

Lower Tule River Irrigation District

October 2017

Daniel Vink, General Manager Lower Tule River Irrigation District 357 E. Olive Ave. Tipton, California

Tel: 559.686.4716 email: dvink@ltrid.org

Sabrina Cook Agriculture Unit Department of Water Resources Sacramento, California

Fethi Benjemaa Agriculture Unit Department of Water Resources Sacramento, California

Dr. Charles Burt, P.E., Chairman Dr. Stuart Styles, P.E., Director Sierra Layous, P.E., Senior Engineer



moving water in new directions irrigation training and research center

California Polytechnic State University San Luis Obispo, California 93407-0730 Tel: (805) 756-2434 Fax: (805) 756-2433 www.itrc.org

TABLE OF CONTENTS

Introduction		1
Background		2
Recommendations Summary		6
Anticipated District Priorities	S	7
Major Capital Improvement Re	ecommendations	8
	Create Superhighways	
, 1	11	
Supervisory Control and Data A	Acquisition (SCADA)	17
Short-Term Recommendations		20
	99 Culverts	
•		
	on Culverts	
4. Debris In/Around Culverts	,	27
Metergates		29
_		
Well Flow Meters		31
Low-Lift Pump Flow Meter		31
Long-Crested Weirs		31
Example Location		33
Current Recharge versus Poten	itial Additional Recharge with Recommendations	34
current Reenarge versus roten	with recommendations with recommendations	51
I	LIST OF ATTACHMENTS	
	-	
Attachment A	Details for Toledo Basin Modifications	
Attachment B	Site-by-Site Details for Taylor Ditch Modifications	
Attachment C	Highway 99 Culvert Vortex Plate Details	
Attachment D	Metergate Design	

Attachment E

Attachment F

Overview of Current Well Flow Meter Options

Overview of Portable Pipe Flow Meter Option

LIST OF FIGURES

Figure 1. DWR-designated disadvantaged communities (DACs) in or near Lower Tule River	
Irrigation District	1
Figure 2. Location of Lower Tule River Irrigation District	2
Figure 3. Acreage of major crops reported, 1984 to 2014, in LTRID	3
Figure 4. Crops reported in LTRID, 2014	
Figure 5. Map of key hydraulic elements of the Lower Tule River Irrigation District	5
Figure 6. Conceptual layout of Friant Kern Canal, Toledo Basin, Creighton Ranch, and Canals 2 and	
3 as superhighways	9
Figure 7. Layout of proposed modifications to Taylor Ditch	10
Figure 8. Map of LTRID with possible regulating basins indicated	11
Figure 9. Conceptual sketch of the downstream end of LTRID as currently operated	12
Figure 10. Changes to be incorporated into the canals	
Figure 11. New flow control and water level controls with Toledo Basin as a regulating reservoir	14
Figure 12. Aerial view of proposed Toledo Basin layout	16
Figure 13. Layout of existing and proposed SCADA sites in LTRID	19
Figure 14. Existing conditions in the Poplar Pipeline	
Figure 15. Effort 1 modifications to Poplar Pipeline	
Figure 16. Effort 2 modifications to Poplar Pipeline stands	
Figure 17. Highway 99 canal crossings	
Figure 18. Current conditions in canal at culvert	
Figure 19. Modifications to canal to increase flow through culvert	
Figure 20. Common culvert entrance conditions	
Figure 21. Curved entrance configurations on new and existing culvert sites	
Figure 22. Example layout of vortex suppression plate on upstream side of culvert	
Figure 23. Example vortex suppression plate layout on Canal 1 Highway 99 culvert	
Figure 24. Debris found in culverts during site visits	
Figure 25. Overview of configuration at head of Woods Central Canal (Canal 3)	
Figure 26. Recommended modifications to Woods Central Canal Replogle Flume	
Figure 27. LTRID's metergate with suggestions for improvement	
Figure 28. Harmon SO ₂ generator at Wonderful Farming in California	
Figure 29. Example simple long-crested weir pointing upstream. Walker River ID, Nevada	
Figure 30. Example long-crested weir pointed downstream. District (un-named to protect the guilty)	
employees are performing a structural test on the bridge used to access the flushing gate	32
Figure 31. Location of example location for long-crested weir at Canal 3 bifurcation point	
Figure 32. Example location for long-crested weir at Canal 3 bifurcation point showing current	
layout (left) and improved layout (right). The installation of a long-crested weir is more	
important than flow control automation at this site	33
Figure 33. Distribution of flows in LTRID, monthly from 2003 to 2017	
Figure 34. Inflows into LTRID compared to total percolation (recharge) as a percent of inflows,	Эт
annually from 2003 to 2017	34
amuany nom 2003 to 2017	54
LIST OF TABLES	
Table 1. SCADA Phase 1 (high priority) sites	18
Table 2. SCADA Phase 2 (medium priority) sites	
	10

Lower Tule River Irrigation District

Rapid Appraisal Process (RAP) With Extended Recommendations Report

Introduction

Dr. Charles Burt, Dr. Stuart Styles, and Sierra Layous of the Irrigation Training and Research Center (ITRC) of California Polytechnic State University, San Luis Obispo conducted multiple site visits to the Lower Tule River Irrigation District in July and September of 2015 to perform a Rapid Appraisal Process (RAP) evaluation on behalf of the California Department of Water Resources (DWR). The visits included contact with Daniel Vink (Gen. Manager), Eric Limas (Business Manager), Mike Battles (Operations Manager), and Kenny Phelps (Water Resources Superintendent). A majority of the field visits were spent with Phelps. This project was supported by DWR funding. Technical assistance was provided to LTRID to make improvements to their overall operation because groundwater supplies are used both by the district and local disadvantaged communities (DACs). Lower Tule River Irrigation District contributes to groundwater recharge, which benefits the water supplies for disadvantaged communities (DACs). By more effectively managing available water supplies through various modernization projects, LTRID will have the potential to increase groundwater recharge and decrease pumping by the agricultural users. In turn, this will provide more groundwater availability for the DAC. This report focuses on modernization opportunities for water conservation and improved water management.

The Lower Tule River Irrigation District was selected for participation in the Rapid Appraisal program because there are a number of DACs located within or near (in the same basin as) the District that rely on groundwater. This is shown in **Figure 1**.

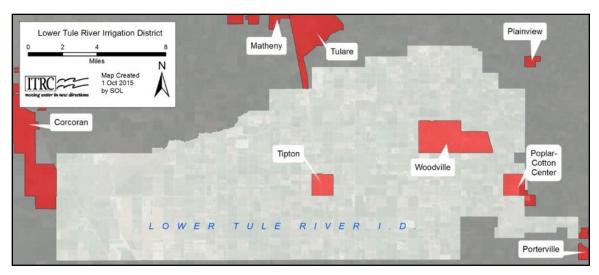


Figure 1. DWR-designated disadvantaged communities (DACs) in or near Lower Tule River Irrigation District

The District provides surface water to farmers, who use a combination of surface water and groundwater. In recent years, with no surface water from the District, growers have relied solely on groundwater.

Groundwater wells provide high-quality water that can be turned on and off as needed, allowing growers to irrigate during off-peak hours, and for shorter durations than the District's 24-hr set time. Ensuring that growers transition back to surface water when it becomes available is a key component to maintaining groundwater levels for surrounding disadvantaged communities. To do this, the District will need to raise its level of service by increasing flexibility to growers and increasing groundwater recharge when sufficient water is available.



Background

Figure 2. Location of Lower Tule River Irrigation District

The Lower Tule River Irrigation District (LTRID) is located in California around the community of Tipton,

CA (about 10 miles south of Tulare). LTRID contains approximately 103,000 acres (84,000 of which are irrigated). The District receives water from the Friant Kern Canal (FKC). It also receives water from the Tule River, when available. The specific entitlements are approximately:

- 61,200 AF, Class I from FKC
- 238,800 AF, Class II from FKC
- 40,000 AF, Tule River Rights¹

The types of crops grown have changed over time. In **Figure 3**, the change in major crop types from 1984 to 2014 (in ten-year increments) is shown. An increasing portion (currently almost ¹/₄) of the District has nut trees. Most of these trees are on drip or micro irrigation, and are typically irrigated in short, frequent blocks of time. The large percentage of cereal (mainly wheat) grown in 2014 is due to the drought.

¹ The District's Tule River Rights are associated with the water received from Lake Success. The average annual supply of the combined rights is about 70,000 AF. However, these water rights are currently impaired by storage issues behind Success Dam due to concerns from the Army Corps of Engineers about the safety of the earthen dam.

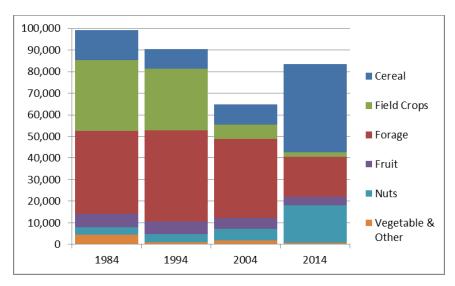


Figure 3. Acreage of major crops reported, 1984 to 2014, in LTRID

Figure 4 shows a breakdown of the specific crops grown in 2014.

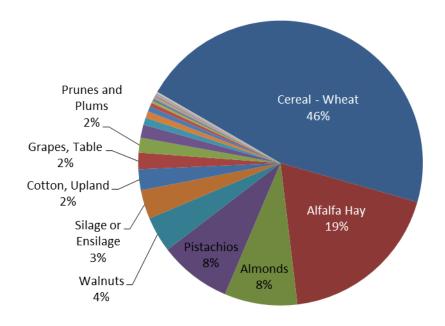


Figure 4. Crops reported in LTRID, 2014

There are approximately 163 miles of unlined canal, 47 miles of unlined river (Tule River), and about 3 miles of unpressurized pipeline in the District. The District does not own or operate groundwater wells. There are 18 groundwater recharge basins covering 3,700 acres. Two of these basins can be used as "in/out" reservoirs: Creighton Ranch and Toledo Basin. Individual ditchriders each operate a specific area continuously during the irrigation season.

The surface water supplies provided by the District are not able to meet the water needs of the growers, so most growers have groundwater wells that are used to fill the deficit. These growers rely solely on groundwater in times of drought (including recent years).

The District makes some deliveries downstream (outside of its boundaries) via the Tule River. In addition, there are some operational spills that leave the District from the ends of canals. An important reason for implementing a good modernization plan is to enable ditchriders to provide more flexibility in water deliveries, while minimizing or eliminating spills at the ends of canals.

Figure 5 on the next page shows the general layout of the District.

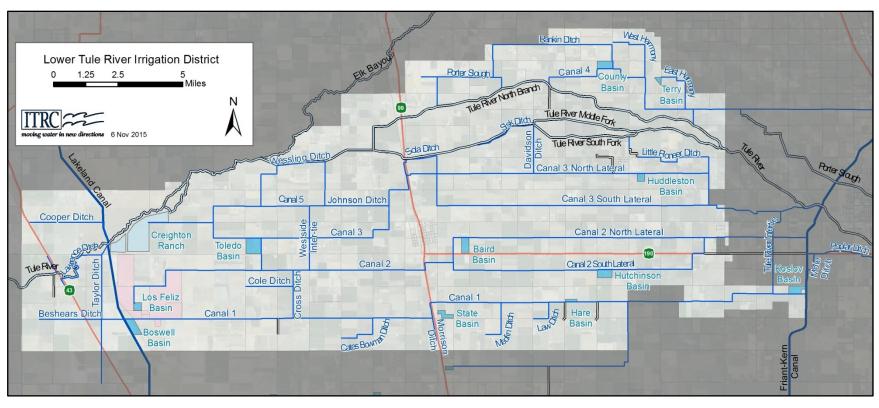


Figure 5. Map of key hydraulic elements of the Lower Tule River Irrigation District

Recommendations Summary

As Lower Tule River Irrigation District (LTRID) moves beyond the current drought, it may find it difficult to transition growers back to surface water. During the drought, growers have relied solely on groundwater. Groundwater wells provide high-quality water that can be turned on and off as needed, allowing growers to irrigate during off-peak hours, and for shorter durations than the District's 24-hr set time. Helping the growers transition back to surface water is a key component to maintaining groundwater levels for surrounding disadvantaged communities. To do this, the District will need to raise its level of service by increasing flexibility to growers. To provide flexibility, the District needs effective operational buffer storage within the District, and the ability to move varying quantities of water quickly through the system to respond to rapid changes in demand.

