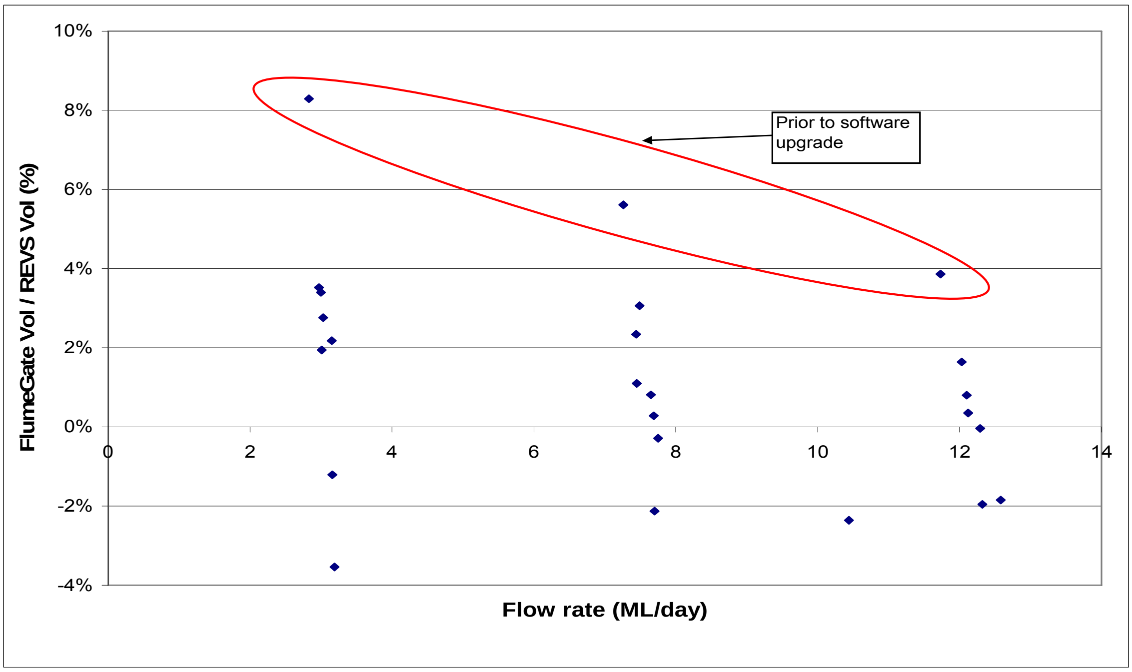

Figure 5: FlumeGate™ Meter Accuracy Results

4.4.3. MagFlow Meter Results

The results for the accuracy verification of seven MagFlow meters, as determined by Thiess, are tabulated in **Appendix D** and are presented as a graph in **Figure 6**. The graph shows the MagFlow meter accuracy (%) (MagFlow meter volume / REVS volume) for various flow rates. It should also be noted that the software and possibly some of the sensor setting were updated immediately before all but the first three tests as Site 1 (RN33). Nevertheless, whilst the limited data set makes it difficult to undertake statistical analysis, the following conclusions have been drawn from the results:

i) MagFlow meters both under and over measured volume during the test period (i.e. there did not appear to be any systematic error)

ii) All G-MW MagFlow meters installed and operated by G-MW measured volume inaccuracies within a range of - 2.3 % to + 3.27 %, which is within the tolerances of ± 5.0 % proposed for field meters in the proposed National Standard

iii) MagFlow meters appeared to be less accurate at lower flow rates

iv) The MagFlow meter installed by G-MW Customer downstream of his G-MW FlumeGate™ at RN 72 is recording significantly different volumes than the REVS and is under recording by about 10 % (range 11.58% (3 ML/d) to 9.67 % (10 ML/d)).

The test undertaken at the Goulburn Weir MagFlow meter was to test the accuracy of the REVS against the NATA tested master meter. The results of the tests showed the REVS unit to be accurate but they have not been included in the analysis with the other results.

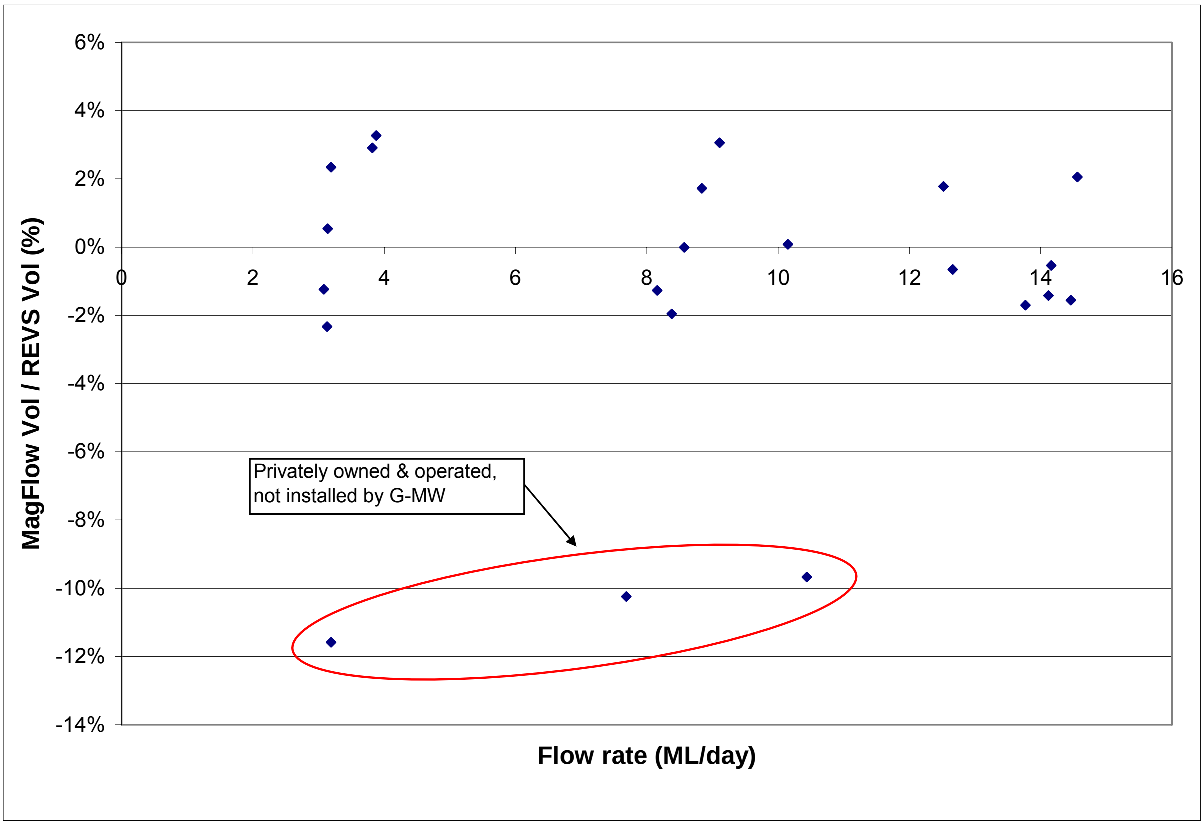

Figure 6: MagFlow Meter Accuracy Results

4.4.4. Doppler Meter Results

The results for the accuracy verification of two Doppler meters installed in G-MW's configuration and field calibrated by G-MW, as determined by Thiess, are tabulated in **Appendix D** and presented as a graph in **Figure 7**. The graph shows the Doppler meter accuracy (%) (MagFlow meter volume / REVS volume) for various flow rates. The very limited data set makes it difficult to undertake statistical analysis, however, the following conclusions have been drawn from the results for the Doppler meters tested in G-MW installations and field calibrated by G-MW:

i) Doppler meters both under and over measured volume during the tests

ii) Five of the six Doppler meter tests recorded volumes outside the tolerance of ± 5.0 %, and were within a range of -11.1 % to + 22.0 %.

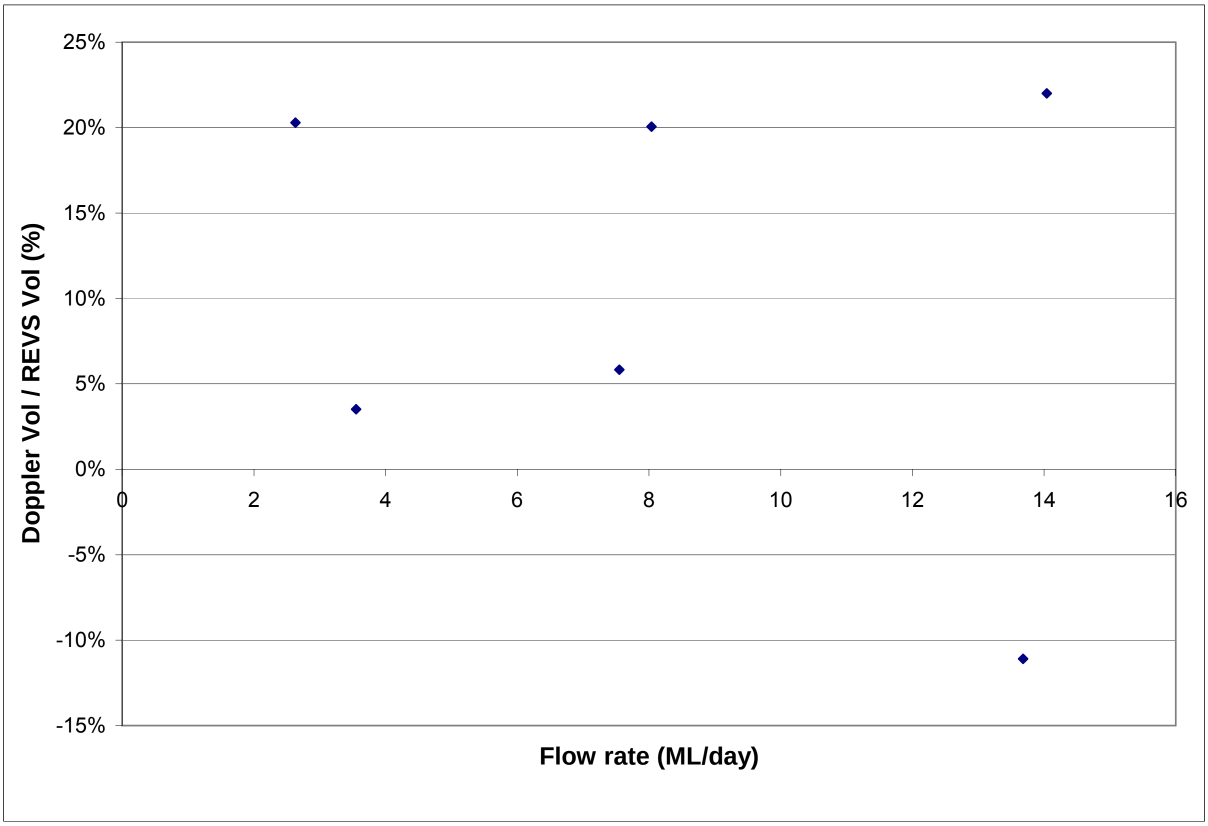

Figure 7: Doppler Meter Accuracy Results

4.4.5. Future Testing

If G-MW want more conclusive and statistically accurate results on the accuracy of the various irrigation meters it is proposed that:

i) a large more random sample be tested across all G-MW operations Areas without first adjusting sensors or wheel settings

ii) the test methodology be adjusted to include the recommendations outlined in **Table 2**

iii) test setup and data sampling be selected to better facilitate forensic analysis of the results and include repetition to enable better statistical analysis.

4.5. Factors Contributing to Dethridge Meter Measurement Error

As is demonstrated by the Thiess testing there are a significant number of factors which impact on the accuracy of the Dethridge meter and many of these factors cannot be controlled or adequately managed by G-MW without remote surveillance being installed at the site of each meter. These factors which affect the measurement accuracy of the Dethridge meter include:

i) tolerances on the drum manufacture (fin length differences, drum roundness etc.)

ii) damage to the drum or fins

iii) tolerances on the concrete emplacement manufacture

iv) damage to the downstream sill of the emplacement

v) clearances between the fins and the emplacement

vi) obstructions to the rotation of the drum

vii) amount of wear on the bearings
viii) flow rate of the water passing through the meter
ix) level and levelness of the floor of the emplacement
x) upstream water level
xi) downstream water level
xii) degree to which the door is sealed under no flow
xiii) the amount the door is opened.

The above list shows that ensuring the Dethridge meter measures accuracy at all times and under all conditions in the field is extremely difficult and requires a significant level of precision in the manufacture, installation and maintenance as well as a well planned preventative maintenance program.

4.6. Future use of Dethridge Meters by Other Water Providers

Each of the major water providers in Eastern Australia using Dethridge meters was contacted and asked how they envisaged the future of the Dethridge meter in their organisations. A summary of their responses is included in **Table 5** with more detailed information included in **Appendix A.**

In summary most irrigation water providers in Australia are no longer installing new Dethridge meters and are only maintaining existing Dethridge meters until such time as they can either secure government funding or finance replacement from customer generated revenue. As an example Murray Irrigation made a decision in August 2005 not to continue with the Dethridge meter and has not install new meters since November 2005. Other Irrigation Water Providers who no longer install any Dethridge meters include, Coleambally Irrigation, SunWater and Murrumbidgee Irrigation.

The key reasons given for not continuing with the long term use of Dethridge meters are as follows:

- lack of reliable accuracy
- anticipated inability to meet the requirements of the new National Irrigation Metering Standards
- inability to provide high discharge rates required for efficient border check irrigation
- Occupation Health and Safety concerns to their staff, customers and the community
- difficulty in gaining access along channel banks.

Replacement meters are generally MagFlow meters (most favoured), FlumeGate™ meters or Doppler meters (only one authority).