This Rapid Appraisal identified some technical recommendations and design concepts that LTRID may find helpful as it plans for the future of the District. Both long-term and short-term recommendations are discussed in this report.

The following are key <u>long-term</u> recommendations (involving major capital expenditures) to improve efficiency and ease of management throughout LTRID:

- 1. Modify existing structures at key locations along the canals. These will provide the District with the ability to move water more quickly through the system, improve water level control within the system, and direct excess flows to storage basins for future use. These modifications will also provide growers with more flexibility and consistent flow rates. Several detailed examples are provided.
- 2. Modify key existing basins (and associated canal structures and canal linkages) so they can be used as irrigation regulating/buffer basins in addition to their current use as recharge basins.
- 3. Continue to expand the existing SCADA system to remotely monitor sites, as well as to adjust target flow rates at key bifurcation points. This will include good access to real-time information by the ditchriders.

The following are key short-term recommendations, which mainly focus on a few key locations:

- 1. Install an air vent system along the Poplar Pipeline.
- 2. Modify the downstream water levels and/or inlets to the Highway 99 culverts to increase their flow rate capacities.
- 3. Modify components of the Woods Ditch Flume to increase accuracy of the flow measurement.
- 4. Test flow meters for grower well pumps.
- 5. Consider an updated flow meter for district low-lift pumps that are used to deliver water from canals to fields.
- 6. Discuss with farmers the possibility of using SO₂ generators for small, private reservoirs with algae problems.

Anticipated District Priorities

It is anticipated that the district will pursue the short and long-term recommendations in the following, or similar, order:

- A. Modify the downstream water levels and/or inlets to the Highway 99 culverts. This will increase the canals' flow rate capacities.
- B. Modify structures along the Taylor Ditch. This will give the district experience with construction techniques and costs related to structure upgrades.
- C. Modify upper canal system bifurcation points to improve flexibility and create "superhighways" for quickly moving water through the system. The modifications detailed in this report should work equally well whether the buffer reservoir is constructed at Creighton Ranch and/or the Toledo Basin.
- D. Simultaneously, continue to upgrade the SCADA system to remotely monitor sites and adjust target flows in the system.
- E. Review completed projects and determine how to proceed with new management of existing storage.
- F. Throughout the entire process, improve flow measurement devices throughout the district.

These technical recommendations were designed to allow LTRID to increase its level of service to growers and more effectively manage its water supplies. This will reduce growers' dependence on groundwater pumping and help maintain groundwater levels for the disadvantaged communities that pump from the same basin.

Major Capital Improvement Recommendations

The recommendations can be implemented in a phased schedule. This report provides specific examples to illustrate the concepts and/or starting points for the long-term recommendations. These examples can be used as templates for later, expanded implementations.

Modify Bifurcation Points and Create Superhighways

ITRC uses the term "superhighway" to describe a canal with appropriate water level control structures along its length. Excellent water level control permits the ditchrider to make a flow rate change at the head of the canal, and the flow rate moves rapidly down the length of the canal without the ditchrider needing to "follow the water" down a canal, making changes at flashboards.

Upper Canal System

It is recommended to convert Canals 2 and 3 between the Friant-Kern (F-K) Canal and the buffer reservoir (Creighton Ranch currently, the Toledo Basin in the future) into "superhighways", focusing first on Canal 2.

If the regulating reservoir level is low, the flow rate into Canal 2 or Canal 3 at the Friant-Kern Canal could be increased. The travel time for a flow change made at the head of Canal 2 or 3 might be reduced from 18 hours to 10-12 hours to the Toledo Basin and from 24 hours to 13-16 hours to Creighton Ranch with a superhighway.

This would allow the District to provide growers with more flexibility regarding request time and irrigation event length. A conceptual drawing of the system is shown in **Figure 6**. The improved water level control devices would replace the existing flashboards. While some districts use PLC-automated check structures for automated upstream control, many districts in the San Joaquin Valley (e.g., San Luis Canal Co., Chowchilla WD, Fresno ID, Modesto ID, Turlock ID) use long-crested weirs because of their simplicity.

Site-by-site details for canal bifurcation point modifications between the Westside Intertie/Cross Ditch and the Toledo Basin are given in **Attachment A**. These modifications can be implemented before the northeast cell of the Toledo Basin is converted to a buffer reservoir; they will improve operation and flexibility within the current system. To create complete "superhighways" in Canals 2 and 3, additional modifications would be needed upstream in the two canals, and downstream between the Toledo Basin and Creighton Ranch. ITRC believes that using the northeast cell of the Toledo Basin as a buffer reservoir (as described in the *Buffer (Operational) Storage* section later in this report) will provide significant additional flexibility to the district and growers.

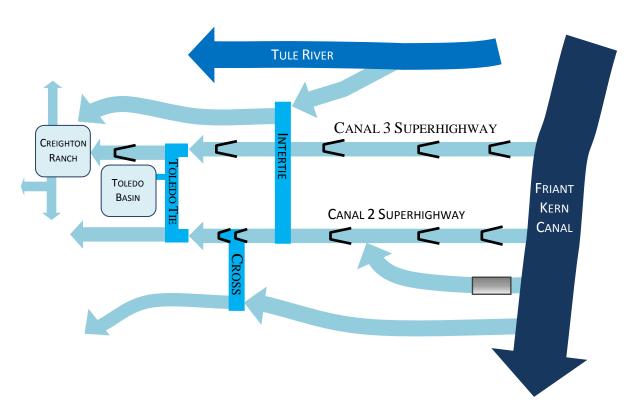


Figure 6. Conceptual layout of Friant Kern Canal, Toledo Basin, Creighton Ranch, and Canals 2 and 3 as superhighways

Taylor Ditch

Taylor Ditch is near the far western (downhill and downstream) side of the District. Making appropriate improvements to Taylor Ditch will help ensure that little/no water is unintentionally spilled from those District boundaries. Plus, improvements should improve service to farmers and make operations simpler for the ditchriders.

The following changes are recommended for Taylor Ditch, and are illustrated in **Figure 7**. Individual structure/section details are given in **Attachment B**:

- 1. The flow rate from Creighton Ranch into Taylor Ditch will be controlled with a newly automated flow control gate, using a PLC (programmable logic controller).
- 2. The flow rate used in the PLC logic will be measured two ways for redundancy:
 - a. Using an acoustic Doppler velocity meter (ADVM) in a specially-designed subcritical walled canal section.
 - b. Using the gate discharge equation (opening, plus change in water level).
- 3. Four or five new long-crested weirs (LCWs) will be installed in the ditch to provide more consistent water level control at various turnouts, including the inlet to the Lawrence Ditch.
- 4. The District may decide to reset the flow rate to the area south of Hwy 43 with a new gate upstream of the highway. This would require that the water level in the canal pool upstream of the new flow control gate be automatically maintained at a constant level with flows from the Boswell Basin. This option would further minimize spill from the end of the system.

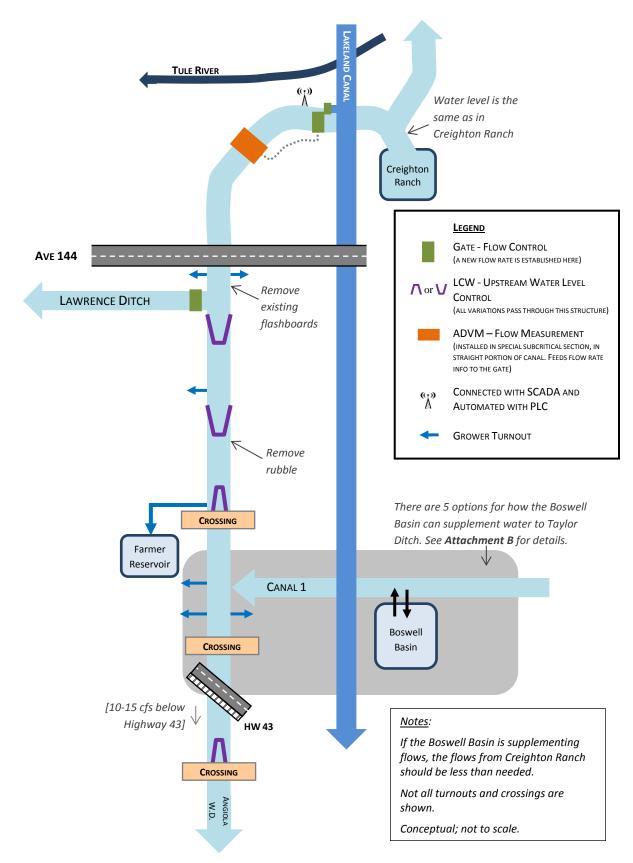


Figure 7. Layout of proposed modifications to Taylor Ditch

Buffer (Operational) Storage

Currently, the district uses Creighton Ranch and the northwest cell of the Toledo Basin as active storage during the irrigation season to buffer flow variations (temporary discrepancies between deliveries and supply along canals) and increase flexibility to growers. These locations have high infiltration rates (which is ideal for groundwater recharge, but not ideal for irrigation water regulation) and do not have significant irrigated acreage downstream. As the district upgrades its system and provides more flexibility to growers, it may find the need to increase/modify its storage.

There are basins throughout the district used primarily for groundwater recharge. Some of the basins are already divided into cells. Certain cells could be upgraded for irrigation water regulation, leaving other cells for groundwater recharge (irrigation water regulation cells could still be used for groundwater recharge, but would likely have much lower infiltration rates).

An example is given on the next few pages, but the principle can be applied throughout the District's system. An ideal regulating reservoir is located more than halfway down a canal system (with about $2/3^{rd}$ of the acreage upstream and $1/3^{rd}$ downstream of the reservoir). However, given the difficulty and expense involved in purchasing new properties, the existing recharge basins were used as starting points for possible locations. The following map indicates some key existing basins that could be used as irrigation regulating basins in the District.

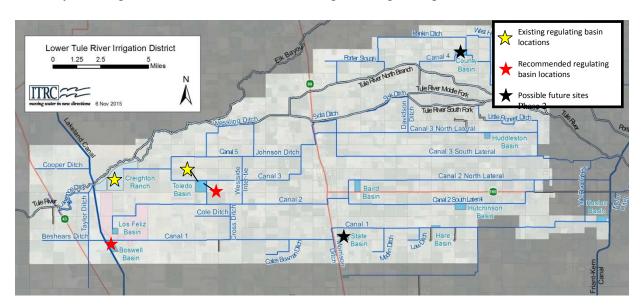


Figure 8. Map of LTRID with possible regulating basins indicated

Toledo Basin - Northeast Cell

The Toledo Basin's northeast cell is ideally located as a primary regulating basin for the District because it is downstream of many inter-connected canals, yet can have substantial acreage downhill from it (depending on how/where it is connected to the canal system).

Existing Operation

A conceptual layout/water flow of the lower portion of the District is shown in **Figure 9**. Currently, the ditchriders spill about 5 cfs each from Canals 1 and 2 to provide upstream flexibility (they can increase turnout flows by 5 cfs without needing to add that flow at the head of a canal in advance). That 10 cfs (average) then flows into Canal 3. The NW corner quarter of the Toledo Basin "floats" with the adjacent Canal 3 pool and therefore acts as a buffer reservoir with very limited capacity. The Canal 3 flow rate is re-started just downstream of the floating connection.

Creighton Ranch is a large groundwater recharge area, with cells that can be used for buffering to feed the Taylor, Lawrence, and Cooper Ditches. It is noted that having a large recharge basin so close to the downhill boundary of the District is unusual. In general, irrigation districts prefer to recharge the groundwater upslope within the District.

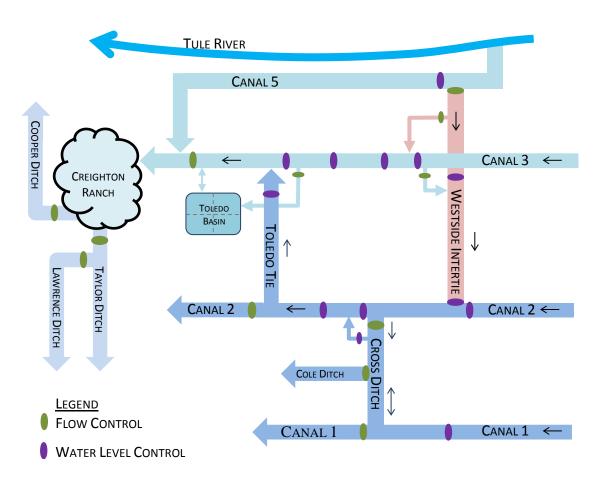


Figure 9. Conceptual sketch of the downstream end of LTRID as currently operated.

With the current operation, the majority of the Toledo Basin is operated strictly as a recharge basin. Recharge water is sometimes deliberately delivered to the Toledo Basin; during typical daily operations the recharge water consists of operational spill water from Canal 3 where it meets Canal 2.

Proposed Modernization of Toledo Basin Operation

The Toledo Basin is in an ideal location to serve as a buffer regulating reservoir. Temporary canal excesses can be diverted into the basin, and temporary downstream canal shortages can be supplied from the basin.

There are two major improvements needed for the basin itself:

- 1. There must be an effective means of removing the water from the basin.
- 2. A portion of the basin (about ¼) must be lined to prevent seepage leaving the remaining ¾ of the basin for groundwater recharge.

In addition, most of the canal bifurcations just upstream of the Toledo Basin will be modified to function differently in terms of where flow rate fluctuations are routed, and where the flows are re-regulated. **Figure 10** shows where changes will be incorporated into the canals so that part of the Toledo Basin can be used as a regulating reservoir.

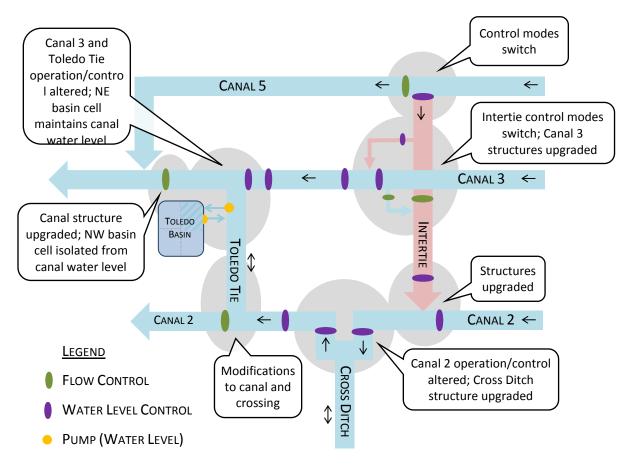


Figure 10. Changes to be incorporated into the canals

Tule River CANAL 5 COOPER DITCH CANAL 3 CREIGHTON **RANCH** TOLEDO OLEDO TIE Başın **LAWRENCE DITCH** CANAL 2 CANAL 2 LEGEND COLE DITCH FLOW CONTROL WATER LEVEL CONTROL CANAL 1 CANAL 1 PUMP (WATER LEVEL) **Excess Flows**

Figure 11 shows the final recommended configurations that are required to fully utilize the Toledo Basin.

Figure 11. New flow control and water level controls with Toledo Basin as a regulating reservoir

The net effects of the changes seen in **Figure 10** and **Figure 11** are these:

- 1. The flow rates of five canals will be re-started along an approximate North-South line just east of the Toledo Basin. These canals are:
 - a. Canal 1
 - b. Cole Ditch
 - c. Canal 2
 - d. Canal 3
 - e. Canal 5
- 2. These new re-start points will have gates for flow control, plus flow measurement. Flow rate changes (plus or minus) can be made on demand (within limits) by the ditchriders, without needing to immediately adjust flows at the head of the canal system. In essence, all five canals will become very short canals, which will be relatively easy to manage.

- 3. Upstream of these new flow control points, ditchriders and farmers will be able to operate turnouts with a higher degree of flexibility. In particular, farmers can shut off their water at any time to conserve water, and those early shutoff flows will move down and automatically spill into the Toledo Basin.
- 4. Canal 1 will deliberately be operated with an excess flow target of about 10-20 cfs, because water cannot be moved from the Toledo Basin back to the Cross Ditch. This excess water will be stored in the Boswell Basin and used to supplement flows in the Taylor Ditch (see Taylor Ditch details, starting on page 13).

See **Attachment A** for detailed structure-by-structure details of the modernization of the Toledo Basin and the surrounding canal network.

There are locations along Canals 2 and 3 that will likely have capacity restrictions for conversion to superhighways due to the shape of the canal, bank heights, crossings, etc. The Highway 99 crossings are addressed in the *Short Term Recommendations* section. The 90° curve in Canal 2, just upstream of the Toledo Basin, is a location that the District has indicated would require modification for increased capacity. There are likely a number of other locations that would also require modification; as the District proceeds with the modernization plan, it will need to identify and remediate these locations.

To determine if the District will be able to move water in the southern direction as well as the northern direction along the Toledo Tie (the end of Canal 2), an in-depth survey of the canal will be needed.

Toledo Basin Capacity

Assuming a \pm 5% discrepancy between what enters into Canals 1, 2, 3, and 5 and what is delivered to growers, the volume of regulation storage needed in the Toledo Basin is:

Volume needed = Plus/Minus Factor (2)

- × (Percent discrepancy of daily flows with flexibility)/100
- × Total canal flow rate between this reservoir and the next upstream regulation reservoir
- × [Travel Time + Reaction Time]
- = $2.0 \times (5\%/100) \times 813 \text{ cfs} \times [((18+12) \text{ hours}) \times (3600 \text{ seconds/hour})] \times (1 \text{ AF/43,560 ft}^3)$
- \approx 200 AF for Toledo Basin

The 2010 Agricultural Water Management Plan (AWMP) indicated that the greatest surface water supply occurs in August; approximately 50,000 AF of surface water enters the District in August. This value translates to an average flow rate of 813 cfs in August.

The 2010 Agricultural Water Management Plan (AWMP) indicated that the capacity of the Toledo Basin is 800 AF. The 200 AF can be obtained by converting the northeast cell to an irrigation regulating reservoir by sealing the bottom and sides, and supplying the proper in/out hardware.

Percolation losses can be eliminated by sealing both the floor and sides of the cell. A geomembrane covered with soil can be used on the floor of the reservoir. The sides should be protected from wave action, so it is recommended to use a combination of geomembrane plus shotcrete on the sides. The Huesker Canal³ geomembrane is designed so that the shotcrete adheres to the geomembrane on slopes.

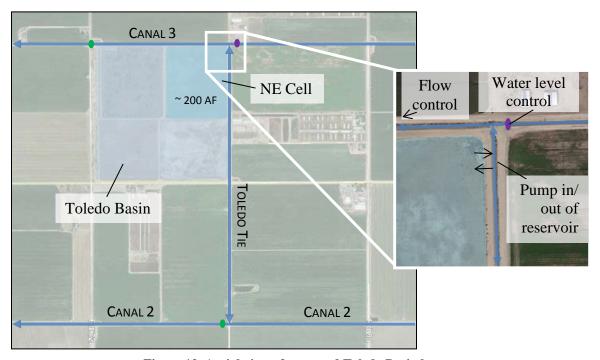


Figure 12. Aerial view of proposed Toledo Basin layout

The 200 AF value came from a variety of assumptions regarding flow rate discrepancy and the times required to respond and send a flow change from the Friant-Kern Canal. It is likely that the 5% flow rate discrepancy is too small for good flexibility. Therefore, it will be important to reduce the response and travel times for flow changes. If those times are reduced, the 200 AF could support ± 10 -15% flow discrepancies.

Reduction of the <u>response time</u> (the time it takes staff to notice a change in conditions at the reservoir, and to respond to those changes by adjusting the flow at the Friant-Kern (F-K) Canal can be achieved with a good SCADA package that will include:

- 1. Remote monitoring of the water level and trends in the Toledo Basin.
- 2. Remote control of the flow rate at the F-K Canal turnouts to Canal 2 and Canal 3.

Reduction of the <u>travel time</u> (the time it takes a flow change to arrive at the Toledo Basin, after a flow change is made at the F-K Canal), can be achieved by:

- 1. Modifying the check structures on Canals 2 and 3 between the F-K Canal and the Toledo Basin, so that they have automatic upstream water level control. This can be accomplished with complex computerized gates, or with relatively simple and static long-crested weirs.
- 2. Reducing bottlenecks at the Hwy 99 crossings of both Canals 2 and 3.

The recommendation is to improve Canal 2 first.

Supervisory Control and Data Acquisition (SCADA)

LTRID has already begun investing in a SCADA system. As the District modernizes, it will add more SCADA, as appropriate, to the system. An enhanced SCADA system would allow District personnel to monitor and control flows from the office as well as monitor reservoir water levels at key locations.

Benefits of SCADA integrated with current and future automation include:

- Real-time monitoring of flows, etc. that allows decisions to be made from the District office when canal operators may be in other locations.
- Remote adjustment of setpoints (target flows, etc.) for gates
- Alarming (a key component). If critical problems (such as decreased flow rates) occur, the SCADA system will contact District personnel and tell them about the problem immediately.

These are just a few of the potential benefits. SCADA is no longer new technology in the irrigation industry. There are numerous companies that manufacture and sell sensors, PLCs, radios, antennas, etc. However, some equipment is more suitable than others, especially in the harsh environments (temperature, dust, vandalism, etc.) common in irrigated areas.

SCADA refers to a variety of items, but <u>should not be confused</u> with the automation/control algorithms that make pumps and gates move appropriately. Most integrators (companies that install sensors, radios, office software, etc.) have algorithms that are adequate for the automation of very simple sites. However, some of the recommended controls in this report are not "simple". For example, more complex control includes:

- 1. Downstream control of flows from the Boswell Basin
- 2. Flow control from Creighton Ranch, using redundant methods of computing flow rates
- 3. In/out control for the Boswell Basin
- 4. In/out control for the Toledo Basin

When the District is ready to begin expanding its SCADA system, ITRC can write the specifications for the integrators (a "SCADA Plan"), and also provide the control code, logic, and quality control for the more complicated sites. This will include the specifications of the correct types of pumps and the VFD (Variable Frequency Drive) controls.

It will be important to have a SCADA Plan that enables the District to purchase software and hardware that will be expandable and compatible with future SCADA installations throughout the District. Such a plan also helps to ensure that the District receives quality equipment and documentation (something rarely received by districts), and that the equipment is installed appropriately.

The plan outlined below is divided into two phases. Phase 1 sites are SCADA sites that need to be completed in order for the modernization projects outlined in this report to be successful (high priority). Phase 2 sites are SCADA sites that should function properly when manually operated but automation and SCADA would allow the District to monitor and modify set points remotely (medium priority).

Table 1. SCADA Phase 1 (high priority) sites

		Automated headgate(s) and improved flow measurement	Automated inlet and outlet (likely VFD pumps)	Monitoring of basin water level	Automated downstream control	Automation, remote changing of target flows, and remote monitoring (flow is "restarted")
1	Head of Canal 2 at FKC	✓				
2	Head of Canal 3 at FKC	✓				
3	Toledo Basin		✓	✓		
4	Head of Taylor Ditch ^a	\checkmark				
5	Boswell Basin / Canal 1 / Taylor Ditch		[dep	ends on cont	rol option]	

^a This site has a fluctuating water level upstream of the gate; this means automation of the gate is necessary to have a constant flow rate through the gate.