Table 5: Summary of outcome of Use of Dethridge Meters by other Water Providers

Water Provider	Indicative Number of Dethridge Meters	Replacement Meter Type	Are any new Dethridge Meters being Installed?	Reason for not Continuing to Use Dethridge Meters
Murray Irrigation (no new Dethridge meters since late 2005)	3,800	MagFlow meters; MIL has standardised on Tyco Irriflow 600	No	• Moving parts pose a potential OH&S issue with staff, customers and the public • The flow range required for rice is often 1 ML to 20 ML. These high flows cannot be accommodated by the DMO and the low flows lead to large metering inaccuracy.
Murrumbidgee Irrigation (no new Dethridge meters since mid 1990s)	1,000	Mainly Doppler meters in open channels and MagFlow on piplines	No	• Inaccuracy; difficulty in achieving desired operating conditions • OH&S • Lack of access along banks
Southern Rural Water	2,100	FlumeGates™ are being installed where TCC is being installed and MagFlows installed in piped areas	No except in subdivisions	• Inability to meet National Standards. The standard may be met in the Lab, but risk of not achieving field verification is too high • Lack of accuracy • Inability to meet high flow rates at acceptable head loses is a barrier to efficient flood irrigation • Potential OH&S issue for customers
Coleambally (no new Dethridge meters since mid 1990s)	409	Replace with either: • FlumeGate™ 1485-620 • MagFlow Tyco Irriflow 600	No	• Inaccuracy; testing indicated (18-30% inaccurate) • Control; mechanical activated gates or FlumeGate™ meters provided greater control and are more precise • Limited by flow rate (4 – 12 ML/d) compared with desired (1 - 30 ML/d) • OH&S for staff and customers
Harvey Water	650 with 70/yr being replaced	Mag Flow	Yes	• A strategy for replacing Dethridge meters in other than the areas being piped has not been developed.
SunWater	1,500	Smaller MagFlows are used (in-line meters, buried too) to match existing infrastructure	No	• Not expected to meet future standards for accuracy and Pattern Approval, • Requirements to achieve operational conditions to meet accuracy of ± 2.5% for Dethridge meter is not achievable

4.7. G-MW Dethridge Meter Replacement Cost

If the G-MW Board takes the decision to no longer use the Dethridge meter, it has some 18,100 Dethridge meters to be replaced. As a result of its channel modernisation and reconfiguration program it is expected that the number of supply points will be reduced hence the number of Dethridge meters to be replaced could be reduced. This reduction could be as high as 25 %.

The replacement cost of the Dethridge meter along with the viable alternatives is shown in Table 6. These indicative costs do not include the cost of remote surveillance or automation.

Table 6: Cost of Irrigation Water Meters

Meter Type	Cost ($/meter)*
Dethridge meter	5,500
Dethridge–Long meter	6,100
Small Dethridge meter	4,900
FlumeGate™ meter	15,000
Doppler Meter	10,500
MagFlow meter	11,000

* These costs do not include the cost of remote access to meter information or remote control of the supply point.

If all existing Dethridge meters were replaced with MagFlow meters in May 2007 the cost would be about $220 M.

G-MW gives all of its assets a condition rating with the condition rating being updated every five years. As part of this process all assets are given a condition score of between 1 and 6, where 1 is as new condition and 6 has a life of less than 1 year. **Table 7** provides a summary of the condition rating of all G-MW Dethridge meters and shows that only 30 % of the Dethridge meters have a remaining life of less than 20 years. The average weighted expected life over all G-MW Dethridge meters is 23 years and should be compared with the life of 60 years applied to new emplacements.

Table 7: Asset Condition Rating of G-MW Dethridge Meters

Asset Condition Rating	6	5	4	3	2	1	Total
Proportion of DMOs	0.2%	7.2%	22.3%	48.9%	11.1%	10.4%	100.0%
Remaining Life (years)	1	5	11	22	28	52	NR

G-MW has advised Consume Affairs Victoria that based on the age profile of its Dethridge meters the discounted Net Present Value (NPV) for replacing and maintaining G-MW's current meters is estimated to be equivalent to $64 M and the Annual Equivalent Value (AEV) of $3.8 M after allowing for the increase in price from the figure of $4,900 then to the latest estimate of $5,500 to install a new Dethridge meter.

This net present replacement cost will increase to $123 M (AEV ~$7.3 M) for replacement with Magnetic Flow meters as the Dethridge meter emplacements reach the end of their useful life and $218 M (AEV ~$13 M) should the accelerated replacement with Magnetic Flow meter occur over a 10 year period.

4.8. Australian Government Funding to Replace Dethridge Meters

If the Victorian Government agrees to sign on to the Australian Governments National Water plan Australian Government funds may be available to G-MW to assist in compliance with the new National Metering Standards. It is however anticipated that the Government is unlikely to make funds available unless the replacement meters:

i) comply with the new metering standards
ii) are accurate over the full range of flows to be encountered
iii) are suitably sized to suit the needs of current and future irrigation technology
iv) are shown to be appropriate “state of the art “ long life and sustainable technology
v) can be cost effectively maintained
vi) are cost effective in terms of capital and ongoing operation costs
vii) are **<u>not</u>** the same as those currently used, in which case the replacement cost would be seen as part of the Water Provider’s core business and hence should be replaced using customer generated funds.

Government funding under the NWI or the National Water Plan for meter upgrading is likely to be short lived. If G-MW decides not to continue with the Dethridge meter it should consider strategically what are the best steps to take to secure some of this funding.

4.9. Potential to Upgrade the Dethridge Meter

The inherent design of the Dethridge meter will always lead to it being difficult to meet the National Metering Standards, however, if G-MW decides that it will be the proponent in seeking and maintaining Pattern approval the following are changes which may be considered in trying to improve the sustainable accuracy of the meter:

i) Changing the pendant meter gearing such that it does not have a systematic error in favour of the customer. This would require a shift of about 5 -10% in measurement (i.e. instead of the metering being calibrate to record 821 L/rev it would measure an indicative say 870 (+6%) -900 (+10%) L/rev. The 5% shift is based on laboratory tests and the 10 % is based on the reported Thiess tests
ii) Install remote surveillance of gate opening, upstream water level and down stream water level to reduce tampering and detect leaks
iii) Designing a mathematical algorithm to determine a better calibration factor on a meter by meter basis, possibly using the information gained through water level and gate opening surveillance
iv) Improving the quality control on the emplacements and drum construction
v) Install bearings which have a longer life and do not influence the drum clearance (associated with a preventative maintenance/ replacement program)
vi) Install a wide mechanically operated downstream gate (remove the upstream gate) to prevent jetting under the wheel and remove the OH&S issues associated with the door
vii) Plastic lining the emplacement and using a plastic or carbon fibre moulded drum
viii) Installing a cage over the drum to prevent OH&S issues.

Although some of these changes may be cost effective and attractive many will be difficult to achieve and will be prohibitively expensive. Even if some of these measure lead to a more accurate and durable product being produced, they will not meet the tamper proof requirement of Pattern approval required by the proposed National Standard.