Table 2. SCADA Phase 2 (medium priority) sites

		Automated headgate(s) and improved flow measurement	Automation, remote changing of target flows, and remote monitoring (flow is "restarted")	Remote monitoring of spill flow and water level
1	Head of Canal 5 at Tule River	✓		
2	Head of Canal 1 at FKC	✓		
3	Head of Poplar Pipeline at FKC	\checkmark		
4	Canal 1 at Cross Ditch b		✓	
5	Canal 3 at Toledo Basin b		✓	
6	Canal 2 at Toledo Tie		✓	
7	Westside Intertie at Canal 3 b		✓	
8	Canal 5 at Westside Intertie b		✓	
9	End of Taylor Ditch			✓
10	End of Lawrence Ditch			✓
11	Entrance to Creighton Ranch			✓
12	Perhaps 6 other locations			✓

^b These sites have water level control upstream of the gate; this means the flow rate through the gate(s) should remain fairly constant without automation. Upgrading these sites would allow for remote monitoring and changing of target flows in addition to automation.

Figure 13 shows the existing SCADA sites (sites at Lake Success and the power plant are not shown) as well as the sites proposed in this report.

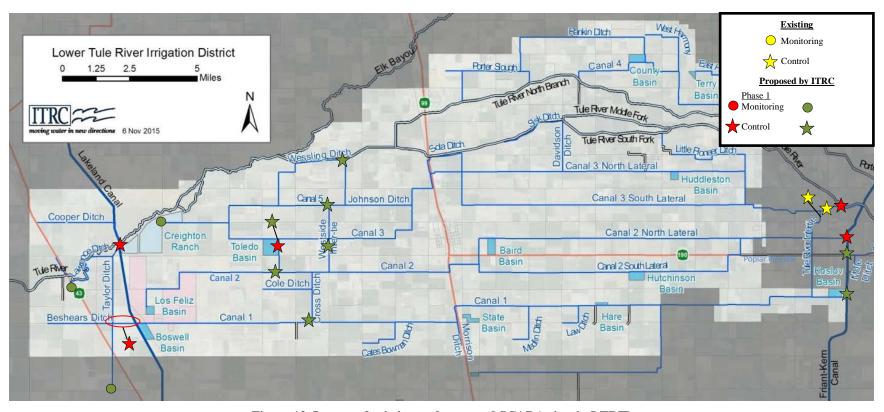


Figure 13. Layout of existing and proposed SCADA sites in LTRID

Short-Term Recommendations

The following short-term recommendations could be implemented in the near future to provide LTRID with increased performance and accurate information. These represent fairly low-cost interventions.

Poplar Pipeline

Currently, the Poplar Pipeline has issues with water surging, resulting in occasional flooding of the adjacent road. This is a common problem associated with trapped air in pipelines. The existing air vents are located only a few feet downstream of the weirs, and have been capped.

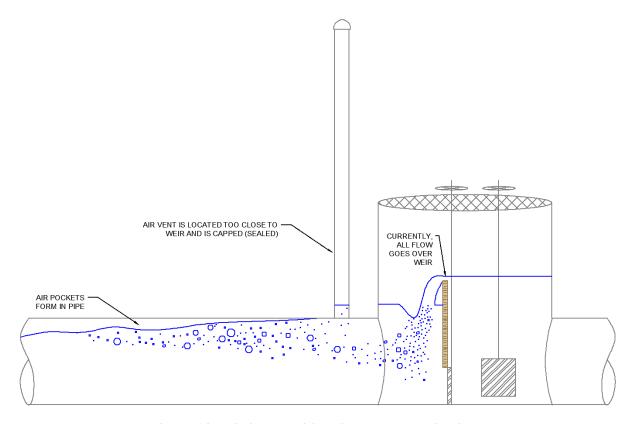


Figure 14. Existing conditions in the Poplar Pipeline

Two levels of effort are described on the next few pages. If Effort 1 is insufficient, Effort 2 can also be implemented. Work should begin at the head of the pipeline and progress downstream.

First Effort

The first effort requires two actions that are simple and inexpensive:

- 1. Route about half of the pipeline flow under the slide gate.

 This would reduce the amount of air that gets entrained in the water. The entrainment occurs because water spills over the weir. It is desirable, from a pressure control standpoint, to have about half the water flow over the weir. The negative consequence of weir flow is the air entrainment.
- 2. Open the existing air vent and route it to the turnout opening.

 This would allow surging water to spill into the turnout box, allowing air to vent and preventing surging water from flooding the adjacent road.

This modified configuration is shown in **Figure 15**.

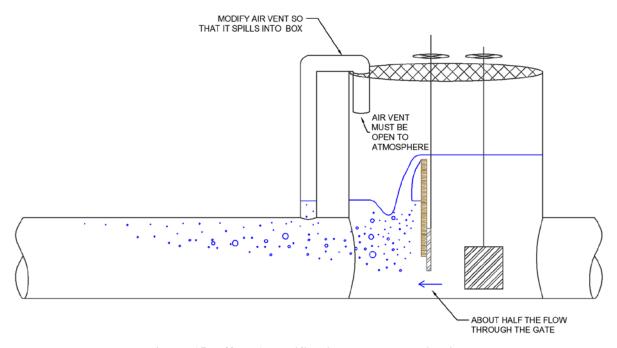


Figure 15. Effort 1 modifications to Poplar Pipeline

Second Effort

If the first effort does not sufficiently reduce the surging and remove air from the pipeline, the following additional modifications can be made:

- 1. Increase the diameter of the first air vent to 12 inches.

 This will more effectively remove air from the pipeline, and also reduce the amount of water that spurts upwards.
- 2. Install two additional 8-inch diameter air vents downstream and connect them to the first air vent.

These air vents should be located at distances of 12' and 24' downstream of the existing vent.

This modified configuration is shown in **Figure 16**.

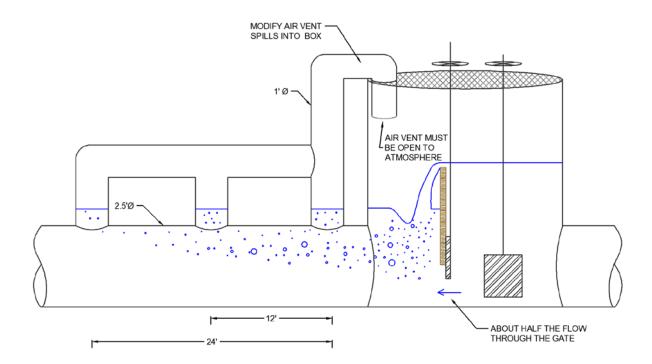


Figure 16. Effort 2 modifications to Poplar Pipeline stands

Flow Restrictions on Highway 99 Culverts

LTRID Canals 1, 2, 3, and the Sola Ditch cross under Highway 99, as shown in **Figure 17**. The canal culverts under the highway currently limit the flow that can pass downstream.

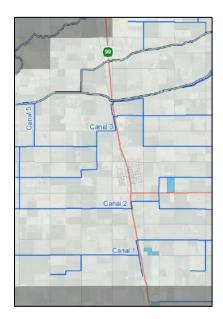


Figure 17. Highway 99 canal crossings

The culverts for Canals 1, 2, and 3 and the Sola Ditch were examined to determine the cause of the flow limitation. For all canals, both the inlet and outlet appeared to be submerged during high flows, indicating that the culverts are controlled by the downstream water level.

The recommended changes at each culvert are:

1. Drop the water level downstream of the Hwy 99 crossing. This will provide a much greater flow capacity, but it will also require the installation of infrequently used, low-lift pumps and/or addition of vortex suppression plates on the inlet to the pumps for the turnouts immediately downstream of the Hwy 99 crossing. With the caveat that water was not running during our surveying and therefore our values are not exact, it appears that:

Dropping the downstream water level by about 1.5' will double the flow rate capacity through the culverts on Canal 1 and Canal 2.

Canal 3 consists of 2 culverts (Highway 99 and a dirt road crossing just downstream). Dropping the water level downstream of the second culvert by about 1.5' will increase the flow rate capacity through the culverts on Canal 3 by about 75%.

- 2. Round and smooth the entrances to the culverts. This will have a beneficial impact, but only in the 5% range of increased flow.
- 3. Install a vortex suppression plate on the inlet to each culvert.
- 4. Keep the culverts cleaned out.

1. Downstream Water Level

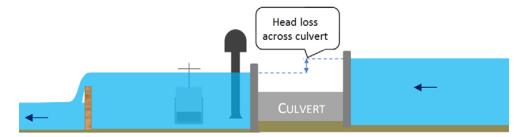


Figure 18. Current conditions in canal at culvert

Lowering the water level on the downstream side will increase the flow rate that can pass through the culvert, but this will likely require modifications to turnouts in the affected pool (the pool between the culvert outlet and the check structure). Installing a low-lift pump and/or adding a vortex plate to an existing pump can allow the water level to be lowered while still making deliveries to the affected turnouts.

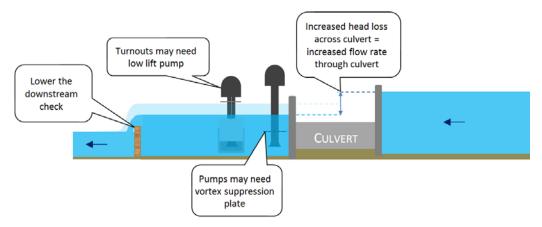


Figure 19. Modifications to canal to increase flow through culvert

2. Entrance Conditions

LTRID's culverts had either square edged (Canals 1 and 3) or nearly square edged (Canal 2) entrances.

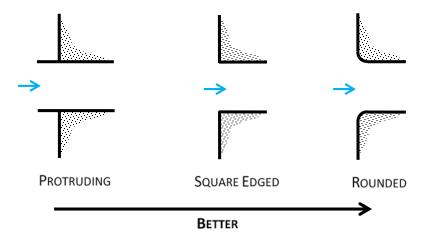


Figure 20. Common culvert entrance conditions

To improve the entrance conditions, LTRID can add a rounded (bell mouth) entrance. In new construction, the curve would typically be inward-facing. After construction (as is the case with the LTRID culverts), it may be more practical to add an outward-facing bell mouth. These two conditions are shown in **Figure 21**.

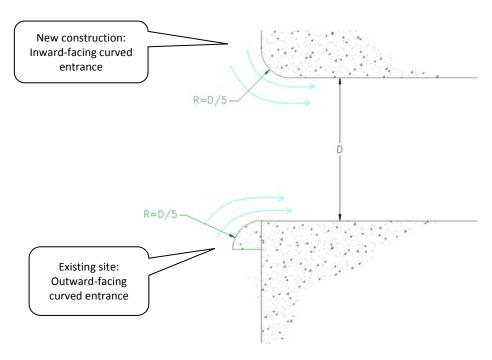


Figure 21. Curved entrance configurations on new and existing culvert sites

3. Vortex Suppression Plates on Culverts

Calculations show vortexing is likely to occur on the inlets to the culverts with the increased flows. Vortexing is a function of the submergence and inlet velocity. Without raising the inlet water level, vortexing can be minimized or prevented by reducing the inlet velocity. This can be done with a vortex suppression plate. A vortex suppression plate is a large, flat plate that is placed horizontally above the culvert but below the water level. An example layout of a vortex suppression plate with bracing is shown in **Figure 22** below.



Figure 22. Example layout of vortex suppression plate on upstream side of culvert

Dimensions for a vortex suppression plate on the upstream side of each culvert were calculated; these dimensions are based on field surveys during non-flow conditions. As such, these dimensions are estimates. However, they should improve the performance of the system and minimize vortexing.

For each culvert, the plate should be placed directly above the culvert (above the rounded entrance if an outward rounded entrance is added) and extend out 5 feet. Detailed recommendations and drawings are given in **Attachment C**. Recommendations are not given for the Sola Ditch; this site should be re-analyzed after the debris has been removed from the site. An example layout is given for the Canal 1 culvert in **Figure 23** below.