As other water providers are not proposing to use Dethridge meters in the longer term the design and development cost would have to be met by G-MW who would also have to undertake testing and seek Pattern approval.

4.10. Considerations for Future Use of the Dethridge Meter by G-MW

4.10.1. Ability of the Dethridge Meter to meet the National Standards

The expected "Meteorological and Technical Requirements for Meters Intended for Metering of Non-Urban Water in Full Flowing Pipes (NMI M 10A-1)" is only available in draft form. **Table 8** provides an overview of how the Dethridge meter will perform relative to the requirements of this draft of the proposed National Standard.

In summary if G-MW continue to install Dethridge meters, or use Dethridge meters which have been extensively maintained, after the exemption for Irrigation meters is lifted under the National Measurement Act, it will be necessary for G-MW to undertake the necessary extensive modifications and testing to obtain Pattern Approval and then to ensure that all of the requirements of the standard are met when these meters are used. Although the Dethridge meter is a reliable and robust meter, based on G-MW's inability to, control the operating conditions (flow and downstream water levels) and, cost effectively provide the necessary access and maintenance to maintain the necessary high level of accuracy, it is unlikely that the Dethridge meter will be able to meet the National Metering Standard requirements

Table 8: Ability of Dethridge Meter to Meet the Proposed National Metering Standards

Compliance Measure	Comment on Compliance
1. Has a sponsor to undertake improvements tests and obtain Pattern approval	G-MW is the only Water Provider who could be using the DMO in the longer term. If the DMO is to gain Pattern approval and comply with the National standards then G-MW must be prepared to invest in and dedicate resources to achieve that end.
2. Repeatable measure within the limits specified limits of ± 2.5% and ± 5% at all times	Recent testing by Thiess has confirmed past testing which indicates that the DMO can achieve these targets under ideal conditions with a properly maintained meter. Because the doors often leak and allow water to pass undetected by the meter, maintaining the meters in calibration condition is very labour intensive and hence expensive, and because the operation conditions (upstream and downstream water levels and flow rates) cannot be controlled at all times the required standard is unlikely to be met in the field at all times
3. Tamper proof	Although the pendant meter, which measures each revolution of the DMO, is relatively tamper proof, the drum on the DMO is exposed and can be, stopped from turning, or retarded, and thus not accurately measure the volume of water passed.
4. Durable for at least one of the three environmental Classes specified in the Metrological and Technical Requirements for Irrigation Meters.	Long term operation of the DMO in Environmental Class C namely "open locations, excluding polar and desert environments. Levels of vibration and shock will be of low significance" should be easily achieved, however, maintenance expenditure and effort will need to be increased to ensure bearings and clearances are maintained to meet the Pattern tolerances.

Cont.

Compliance Measure	Comment on Compliance
5. Corrosion proof	The DMO has a galvanised drum and an aluminium door and these have been found to be durable in most situations. Where saline environments are encountered high chromium steel of stainless steel can be used to extend the life of the drum. The plastic coated pendant meters have already operated satisfactorily in these environments for many years. This condition could be met.
6. Performance must not be temperature dependent	The DMO is a positive displacement meter and the clearances between the metal drum and concrete emplacement are such that expansion due to temperature change should not be an issue. The pendant meters have already operated satisfactorily in these environments for many years.
7. Volume indicator cover to be ultraviolet light resistant	There have been no problems with the pendant meters in this regard in the past
8. Be fail safe and retain data	As the pendant meter is a mechanical meter this should be achievable
9. Only be installed in the manner for which they have Pattern approval	DMO are often found to have incorrect clearances and levels and are generally assembled in the field after the emplacement is installed to ensure clearances are correct. Significant improvement in the assembly and installation quality will therefore be required to ensure Pattern approval is maintained.
10. Operate within its Pattern approved operating range.	The variability in upstream and down stream conditions, the lack of surveillance and the inability to automatically control flow rates and conditions mean there is no way of preventing the DMO operating at very low and very high flows or with high tailwater level all of which lead to inaccuracy. Unless access to many of the DMOs in G-MW is improved, and maintenance levels are increased significantly, the clearance between the drum and the emplacement, which will affect accuracy, cannot be maintained.
11. Performance Testing	New tests specifically addressing the requirements of the new national Metrological and Technical Standard will need to be undertaken at the cost of the Pattern application proponent past testing will be not be acceptable

4.10.2. Other Considerations

In addition to the requirement to meet the National Metering Standards to be attractive to G-MW in the longer term, other factors need to be considered. Some of these factors include:

- ability to seal the Dethridge meter door to ensure trickle flows are not lost to G-MW. This has proven to be a significant issue on the CG 1, 2, 3 & 4 project where significant losses have been detected from this source. On that project 21 % of doors on Dethridge meters were found to be leaking with 4% leaking more than 0.12 ML/d and 1 % leaking more than 0.24 ML/d.
- inability to provide high discharge rates. The Dethridge meter is limited to 10 ML/d at standard settings of 380 mm on the upstream sill and 75 mm of head loss
- inability to accurately measure flows below 3 ML/d
- Occupation Health and Safety concerns to related to the uncovered spinning finned wheel and the need to raise and lower the upstream control door manually
- difficulty in gaining access along channel banks however this can be overcome by installing a culvert downstream of the Dethridge meters
- G-MW would be the only major water provider still using Dethridge meters.

4.11. Potential Dethridge Meter Replacements

4.11.1. Options

On the basis of meters adopted by other water providers throughout Australia the options that could be considered as replacements for the Dethridge meters are:

i) MagFlow meters
ii) FlumeGate™ meters
iii) Doppler meters.

Each of these meters, with the exception of the FlumeGate™ which is only manufactured by Rubicon Systems, has a number of manufactures each of which has added their particular propriety enhancements to the fundamental functionality of the particular meter type.

4.11.2. Ability of Replacement Options to Meet National Standards

MagFlow Meters

MagFlow meters have been adopted as the standard for use in many NATA certified meter testing laboratories and is viewed as the most accurate form of metering after using calibrated scales or surveyed volumetric tanks.

MagFlow meters already meet the requirements of the National Measurement Act, NMI R49 Part 1: *Metrological and technical requirements for Water meters intended for metering cold potable water and hot water*. It should therefore be relatively easy for the manufacturers to gain Pattern Approval for MagFlow meters to meet the requirements of "Meteorological and Technical Requirements for Meters Intended for Metering of Non-Urban Water in Full Flowing Pipes (NMI M 10A-1)".

The MagFlow meter should therefore be the easiest meter for which the manufacture can gain Pattern Approval, however, because the meter to be used by G-MW in its MANN design has the meter installed on the end of the pipe, rather than within the pipe, the accuracy of the meter will be impacted by the pit design. Pattern approval may therefore need to be obtained for the combination of the pit and the meter.

FlumeGate™ Meters

It is understood that Rubicon Systems has already commenced discussion with the National Measurement Institute so that it can commence the testing and documentation preparation to gain Pattern Approval for the FlumeGate™. Experience would indicate that although the measurement accuracy requirements may be met, reliability in terms of retaining the accuracy without significant input over time could be an issue.