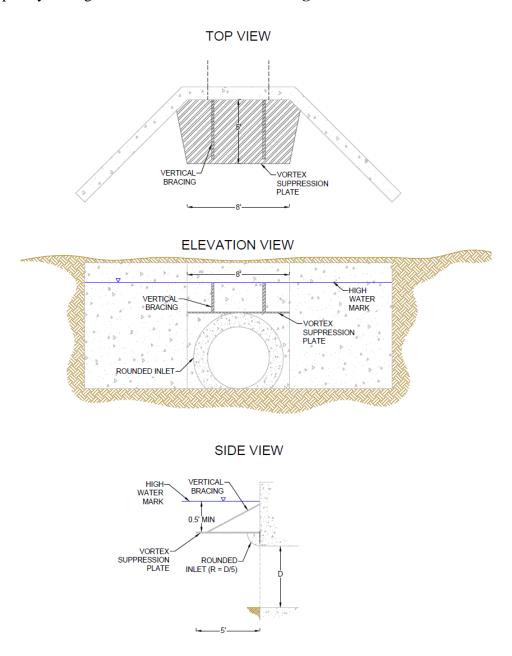


Figure 23. Example vortex suppression plate layout on Canal 1 Highway 99 culvert

4. Debris In/Around Culverts

Significant debris (including rocks, silt, and tumbleweeds) was found in the canals during the field visits. Canal 3 and the Sola Ditch were extremely congested, as shown in **Figure 24**. The debris should be removed. If debris continues to be an issue, the district should consider automatic debris screens.



Figure 24. Debris found in culverts during site visits

Canal 3 (Woods Ditch) Flume

There is a question about the accuracy of the flume measurement at the head of the Canal 3 system. **Figure 25** shows the layout of the head of the canal and the flume.

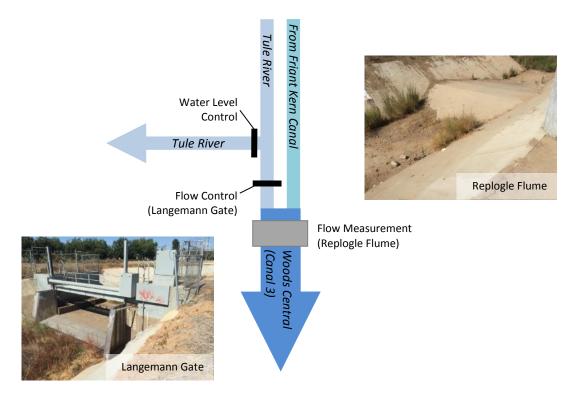


Figure 25. Overview of configuration at head of Woods Central Canal (Canal 3)

The dimensions were surveyed during a field visit, and were entered into the WinFlume program. The WinFlume program did not show any errors except at flows higher than 600 cfs, and the program provided the following head/discharge relationship:

Head, feet	CFS
0.40	20.2
1.00	85.2
2.00	259.2
3.00	509.0
3.20	567.9

The rating curve that is used by the District should be compared to the values above.

Regardless of the results of the curve comparison, three items need modification:

- 1. Cut the stilling well pipe that protrudes from the wall of the flume so that it is flush with the concrete wall. This is important.
- 2. Smooth the upstream side of the gauge by adding a patch about 2' wide, so that there is no hydraulic bump next to or on the gauge, and so that it can be read correctly. (Note: the gauge sticks out from the walls.)
- 3. Clean out the entrance (the upstream side) to the flume.

It is not known if the gauge is scaled properly. To check this, the <u>elevations above the crest of the flume</u> at various flow rate markings must be compared against the head/discharge relationship given above.

Finally, the calibration of any sensor needs to be checked to see that it has the proper offset (zero value) and slope.



Figure 26. Recommended modifications to Woods Central Canal Replogle Flume

Metergates

LTRID is adopting a standard design for its turnout metergates. The gates have incorporated many of the recommended design components. The following suggestions could help improve LTRID's design. For further information, details, and example photographs, a document summarizing metergate design is included as **Attachment D**.

- 1. The top of the stilling well pipe should be at the same elevation as either the top of the gate frame or the concrete structure. This makes it easy to determine the head difference across the gate.
- 2. The stilling well pipe should be made of a sturdy material so that canal maintenance equipment, weather, etc. does not break the pipe.
- 3. The stilling well pipe should have a cover that is easily removable. The cover protects the stilling well from filling with debris.

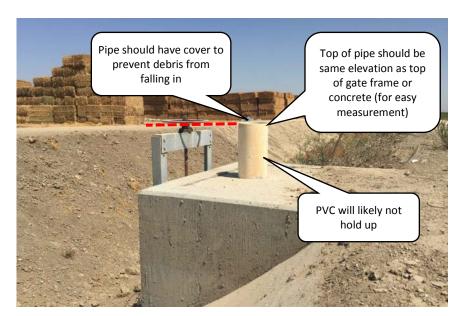


Figure 27. LTRID's metergate with suggestions for improvement

Private Reservoirs

During the field visit, it was noted that a number of the farmers had installed private reservoirs. Currently, the District estimates there are 50-100 small, private reservoirs in the District. If the farmers find that the small reservoirs have algae issues, one possible solution the District could suggest is to inject sulfurous acid, as described in this section.

Sulfur dioxide creates sulfur<u>ous</u> acid (not sulfuric acid). The sulfurous acid would be injected into the small reservoirs, upstream of any filters. Sulfurous acid is generated by an SO₂ generating machine. Clean pellets of elemental sulfur are burned. The exhaust (containing SO₂) is mixed with water, and sulfurous acid is generated. Very clean sulfur must be used as an input. The Harmon SO₂ generator (<u>www.harmonso2generators.com</u>) is a well-established product, with a straightforward chemical process. An example installation is seen in **Figure 28**.



Figure 28. Harmon SO₂ generator at Wonderful Farming in California

The basic principles are:

- 1. The sulfurous acid (H₂SO₃) is much safer to use than sulfuric acid (H₂SO₄).
- 2. The hydrogen ion of the sulfurous acid is used to reduce the water pH, and the bisulfite ion (HSO₃⁻) remains. This has anti-bacterial properties, and can prevent algae issues in reservoirs.
- 3. The acid lowers the pH of the water, which can reduce and/or eliminate carbonates and bicarbonates in the water. Their removal can be important because:
 - a. They are a cause of emitter plugging when they combine with calcium in the water.
 - b. They cause soil water infiltration problems.

The Harmon SO₂ generators have been used widely in the US for about 50 years, with continual improvements. However, it is not perfect because it requires manual lighting of the fire, manual adjustments of flow to obtain the desired pH, and an excellent supply of elemental sulfur granules. One machine would be used at each reservoir.

Well Flow Meters

A memorandum summarizing the current options for well flow meters was provided to the District and can be found in **Attachment E**.

Low-Lift Pump Flow Meter

A memorandum summarizing an option for a portable pipeline flow meter for the District to use for its yearly measurements on low-lift pumps was provided to the District and can be found in **Attachment F**.

Long-Crested Weirs

The following problems are common to irrigation districts of similar size and operation as LTRID:

- Fluctuating water levels in the canals and laterals
- Excessive labor to adjust flashboards in the canals
- Inability to modify canal flow rates throughout the day

Individual ditchriders each maintain an area of the District 24-7. Ideally, the District should have check structures that can maintain reasonable water levels without the need for adjustment, as canal flows vary.

Additionally, conventional flashboard structures typically have a significant "art" associated with their use (knowledge of the boards needed for different flows, travel times, etc.), making transfer of responsibilities (either for shift changes or due to dismissal of an employee) difficult. Where such problems exist, a common solution for irrigation districts is to install long-crested weirs in the canal.

With typical check structures found in LTRID, one of the flashboard bays would be modified as a long-crested weir. The other flashboards would remain. Two examples of this configuration are seen in **Figure 29** and **Figure 30**.

There are many specific details that go into the proper design of a long-crested weir. When the District is ready to begin installing long-crested weirs, ITRC can design the weirs.



Figure 29. Example simple long-crested weir pointing upstream. Walker River ID, Nevada.



Figure 30. Example long-crested weir pointed downstream. District (un-named to protect the guilty) employees are performing a structural test on the bridge used to access the flushing gate.

Example Location

An example of where a long-crested weir (LCW) could be utilized to provide improved water level control is at the Woods Central Canal Bifurcation Point ("The Forks"), where the Woods Central Canal (Canal 3) splits into North Canal and South Canal. Currently, the South Canal has flashboards, and the North Canal has a gate.

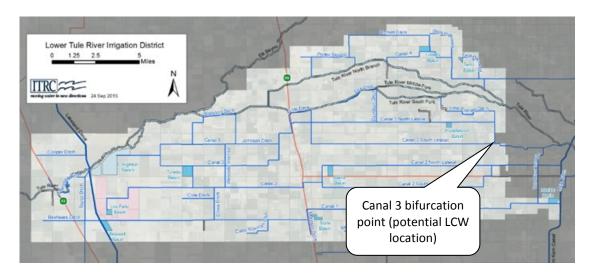


Figure 31. Location of example location for long-crested weir at Canal 3 bifurcation point

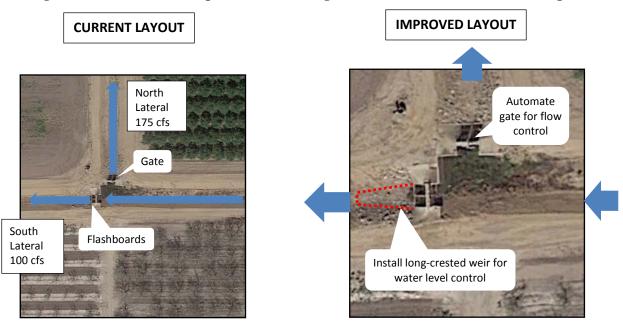


Figure 32. Example location for long-crested weir at Canal 3 bifurcation point showing current layout (left) and improved layout (right). The installation of a long-crested weir is more important than flow control automation at this site

Current Recharge versus Potential Additional Recharge with Recommendations

Over the past 15 years (2003-2017), on average, approximately 36% of the flow into the district percolates to (recharges) the groundwater through the canals. An additional 8% and 1% percolates through the basins and river, respectively, on average, resulting in a total recharge rate of about 45% of the inflow. A simplified analysis based on weather data and an estimate of the open water surface area in the district was used to estimation evaporation from the canals and basins, and showed it to be minor in comparison to deliveries and groundwater recharge. These values are summarized in Figure 33 below. Figure 34 shows that the total recharge as a percent of the inflow fluctuates between about 30% in drier years and 50% in wetter years (note that water years in the graph are March to March).

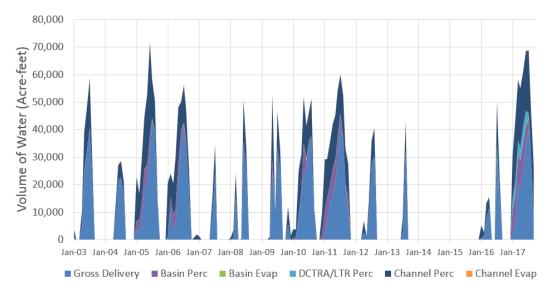


Figure 33. Distribution of flows in LTRID, monthly from 2003 to 2017

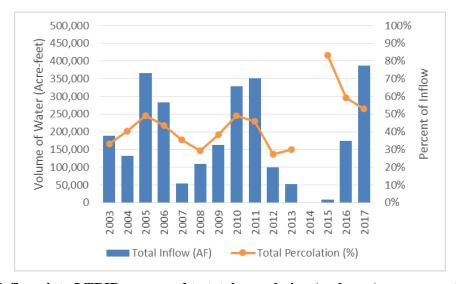


Figure 34. Inflows into LTRID compared to total percolation (recharge) as a percent of inflows, annually from 2003 to 2017

An analysis of the canal system during full capacity showed an average percolation rate of approximately 56 ft³ (418 gallons) per ft (length) of filled canal per day. This is an average value, as canal widths and depths vary throughout the system. However, it does show that a significant amount of water can percolate the canal system if it can readily and efficiently be moved through the canal system to available canals and basins for percolation.

The recommendations in this report will primarily affect the groundwater recharge in two ways:

- 1) The current primary recharge facilities are at the western (downstream) edge of the district. This recharge likely primarily benefits users outside of the district boundaries (to the west of the district). The recommendations in this report will provide the district with better control throughout the district, allowing the district to recharge groundwater at basins in the central and eastern (upstream) portions of the district. This will make the recharged water primarily available to (agricultural and residential) users within the district. This is a difficult benefit to quantify.
- 2) The improved control will also allow the district to move any available excess flows (winter or otherwise) efficiently through the district for recharge. Given the comparatively low evaporation rates (especially in the winter months), nearly all of this water should percolate and recharge the groundwater basin. As a general estimate, a 10% increase in inflow solely directed toward recharge would result in about a 23% increase in groundwater recharge. Likewise, a 20 percent increase in inflow solely directed toward recharge would result in about a 45% increase in groundwater recharge.

Attachment A Details for Toledo Basin Modifications

Overview

The overall control objective is to be able to route excesses and deficits in flow rate into and out of the Toledo Basin. Figure 9 from the main body of the report is shown below.

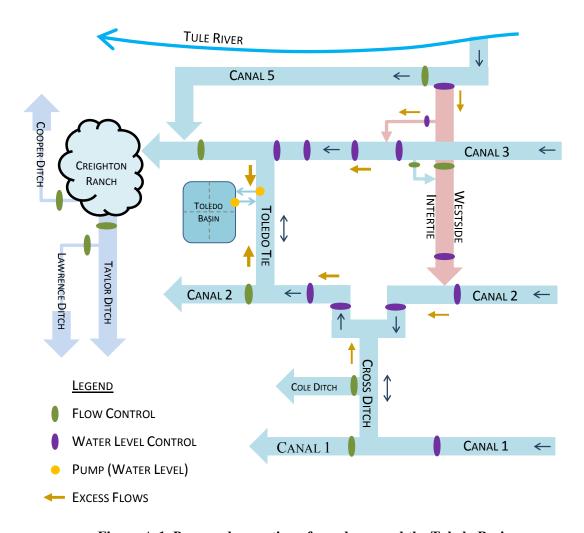


Figure A-1. Proposed operation of canals around the Toledo Basin

The following sections summarize the current and recommended operation as well as modifications to structures for the new operation of the Toledo Basin.

Canal 5 and Westside Intertie

The flow rate into the downstream portion of Canal 5 (to the west of the Westside Intertie) will be restarted at the junction between Canal 5 and the Westside Intertie.

Current Operation

Present operation is depicted in **Figure A-2** below.

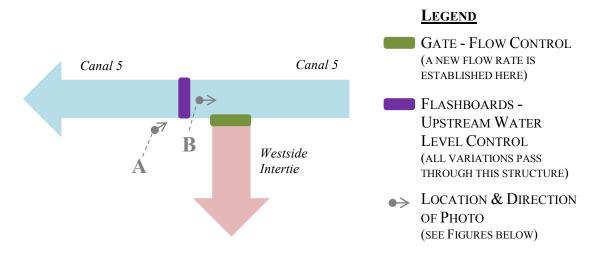


Figure A-2. Current operation at the bifurcation of Canal 5 and the Westside Intertie

- 1. The variations in Canal 5 flow pass over a flashboard structure, continue down Canal 5, and eventually flow into the Creighton Ranch. In other words, the flashboard check structure in Canal 5 is designed for manual upstream water level control.
- 2. The flow rate from Canal 5 into the Westside Intertie is controlled by two flow control gates.

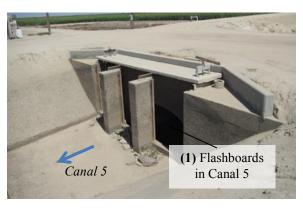


Figure A-3. Location A from Figure A-2. Existing flashboard structure for water level control in Canal 5. Located downstream of the road crossing. The photographer is facing in the NE direction (upstream is in the east direction).

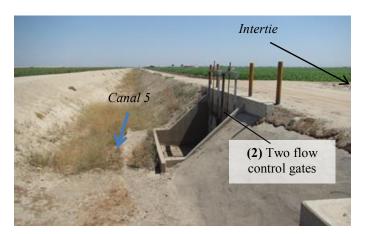


Figure A-4. Location B from Figure A-2. Existing gates that control flow into the Westside Intertie. Photo looks to the east, and upstream in Canal 5.

Proposed Modifications

The functions of the existing structures will be switched, which will also require different structures at both locations. Specifically,

1. Just downstream of the road crossing of Canal 5, the flow rate will be controlled and measured in the structure. The flow control gates (recommendation: rectangular sluice gates) must be installed downstream of the road crossing because two turnouts are located there.

The flashboards in Canal 5 will be replaced with two rectangular sluice gates. They could be automated for flow control or could be manually operated. As indicated in the main report, this site is considered a "Phase 2" (medium priority) SCADA site. The long-crested weir (item 2, below) will keep a fairly constant water level upstream of the flow control gates, so even with manual control, the flow through those gates should remain fairly constant. However, automation is recommended for this site because it will allow the District to remotely monitor and adjust the flow rate through the gates.

Some surveying of elevations would be necessary to determine if a flume could be used downstream for flow <u>measurement</u>, but it is likely that the flow measurement will be done using the values of the water level difference across the gates, plus the gate openings.

2. The structure at the beginning of the Westside Intertie (the northern entrance, which is fed by Canal 5), will control the water level in Canal 5.

A long-crested weir will be installed in the Intertie downstream of the road crossing and turnouts. The design of the length of the long-crested weir and the crest height will require some survey information regarding freeboard and the drop available across the new sluice gates. It may be possible to use an ITRC flap gate here if there is sufficient drop.

3. The existing two gates at the head of the Westside Intertie will remain in place.

The existing two gates will remain in place to maintain the ability to stop flow from entering the Intertie. During normal operation, those two gates will be kept fully open.

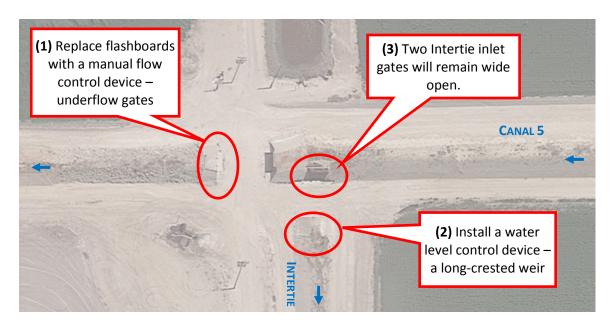


Figure A-5. Recommended structure and function changes at the intersection of Canal 5 and the Westside Intertie

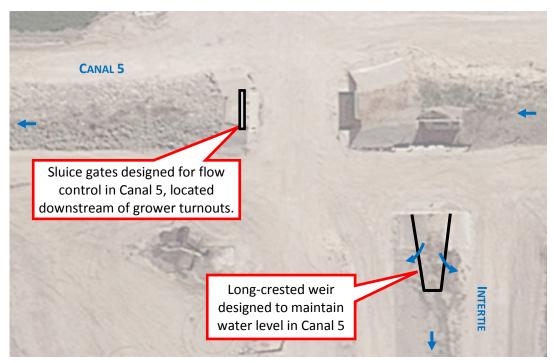


Figure A-6. Recommended structure layout at the intersection of Canal 5 and the Westside Intertie

The net result for operations will be:

- a) The Canal 5 flow rate will be re-started at this bifurcation point, allowing the remainder of Canal 5 (downstream) to be operated as a very short canal.
- b) The long-crested weir should always have some flow over it, into the Intertie, to provide flexibility in operation along Canal 5.
- c) The variable flow over the long-crested weir will be captured in the Toledo Basin.

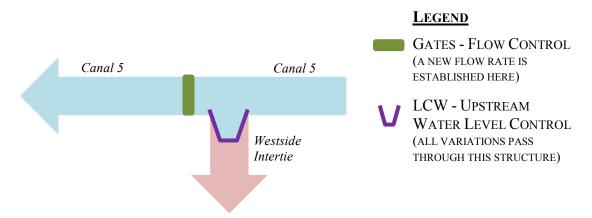


Figure A-7. New operation at the bifurcation of Canal 5 and the Westside Intertie

Canal 3 and Westside Intertie

The flow rate into the downstream portion of the Westside Intertie (to the south of Canal 3) will be restarted at the junction between Canal 3 and the Westside Intertie.

Current Operation

Present operation is depicted in **Figure A-8** below.

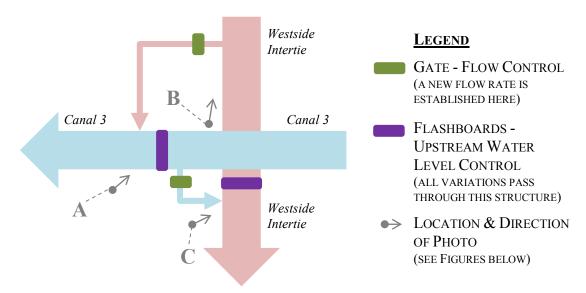


Figure A-8. Current operation at the bifurcation of Canal 3 and the Westside Intertie

- 1. The variations in Canal 3 flow pass over a flashboard structure, continue down Canal 3, and eventually flow into either the Toledo Basin and/or Creighton Ranch. In other words, the flashboard check structure in Canal 3 is designed for manual upstream water level control.
- 2. One of the turnouts upstream of the flashboard structure in Canal 3 allows the District to deliver a specific flow to the Intertie.
- 3. The variations in the Intertie flow pass over a flashboard structure just downstream of Canal 3, continue down the Intertie into Canal 2, and eventually flow into the Toledo Basin and/or Creighton Ranch. In other words, the flashboard check structure in the Intertie is designed for manual upstream water level control.
- 4. Through an upstream gate, the Westside Intertie can deliver a specific flow to Canal 3 downstream of the Canal 3 flashboard structure

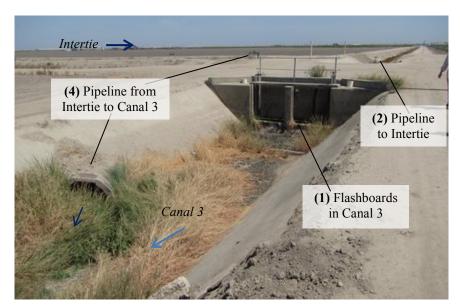


Figure A-9. Location A from Figure A-8. View toward the northeast, looking upstream along Canal 3. The Westside Intertie flows from left to right, under Canal 3.



Figure A-10. Location B from Figure A-8. View toward the north, looking upstream along the Intertie.



Figure A-11. Location C from Figure A-8. View toward SE of the Intertie after flowing under Canal 3 (Canal 3 is shown on left).

Proposed Modifications

The functions of the structures in the Westside Intertie will be switched, which will require different structures at two locations. The function of the structure in Canal 3 will remain the same, but an upgrade to the structure is also recommended. Specifically,

1. The flow rate in the Intertie will be controlled and measured at the structure just downstream of Canal 3. The structure will consist of flow control gates (recommendation: rectangular sluice gates).

The flashboards in the Intertie will be replaced with rectangular sluice gates. They could be automated for flow control or could be manually operated. As indicated in the main report, this site is considered a "Phase 2" (medium priority) SCADA site. The long-crested weir (item 2, below) will keep a fairly constant water level upstream of the flow control gates, so even with manual control, the flow through those gates should remain fairly constant. However, automation is recommended for this site because it will allow the District to remotely monitor and adjust the flow rate through the gates.