Doppler Meters

Testing of the Doppler meter would indicate that reliable accurate measurement could be an issue and will require considerable effort on behalf of the manufactures to gain Pattern Approval.

4.11.3. Advantages of Each of the Replacement Options

The advantage of the MagFlow, FlumeGate™ and Doppler meters relative to the Dethridge meters are outlined in **Table 9**. From the information included in **Table 9** it is concluded that the MagFlow meter is the most cost effective and reliable option to replace the Dethridge meter, however, if flexibility in maximum flow and ease of adding remote surveillance and automation provide an advantage to the FlumeGate™.

Table 9: Advantage Compared with the Dethridge Meter

Meter Type Issue	MagFlow (with MANN Design)	FlumeGate™	Doppler
Ability to meet the National Standard	Yes	Possibly	Possibly
Cost	About twice the cost of a Dethridge meter	About three times the cost of a Dethridge meter	About twice the cost of a Dethridge meter
Accuracy	World renowned to be accurate at high velocities	Initial testing in the laboratory and field indicates that it should meet the requirements if sensor drift can be overcome	Relies on water containing some suspended solids. Not sufficiently accurate in G-MW installations and with G-MW calibration to be considered.
Flow Range	Has a high flow range, is limited by the size of the pipe and friction loss in the pipe	Has the best flow range due to the open weir design	Has a high flow range, is limited by the size of the pipe and friction loss in the pipe
Ease of upgrading to remote surveillance and automation	Automation should be relatively simple to add	Both automation and remote surveillance is relatively simple to add	Automation should be relatively simple to add
Tampering Proof	All sealed no moving parts. Very well protected	Reasonably robust	All sealed no moving parts but not weel protected from the sensors being moved
Seals/Leakage	Mechanical gate with upgraded seals means that leakage should be minimal	Sealed with no leakage	Mechanical gate with upgraded seals means that leakage should be minimal
Reliability	Few problems with drift proven over many yeas of operation	Has only about 10 years of service. Sensor reliability and durability yet to be proven	Reliability has been proven in the field over the past 10 years
Potential for remote access to data and automation	Yes; if installed with a motorised slide gate	Yes	Yes; if installed with a motorised slide gate
Ease of upgrading software	Software is easily upgraded	Software is easily upgraded and may be done remotely if remote surveillance option is added	Software is easily upgraded
Ease of Maintenance	Maintenance is minimal but requires skilled labour well versed in MagFlow technology	Auditing and maintenance is significant but requires skilled labour well versed in FlumeGate™ technology	Auditing and maintenance is significant but requires skilled labour well versed in Doppler meter technology
Channel Bank Access	Pipe offtake used for access	Additional costly culverts required to facilitate access	Pipe offtake used for access
Occupation Health and Safety	No OH&S issues	Expensive walkway and handrail have removed OH&S issues	No OH&S issues

5. Conclusions

Based on the content of this report the following general conclusions are drawn:

Field testing Results

i) The Thiess field testing and report shows;

   a. the REVS unit measures accurately and the level of uncertainty is between 0.5% and 0.6% for this series of tests
   b. subject to conclusion (ii) the accuracy and process used by Thiess are appropriate
   c. the Dethridge meter errors are significant (-1 % to -24 %) and favour G-MW customers
   d. Dethridge meter errors are caused by a range of factors many of which cannot be controlled or influenced by G-MW. The REVS tests clearly showed that the errors increased with the increase in the clearance between the drum and the emplacement (Test 2 at each site)
   e. the G-MW MagFlow meters tested measure accuracies between -2.3 % and +3.3 % which is within the desired level of accuracy
   f. the MagFlow meter installed by a landowner on his property under recorded by about 10 %
   g. the FlumeGate™ meters fitted with the new software and tested by Thiess produced accuracies within ± 3.5 % which is within the required level of accuracy.

ii) The Thiess test and analysis methodology associated with their portable field test unit (REVS) is sound for testing meters using constant or near constant flow. It is suggested that in future:

   a. The leakage from the pondage test be measured over night and used to adjust the results
   b. Where possible the REVS data logger record and the analysis be based on volume delivered rather than flow rate (this will allow variable flows to be analysed with minimal error)

iii) The Thiess field testing was based on a small sample which may have been biased due to the ease of access or the maintenance regime of the G-MW Area Manager operating the meters. If the Dethridge meter is to be used in the longer term, or if the extent of measurement error is to be better quantified, it would be appropriate to test a larger random sample of Dethridge meters in each of the Irrigation Areas. For the same reason further testing of FlumeGate™ meters would also be appropriate.

iv) Some of the Thiess field tests showed significant variation in results and should have been repeated so that they could be verified. Future testing should be designed to better suit the proposed forensic analysis by, for example, holding all but one variable constant and conducting repeated tests

Meeting National Standards

v) There are a significant number of factors which will lead to it being difficult, time consuming and costly to bring the Dethridge meter to a standard such that it will meet the proposed National Metering Standards

Future of the Dethridge Meter for G-MW

vi) Most other eastern State Water Providers, have decided not to use the Dethridge meter in the longer term most having short term replacement program to remove Dethridge meters from their supply systems

vii) The opportunity to obtain Australian Government funding for meter upgrading will be increased if a meter other than the Dethridge meter is used

viii) Government funding under the NWI or the National Water Plan for meter upgrading are likely to be short lived. If G-MW decides not to continue with the Dethridge meter it should consider strategically what are the best steps to take to secure some of this funding

ix) The MagFlow meter should be the easiest meter for which the manufacture can gain Pattern Approval however because the accuracy of the meter will be impacted by the pit design Pattern approval may need to be obtained for the combination of the two.

6. Key Findings and Recommendations

A. The following key findings should be noted:

A1. The results in the Thiess report on in-situ testing of meters are generally as expected with the Dethridge meter significantly under recording by an average of 10 % based on the limited sample

A2. Based on current knowledge, the Dethridge meter is unlikely to meet the proposed requirements of the National Metering Standard

A3. Australian Government funding is unlikely to be available to assist with upgrading Dethridge meters to meet the new National Metering Standard

A4. Most irrigation water providers in Australia are not planning on using Dethridge meters in the longer term

A5. The small sample Doppler type meters tested did not perform well and the MagFlow and FlumeGate™ meters performed well as part of these tests. The latter two meters met the proposed National Standards for accuracy however A larger sample size of each of the meters is however required to verify this conclusion

B. It is recommended that:

B1. further in-situ field testing be undertaken to verify the accuracy of a broader sample of Dethridge meters in various G-MW Irrigation Areas

B2. further in-situ field testing be undertaken to verify the accuracy of FlumeGate™ meters under a normal maintenance regime

B3. future test methodology and analysis be modified and undertaken as indicted in this report

B4. G-MW not pursue the long term use of the Dethridge meter unless the requirements of the National Metering standards are relaxed

B5. G-MW consider strategically what are the best steps to take to secure funding for its meter upgrade/replacement program.