Some surveying of elevations would be necessary to determine if a flume could be used downstream for flow <u>measurement</u>, but it is likely that the flow measurement will be done using the values of the water level difference across the gates, plus the gate openings.

2. The structure in the Westside Intertie, just upstream of Canal 3, will maintain the water level in the Westside Intertie (recommendation: long-crested weir).

A long-crested weir will be installed in the Intertie just upstream of the Canal 3 crossing. The existing gate will remain in place, to maintain the ability to stop flow from entering the Intertie. During normal operation, the gate will be kept fully open. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard and the drop available across the new sluice gates. It may be possible to use an ITRC flap gate here if there is sufficient drop.

3. The water level in Canal 3 will continue to be maintained by a structure just downstream of the Westside Intertie crossing and turnouts (recommendation: long-crested weir)

The flashboards in Canal 3 will be replaced with a long-crested weir for better water level control. The long-crested weir should be located downstream of the road crossing and turnouts. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard, and the drop available across the existing sluice gate. It may be possible to use an ITRC flap gate here if there is sufficient drop.

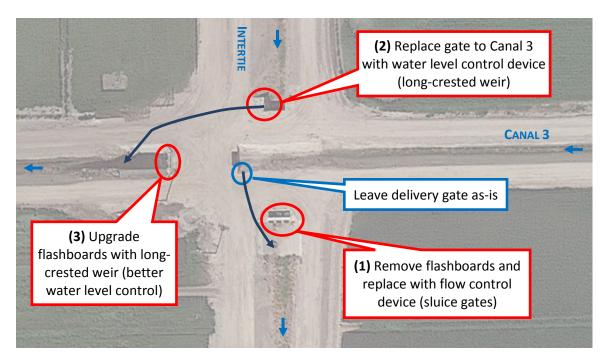


Figure A-12. Recommended structure and function changes at the bifurcation of the Westside Intertie and Canal 3.

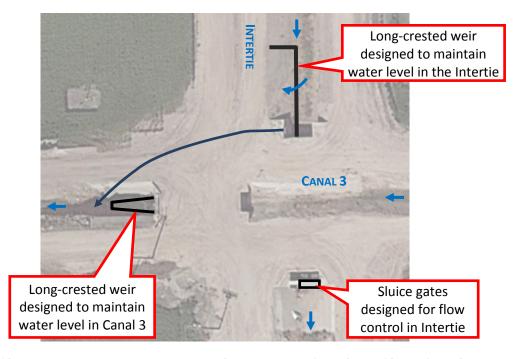


Figure A-13. Recommended structure layout for new operation of the bifurcation of the Westside Intertie and Canal 3, not to scale.

The net result for operations will be:

- a) The Westside Intertie flow rate will be re-started at this bifurcation point.
- b) Both of the long-crested weirs should always have some flow over them, into Canal 3, to provide flexibility in operation along Canal 3 and the Westside Intertie.
- c) The variable flows over the long-crested weirs will be captured in the Toledo Basin via Canal 3.

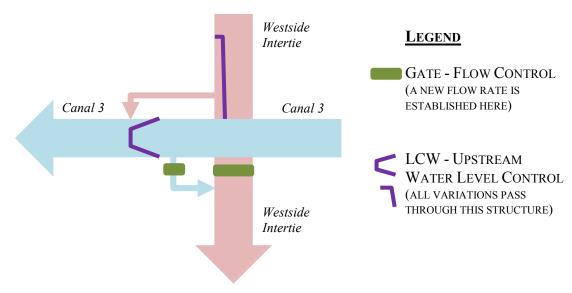


Figure A-14. New operation at the bifurcation of Canal 3 and the Westside Intertie

Canal 2 and Westside Intertie

The upstream water level control structures will be upgraded to provide better water level control in the canals despite varying flows.

Current Operation

Present operation is depicted in **Figure A-15** below.

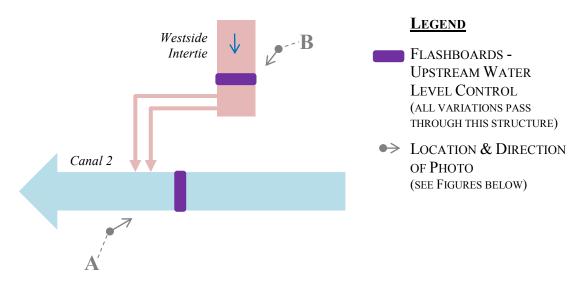


Figure A-15. Current operation at the bifurcation of Canal 2 and the Westside Intertie

- 1. The variations in Canal 2 flow pass over a flashboard structure, continue down Canal 2, and eventually flow into the Toledo Basin and/or Creighton Ranch. In other words, the flashboard check structure in Canal 2 is designed for manual upstream water level control.
- 2. The flow in the Intertie passes over a flashboard structure, through two parallel pipelines, and into Canal 2. The flashboard check structure in the Westside Intertie is designed for manual upstream water level control.

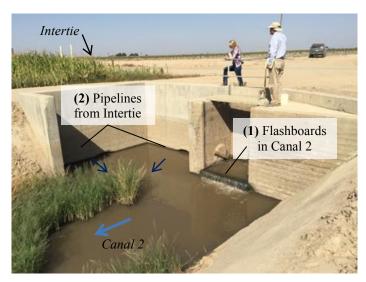


Figure A-16. Location A from Figure A-15. Existing flashboard structure for water level control in Canal 2 and pipeline outlets of flow from the Intertie. Located downstream of the road crossing. The photographer is facing in the NE direction.



Figure A-17. Location B from Figure A-15. Existing flashboard structure that maintains water level in the Westside Intertie before spilling into Canal 2 through two pipelines. Photo looks to SW.

Proposed Modifications

The functions of the existing structures in the Westside Intertie and Canal 2 will remain the same. However, the structures used should be upgraded to provide better control despite varying flows. Specifically,

1. The water level in Canal 2 will continue to be maintained by a structure just upstream of the Intertie outlet (recommendation: long-crested weir).

The flashboards in Canal 2 will be replaced with a long-crested weir downstream of the road crossing and turnouts for better water level control. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard and the drop available across upstream turnouts. It may be possible to use an ITRC flap gate here if there is sufficient drop.

2. The water level in the Westside Intertie will continue to be maintained by a structure upstream of the Canal 2 intersection.

The existing flashboards may need to be replaced with a long-crested weir. A long-crested weir would provide a near-constant downstream water level on the Westside Intertie gates at Canal 3. This would allow for simple adjustment of the flow through the gates (the upstream and downstream water levels would be constant).

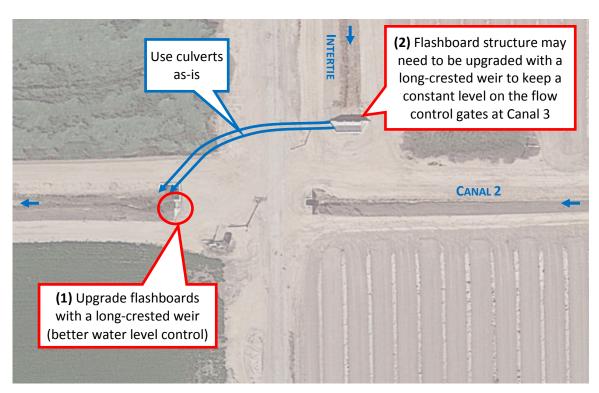


Figure A-18. Recommended structure and function changes at the bifurcation of the Westside Intertie and Canal 2.

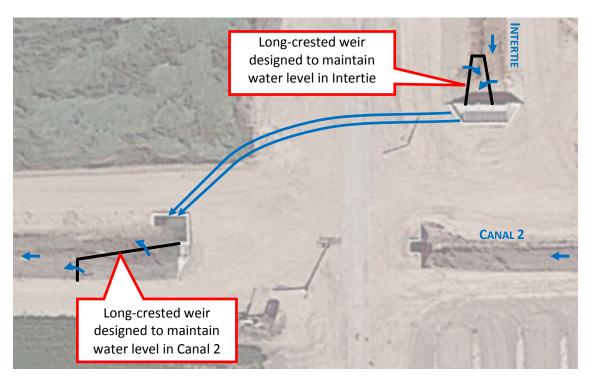


Figure A-19. Recommended structure layout at the bifurcation of the Westside Intertie and Canal 2, not to scale.

The net result for operations will be:

- a) The long-crested weirs should maintain constant upstream water levels despite varying flows without any manual adjustment.
- b) Both of the long-crested weirs should always have some flow over them, into Canal 2, to provide flexibility in operation along Canal 2 and allow easy adjustment of the upstream flow rate in the Westside Intertie.
- c) The variable flows from the Westside Intertie and Canal 2 will be captured in the Toledo Basin.

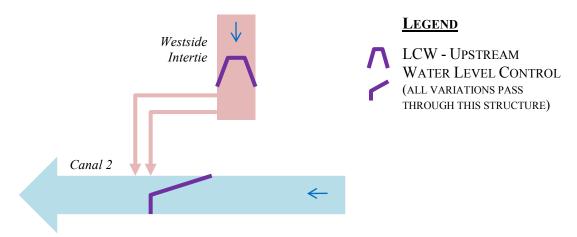


Figure A-20. New operation of the bifurcation of the Westside Intertie and Canal 3 – same as current operation.

Canal 2 and Cross Ditch

Excess flows in Canal 2 will flow into the Cross Ditch, which will, in turn, flow back into Canal 2, providing flexibility to turnouts along the two canals.

Current Operation

Present operation is depicted in Figure A-21 below.

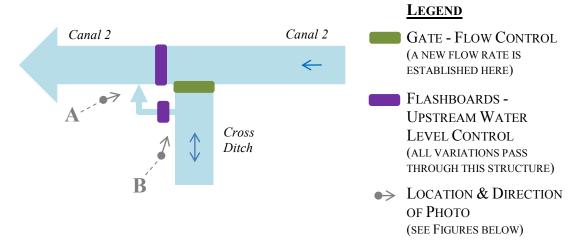


Figure A-21. Current operation at the bifurcation of Canal 2 and the Cross Ditch

- 1. The variations in Canal 2 flow pass over a flashboard structure, continue down Canal 2, and eventually flow into the Toledo Basin and/or Creighton Ranch. In other words, the flashboard check structure in Canal 2 is designed for manual upstream water level control.
- 2. The flow rate from Canal 2 into the Cross Ditch is controlled by one flow control gate.
- 3. The variations in Cross Ditch flow pass over a flashboard structure into Canal 2, continue down Canal 2, and eventually flow into the Toledo Basin and/or Creighton Ranch. In other words, the flashboard check structure in Cross Ditch is designed for manual upstream water level control.

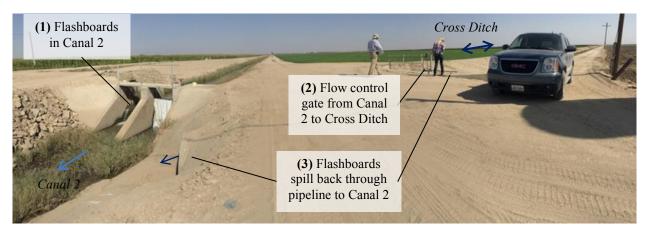


Figure A-22. Location A from Figure A-21. View toward NE, looking upstream along Canal 2. The start of the Cross Ditch is shown on the right.

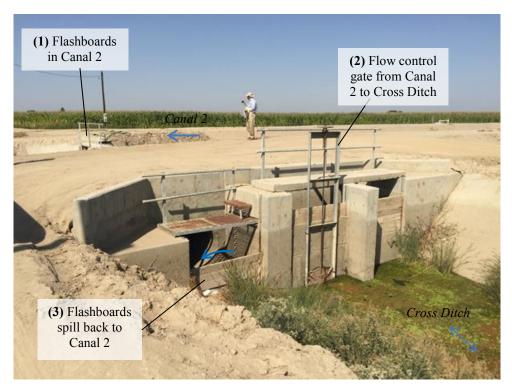


Figure A-23. Location B from Figure A-21. View toward NE of the Cross Ditch headworks at Canal 2 (Canal 2 flows right to left).