xxxXXXxxx

7. References

In preparing this report the following documents were used:

i) Dethridge and Dethridge-Long Meters Report – A Long Dec 1989

ii) Dethridge Meter Error Algorithm development – D Poulton (G-MW) email dated 14 May 2007

iii) Field verification of Accuracy of Various Water Measuring Devices – interim report – G-MW March 2007

iv) Goulburn-Murray Water DSS Research Project – Dethridge Meter Accuracy Status Report – G-MW May 2006

v) Goulburn-Murray Water Assessment of leak rate through Dethridge meter gates in the CG 1, 3, 4 channels – G-MW July 2006

vi) Goulburn-Murray Water National Water Initiative – Metering and Measurement Implementation Plan Request for information on Metering costs - G-MW February 2007

vii) In-situ Flow Verification Report on Irrigation Metering Structures G-MW – Thiess Services 5 April 2007

viii) Irrigation Water Provider Benchmarking Data Report 2004/2005 – ANCID April 2006

ix) Irrigation Water Provider Benchmarking Data Report 2005/2006 – ANCID May 2007

x) Know the Flow Training Manual – ANCID 2002

xi) Katandra Invergordon Irrigation Area Refurbishment Project –Phase 1 – SKM 2004

xii) "Meteorological and Technical Requirements for Meters Intended for Metering of Non-Urban Water in Open Channels and partially filled Pipes (NMI M 10B-1)" - National Measurement Institute December 2006

xiii) "Meteorological and Technical Requirements for Meters Intended for Metering of Non – Urban Water in Full Flowing Pipes (NMI M 10A-1)" - National Measurement Institute September 2005

xiv) National Plan For Water Security – Australian Government 25 January 2007

xv) Potential Economic Impact due to Introduction of the National Metrological and Technical Requirements – G-MW November 2006

APPENDIX A

Appendix A – Interviews with Other Irrigation Water Providers

Table A1: Outcome of Use of Dethridge Meters by other Water Providers

Water Provider	Indicative Number of Dethridge Meters	Long Term Strategy for Metering	Reason For not Using Dethridge Meters in Longer-term Future	Dethridge Meter Replacement Strategy	Dethridge Meter Maintenance Strategy
Murray Irrigation	3,800	No new Dethridge meters are being installed. Decision was made in August 2005 Replacing Dethridge meters at about 50-100 per year and only use Mag Flow meters. (MIL has standardised on Tyco Irriflow 600).	• Moving parts pose a potential OH&S issue with staff, customers and the public • The flow range required for rice is often 1 ML to 20 ML. These high flows cannot be accommodated by the DMO and the low flows lead to large metering inaccuracy.	Currently replace as emplacements reach the end of their life or require replacement.. Opportunistic replacement when rationalisation can occur (one outlet for 2) in which case MIL keeps the water savings, or when nearby culverts need replacement or wheels fail. Currently landowners may pay for replacement of DMOs at $13,000 to gain flexibility and better service. MIL is currently seeing Federal funding ,however ,the current approach to replacement will continue unless the Federal Government funds a wholesale replacement of the meters.	Replace wheels but not emplacements. Generally use second hand parts salvaged from DMOs being replaced
Murrumbidgee Irrigation	1,000	Have not installed DMOs since early 1990s Other meters being used include: Doppler meters in open channels and Mag Flow meters on piped systems	Replacing DMO due to • Inaccuracy; • difficulty in achieving desired flows • OH&S • access along channel banks	Replacement program will be completed by 2012 (currently replacing 200 – 400/year). Replacement program is funded by dowry provided by NSW Government as part of privatisation in the mid 1990s	Wheels are not being pulled out over winter for maintenance as was the practice of all Authorities in the past. Any DMO maintenance is undertaken with second hand parts

Water Provider	Indicative Number of Dethridge Meters	Long Term Strategy for Metering	Reason For not Using Dethridge Meters in Longer-term Future	Dethridge Meter Replacement Strategy	Dethridge Meter Maintenance Strategy
Coleambally	409	Replace with either: 1. FlumeGate™ 1485-620 2. MagFlow Tyco Irriflow 600 By winter 2007 – TCC will be installed in all channels	• Inaccuracy; testing indicated DMO 18-30% inaccurate • Control; mechanical activated gates or FlumeGate™ meters provided greater control • DMO limited by flow rate (4 – 12 ML/day) compared with desired (1 - 30 ML/day) • OH&S	Blanket replacement program, 18 month program commencing in Autumn 2008 and completing in Spring 2009. Replacement program funding is through a Water Smart Australia funding application, and if unsuccessful internal funding will be used	Winter 2005 was the first time in 5-6 years that maintenance was been undertaken on the DMO and its components. Maintenance is undertaken annually to maintain reliability and accuracy
Southern Rural Water	2,100	FlumeGate™ meters are being installed where TCC has been installed. Installing MagFlows in piped areas.	• Requirements to comply with National Standards, therefore DMO will not be used. • Despite the possibility of gaining pattern approval in Lab, risk too high • Lack of accuracy • DMOs are a barrier to efficient flood irrigation because cannot get sufficiently high flow rates • Potential OH&S issue for customers	Replacements with MagFLow and FlumeGate™ meters are project specific. Will not release a new SRW policy on DMO replacement until National Government has provided direction. Still installing new DMOs for subdivisional works only	Continuing to maintain DMOs on a routine basis.

Water Provider	Indicative Number of Dethridge Meters	Long Term Strategy for Metering	Reason For not Using Dethridge Meters in Longer-term Future	Dethridge Meter Replacement Strategy	Dethridge Meter Maintenance Strategy
Harvey Water	625	Have not developed a longer term strategy for replacing Dethridge meters but expect that over the next 10 years all will be replaced or renewed	Want to pipe the whole system and Detrhidge meters are not suitable for that application.	Use closed system Mag Flow meters where systems are piped. When the current piping project is finished only 250 Dethridge meters will remain.	Continue to maintain and replace meters routinely as required
SunWater	1,500	• No new DMOs being installed • For piped systems smaller MagFlows are used (in-line meters, buried) to match existing infrastructure (generally high head)	• DMOs are not expected to meet future standards for accuracy and Pattern Approval, • Requirements to achieve operational conditions to meet accuracy of 2.5% for DMO are not achievable	• Replacing small DMO • No existing replacement program, waiting for National Standards and possible Australian Government Funding • Replace wheels, but not emplacements	Continue to maintain and replace meters routinely as required

APPENDIX B

Appendix B – Field Test Results – Dethridge Meters

Table B1: Field Test Results – Dethridge Meters

				Readings & Settings at Test Commencement					Test		Result			Uncertainty	
Outlet	**Site**	**Test No**	**Date**	**Wheel Clearance**	**Gate opening**	**U/S Supply Depth**	**Depth D/S of Gate**	**Tail Water Depth**	**Average Flow Rate Ml/d**	**Test Duration Minutes**	**% Under**	**% Over**	**Litres Per Revolution**	**Result @ 95 % Confidence +/-**	**Comments**
	[redacted]	1	12-Jan-07	6.1	out	363	open	215	6.61	60	3.95		854.8	0.50%	
		2	12-Jan-07	6.1	170	350	310	150	8.25	60	3.63		851.9	0.50%	
		3	12-Jan-07	13.3	out	328	open	200	5.99	60	9.08		903.0	0.50%	
		4	12-Jan-07	13.3	120	380	305	189	5.99	60	13.14		945.2	0.50%	
R[redacted]	[redacted]	1	7-Feb-07	11.0	225	450	450	290	3.05	60	17.5		995.2	0.50%	
		2	7-Feb-07	14.0	225	450	450	290	3.39	60	20		1026.2	0.50%	
		3	7-Feb-07	13.6	225	450	450	290	3.33	55	17.18		991.3	0.50%	Bearings Replaced
[redacted]	[redacted]	1	18-Jan-07	7.5	out	475	open	275	9.8	120	12.98		943.4	0.50%	
		2	18-Jan-07	12.5	out	470		270	9.56	60	16.15		979.2	0.50%	
		3	18-Jan-07	6.5	out	480	open	265	8.86	60	12.52		938.5	0.50%	Bearings Replaced
[redacted]	[redacted]	1	17-Jan-07	7.5	280	380	330	150	9.5	120	8.4		896.3	0.50%	
		1.1	17-Jan-07	7.5	280	380	330	150	9.55	60	8.46		896.9	0.51%	
		1.2	17-Jan-07	7.5	280	380	330	150	9.45	60	8.33		895.6	0.51%	
		1.3	17-Jan-07	7.5	280	380	330	150	9.52	90	8.4		896.3	0.51%	
		2.0	17-Jan-07	14.0	out	375	open	170	10.59	120	11.19		924.4	0.50%	
		2.1	17-Jan-07	14.0	out	375	open	170	10.42	60	11.04		922.9	0.51%	
		3	17-Jan-07	6.0	280	380	345	160	9.21	60	9.47		906.9	0.52%	Bearings Replaced
[redacted]	[redacted]	1	23-Jan-07	7.0	75	405	325/330	180	4.14	60	32.6		1218.1	0.55%	Dethridge Pulse counter malfunction (-2 counts/rev) Not used in Hydro Environmental analysis
		2	23-Jan-07	7.0	50	405	330	180	2.97	30	17.22		991.8	0.82%	
[redacted]	[redacted]	2.1	6-Feb-07	8.0	60	400	335	180	3.22	60	20.74		1035.9	0.60%	
		2.2	6-Feb-07	16.0	60	410/450	325	180	3.78	60	22.38		1057.7	0.57%	
		2.3	6-Feb-07	8.0	60	450	330	180	4.17	60	17.3		992.7	0.56%	
[redacted]	[redacted]	1	30-Jan-07	10.5	180	397/408	380	255/250	4.35	60	24.05		1080.9	0.51%	
		2	30-Jan-07	8.0	180	400	370-375	240/245	4.16	60	10.32		915.4	0.51%	Stones preventing continuous free turning of Dethridge Meter
		2.1 *	30-Jan-07	8.0	180	400	370-375	240/245	4.25	38	9.77		909.9	0.51%	
		2.2	30-Jan-07	8.0	180	405	370-375	240/245	4.81	35	9.67		908.9	0.51%	
		3	30-Jan-07	8.0	180	410	380	245	5.1	55	9.22		904.4	0.50%	
[redacted]	[redacted]	1	29-Jan-07	9.0	out	426	open	310	5.41	60	7.79		890.4	0.50%	
		2	29-Jan-07	14.5	out	413	open	310	4.54	50	12.78		941.3	0.51%	D/S reg. gate opened near test end. Fins straightened
		3	29-Jan-07	7.5	out	386	open	265/260	7.02	60	4.46		859.4	0.50%	
[redacted]	[redacted].	1	22-Jan-07	4.0	out	395/400	open	235	7.43	60	1.46		833.2	0.55%	mean of 2 tests for algorithm
		2	22-Jan-07	13.0	out	385	open	235	5.74	60	17.22		991.8	0.58%	
		3	22-Jan-07	5.5	out	385	open	235	6.09	60	11.08		923.4	0.57%	Bearings replaced

Table B1: Field Test Results – Dethridge Meters (cont.)

Outlet	Site	Test No	Date	Readings & Settings at Test Commencement					Test						Comments
											Result			Uncertainty	
				Wheel Clearance	Gate opening	U/S Supply Depth	Depth D/S of Gate	Tail Water Depth	Average Flow Rate Ml/d	Test Duration Minutes	% Under	% Over	Litres Per Revolution	Result @ 95 % Confidence +/-	
[redacted]	[redacted]	1	24-Jan-07	7.0	310	500	495	340	4.33	60	8.58		898.1	0.50%	
		2	24-Jan-07	12.5	350	495	495	340	4.83	60	14.61		961.5	0.50%	
		3	24-Jan-07	6.0	310	510	495	340	4.18	60	10.3		915.3	0.50%	Bearings replaced
[redacted]	[redacted]	1	1-Feb-07	6.5	290	380	355	210	5.47	60	8.2		894.3	0.50%	
		2	1-Feb-07	16.5	245	370	360	210	6.21	60	15.65		973.3	0.50%	
		3	1-Feb-07	7.0	165	425/530	370/440	210/230	8.58	60	14.17		956.5	0.50%	Supply level rose significantly nearing end of test
															Straightened Fins
[redacted]	[redacted]	1	19-Jan-07	7.0	240	400	310	160	10.99	60	5.92		872.6	0.51%	
		2	19-Jan-07	13.5	250	390	310	170	11.3	60	9.6		908.2	0.51%	
		3	19-Jan-07	7.5	250	390	310	170	10.53	60	6.31		876.3	0.51%	Replaced Bearings
		3.1 *	19-Jan-07	7.5	250	390	310	170	10.54	53	6.21		875.3	0.51%	
[redacted]	[redacted]	1	31-Jan-07	8.0	155	350	200	80	9.8	60	5.59		869.6	0.50%	General conditions windy
		2	31-Jan-07	16.5	155	350	190	80	10.24	60	10.69		919.2	0.50%	
		3	31-Jan-07	7.0	155	350	200	80	10.08	60	4.69		861.4	0.50%	Dethridge Fins straightened. Replaced Bearings

APPENDIX C

Appendix C – Field Test Results – FlumeGate™ Meters

Table C1: Field Test Results – FlumeGate™ Meters

Outlet	Site	Test No	Date	Meter Details		Readings & Settings at Test Commencement					Test						Comments
													Result			Uncertainty	
				Model	Serial No.	U/S Primary	D/S Primary	Pre. gate Level	Op. Gate Level	Op. Gate Open	Average Flow rate	Test Duration Minutes	% Under	% Over	Calibration Factor	Result @ 95 % Confidence +/-	
[redacted]	[redacted]	1	8-Feb-07	1050-0674	885	9.612	9.21	9.749	9.61	0.156	2.83	60		8.29	1.083	0.52%	Prior to FlumeGate software upgrade by Rubicon Not used in Hydro Environmental analysis
		2	8-Feb-07	1050-0674	885	9.612	9.21	9.749	9.61	0.156	7.26	60		5.61	1.056	0.50%	Prior to FlumeGate software upgrade by Rubicon Not used in Hydro Environmental analysis
		3	8-Feb-07	1050-0674	885	9.612	9.21	9.749	9.61	0.156	11.73	60		3.86	1.039	0.50%	Prior to FlumeGate software upgrade by Rubicon Not used in Hydro Environmental analysis
		4	8-Feb-07	1050-0674	885	9.605	9.306	9.486	9.599	0.167	3.16	16	1.21		0.988	0.69%	After FlumeGate software upgrade by Rubicon
		5	8-Feb-07	1050-0674	885	9.605	9.306	9.486	9.599	0.167	7.70	60	2.13		0.979	0.50%	After FlumeGate software upgrade by Rubicon
		6	8-Feb-07	1050-0674	885	9.605	9.306	9.486	9.599	0.167	12.32	60	1.96		0.980	0.50%	After FlumeGate software upgrade by Rubicon
[redacted]	[redacted]	1	9-Feb-07	1050-0674	886	9.598	9.462	9.756	9.599	0.167	7.65	60		0.81	1.008	0.50%	Weeds at entrance to FlumeGate
		2	9-Feb-07	1050-0674	886	9.598	9.462	9.756	9.599	0.167	12.29	60	0.04		1.000	0.50%	
		3	9-Feb-07	1050-0674	886	9.598	9.462	9.756	9.599	0.167	2.97	60		3.52	1.035	0.53%	
[redacted]	[redacted]	1	13-Feb-07	1050-0674	894	9.562	9.139	9.769	9.562	0.208	7.75	60	0.29		0.997	0.51%	Weeds at entrance to FlumeGate
		2	13-Feb-07	1050-0674	894	9.562	9.139	9.769	9.562	0.208	12.58	60	1.85		0.982	0.50%	
		3	13-Feb-07	1050-0674	894	9.562	9.139	9.769	9.562	0.208	3.15	60		2.18	1.022	0.55%	
[redacted]	[redacted]	1	14-Feb-07	1050-0674	674	9.642	9.32	9.762	9.645	0.123	3.03	60		2.76	1.028	0.51%	
		2	14-Feb-07	1050-0674	674	9.642	9.32	9.762	9.645	0.123	7.49	60		3.06	1.031	0.50%	
		3	14-Feb-07	1050-0674	674	9.642	9.32	9.762	9.645	0.123	12.10	60		0.8	1.008	0.50%	
[redacted]	[redacted]	1	16-Feb-07	1050-0674	860	9.593	9.364	9.768	9.586	0.182	3.00	60		3.4	1.034	0.54%	
		2	16-Feb-07	1050-0674	860	9.593	9.364	9.768	9.586	0.182	7.44	60		2.34	1.023	0.51%	
		3	16-Feb-07	1050-0674	860	9.593	9.364	9.768	9.586	0.182	12.03	60		1.64	1.016	0.50%	
[redacted]	[redacted]	1	22-Feb-07	1050-0674	831	9.542	9.139	9.77	9.54	0.229	3.19	60	3.54		0.965	1.02%	
	[redacted]	2	22-Feb-07	1050-0674	831	9.542	9.139	9.77	9.54	0.229	7.69	60		0.28	1.003	0.69%	
		3	22-Feb-07	1050-0674	831	9.542	9.139	9.77	9.54	0.229	10.44	60	2.36		0.976	0.57%	
[redacted]	[redacted]	1	15-Feb-07	1050-0674	841	9.593	9.14	9.77	9.594	0.175	7.45	60		1.1	1.011	0.51%	
		2	15-Feb-07	1050-0674	841	9.593	9.14	9.77	9.594	0.175	12.12	60		0.35	1.003	0.51%	
		3	15-Feb-07	1050-0674	841	9.593	9.14	9.77	9.594	0.175	3.01	60		1.94	1.019	0.58%	

APPENDIX D

Appendix D – Field Test Results – MagFlow and Doppler Meters

Table D1: Field Test Results – Doppler and MagFlow Meters

Site	Test No	Date	Test						Comments
			Average Flow rate	Test Duration Minutes	Result			Uncertainty	
					% Under	% Over	Calibration Factor	Result @ 95 % Confidence +/-	
MagFlow Meters									
Tivendale	1	21-Feb-07	3.82	60		2.91	1.029	0.52%	
(double pit)	2	21-Feb-07	10.15	60		0.08	1.001	0.50%	
	3	21-Feb-07	14.16	60	0.54		0.995	0.50%	
Owen	1	22-Feb-07	14.56	60		2.05	1.021	0.51%	Supply level approx. 70mm low
(12r)	2	22-Feb-07	9.11	60		3.06	1.031	0.51%	
	3	22-Feb-07	3.88	60		3.27	1.033	0.57%	
Sorraghan	1	28-Feb-07	3.14	60		0.54	1.005	0.72%	Upsream Gate out.
Tyco Mag	2	28-Feb-07	8.16	60	1.27		0.987	0.54%	Upsream Gate out.
	3	28-Feb-07	14.12	60	1.42		0.986	0.51%	Upsream Gate out.
Shermans	1	1-Mar-07	12.66	60	0.66		0.993	0.50%	
Tyco mag	2	1-Mar-07	8.57	60	0.01		1	0.51%	
	3	1-Mar-07	3.13	60	2.33		0.977	0.54%	
Man Pit	1	06-Mar-07	13.77	60	1.7		0.983	0.51%	General conditions Windy
450mm Magflow	2	06-Mar-07	8.38	60	1.96		0.98	0.53%	Shroud fitted between magflow and Outlet
	3	06-Mar-07	14.46	60	1.56		0.984	0.51%	With Shroud
	4	06-Mar-07	3.08	60	1.24		0.988	0.70%	With Shroud
Exton pit	1	08-Mar-07	8.84	60		1.72	1.017	0.50%	
600 Magflow	2	08-Mar-07	12.52	60		1.78	1.018	0.50%	
	3	08-Mar-07	3.19	60		2.34	1.023	0.52%	
Corbo	1	22-Feb-07	3.19	60	11.58		0.884	1.02%	Tested Inline with Flumegate
(Mag meter)	2	22-Feb-07	7.69	60	10.24		0.898	0.69%	
	3	22-Feb-07	10.44	60	9.67		0.903	0.57%	
Doppler Meters									
1	1	2-Mar-07	3.55	43		3.51	1.035	0.92%	
(Mace, Doppler)	2	2-Mar-07	7.55	60		5.83	1.058	0.56%	
	3	2-Mar-07	13.68	60	11.1		0.889	0.52%	
Archards	1	07-Mar-07	2.63	60		20.29	1.203	0.60%	
(Mace, Doppler)	2	07-Mar-07	8.04	60		20.05	1.2	0.51%	
	3	07-Mar-07	14.04	60		22	1.22	0.50%	