Proposed Modifications

Rather than providing a delivery (specific flow rate) to the Cross Ditch, all flows from Canal 2 will be routed into the Cross Ditch. Excess flows will be routed back into Canal 2 downstream (as they currently are). Specifically,

1. The water level in Canal 2 upstream will be maintained by a water level control device (recommendation: long-crested weir). The device will be located in the canal, upstream of the existing slide gate.

A long-crested weir will be installed in Canal 2. A long-crested weir will allow Canal 2 to maintain a constant water level despite varying flows without any manual adjustment. The design of the length and crest height of the long-crested weir is given on the next few pages.

2. As it is currently operated, the water level in the Cross Ditch will be maintained by a water level control device (recommendation: long-crested weir).

The existing flashboards will be replaced with a long-crested weir for better water level control. A long-crested weir will allow the Cross Ditch to maintain a constant water level despite varying flows without any manual adjustment. The design of the length and crest height of the long-crested weir is given on the next few pages.

3. A second culvert will be added next to the existing culvert from the Cross Ditch to Canal 2. As the flow from Cross Ditch to Canal 2 will increase significantly (all flow routed through Cross Ditch), the existing culvert from Cross Ditch to Canal 2 will not be

- sufficient. A second culvert will be added next to the existing culvert. The design of the culvert size and elevations is given on the next few pages.
- 4. The existing flashboard structure in Canal 2 should be kept closed, routing all flows from upper Canal 2 into the Cross Ditch.

The existing flashboard structure will remain in place to maintain the ability to route flow around the Cross Ditch. During normal operation, the flashboard structure will be kept fully closed.

5. The existing gate and flashboard structure from Canal 2 to the Cross Ditch can remain in place. The existing gate and flashboard structure will remain in place to maintain the ability to stop flow from entering the Cross Ditch. During normal operation, the gate and flashboard structure will be kept fully open.

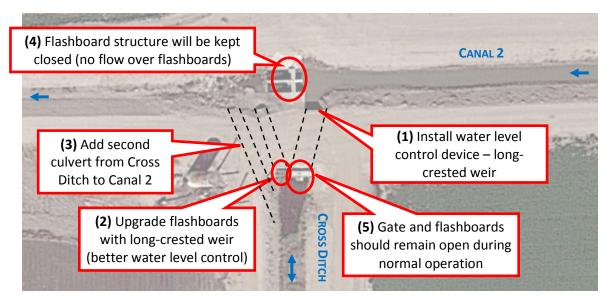


Figure A-24. Recommended structure and function changes at the intersection of Canal 2 and the Cross Ditch

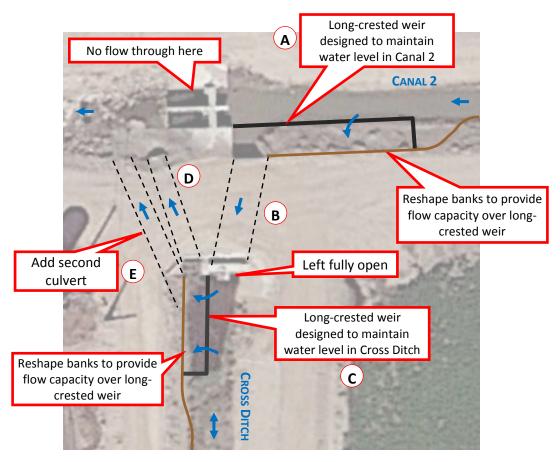


Figure A-25. Recommended structure layout at the intersection of Canal 2 and the Cross Ditch – not to scale

Design Details

All elevations given below are based on a reference elevation of 100.00' on the concrete structure in the Cross Ditch (shown in **Figure A-26**). Letters are indicated in **Figure A-25** above.



Figure A-26. New operation at the bifurcation of Canal 2 and the Cross Ditch

A. New Long-Crested Weir from Canal 2 to Cross Ditch

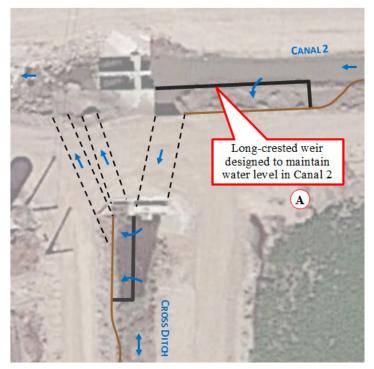


Figure A-27. Location of new long-crested weir from Canal 2 to the Cross Ditch – not to scale

Length = 100 ft Elevation of crest = 98.29'

Upstream water level at high flow (120 CFS) = 98.93'

→ The existing high water level in Canal 2 is 98.68'. This means the high water level will be raised by about 0.25'. This does not appear to be an issue with the existing structures that will remain, but it should be verified that the structures do not need to be modified to accommodate the increased water level.

B. Existing Culvert from Canal 2 to Cross Ditch

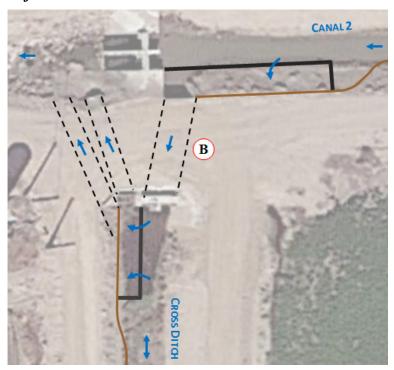


Figure A-28. Location of existing culvert from Canal 2 to the Cross Ditch – not to scale

Diameter = 6' Invert of culvert ≈ 88.97 ' (approximately flat)

C. New Long-Crested Weir from Cross Ditch to Canal 2

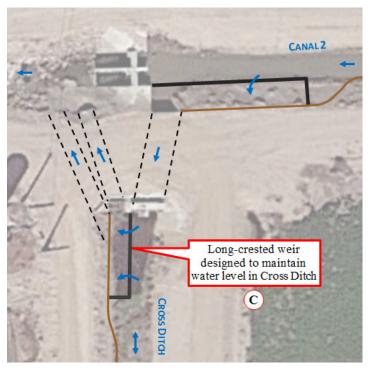


Figure A-29. Location of new long-crested weir from the Cross Ditch to Canal 2 – not to scale

Length = 100 ft Elevation of crest = 97.19'

Upstream water level at high flow (145 CFS) = 97.85'

→ This is the existing high water level in Cross Ditch.

D. Existing Culvert from Cross Ditch to Canal 2

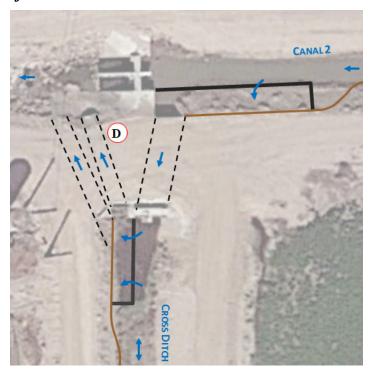


Figure A-30. Location of existing culvert from the Cross Ditch to Canal 2 – not to scale

Diameter = 3.5' Invert of culvert ≈ 94.04 ' (approximately flat)

E. New Culvert from Cross Ditch to Canal 2

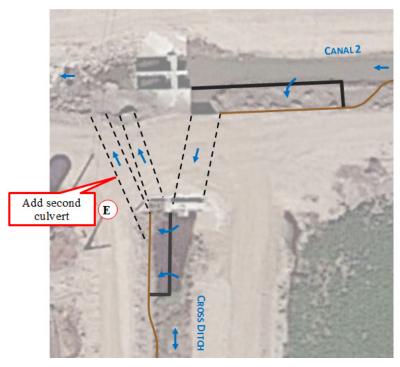
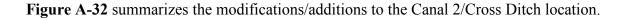


Figure A-31. Location of new culvert from the Cross Ditch to Canal 2 – not to scale

Diameter = 4.5' Invert of culvert = 92.00' (flat)



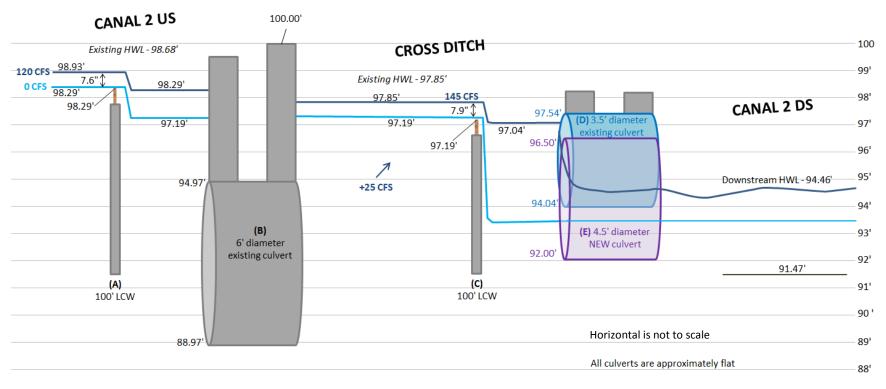


Figure A-32. Layout and elevations of Canal 2 and Cross Ditch Intersection

The net result for operations will be:

- a) The long-crested weir from upper Canal 2 should always have some flow over it, into the Cross Ditch, to provide flexibility in operation to the turnouts upstream in Canal 2.
- b) The long-crested weir from the Cross Ditch should always have some flow over it, into lower Canal 2, to provide flexibility in operation to the turnouts off of the Cross Ditch (Cole Ditch and lower Canal 1).
- c) The variable flow over the long-crested weirs will be captured in the Toledo Basin.

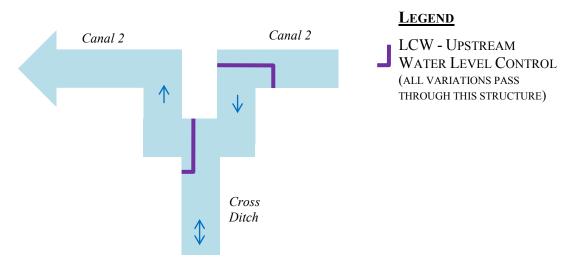


Figure A-33. New operation at the bifurcation of Canal 2 and the Cross Ditch

Canal 2 and the Toledo Tie

The structures at the bifurcation of Canal 2 and the Toledo Tie will remain the same, but the surrounding canal will need to be modified.

Operation

Present operation is depicted in Figure A-34 below.

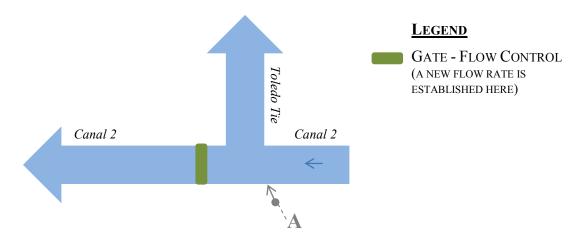


Figure A-34. Operation at the bifurcation of Canal 2 and the Toledo Tie

- 1. The flow rate into lower Canal 2 from Canal 2 is controlled by two flow control gates.
- 2. The variations in Canal 2 flow continue down the Toledo Tie, and eventually flow into the Toledo Basin and/or Creighton Ranch.



Figure A-35. Location A from Figure A-36. View toward the NW at bifurcation of Canal 2 and Toledo Tie.

Proposed Modifications

The Toledo Tie, intersection of Canals 2 and 3, and the Toledo Basin will be modified to allow water to flow from upper Canal 2 to the Toledo Basin, or from the Toledo Basin to lower Canal 2. Specifically,

1. Upper Canal 2 and the Toledo Tie is a single, floating pool from this location to the end of the canal

The Canal 2/Toledo Tie pool will be connected with Canal 3 to create a larger pool ("Toledo Tie pool"). Under the new plan, the water level in this pool will be maintained by the Toledo Basin.

- 2. A second culvert will need to be added adjacent to the existing culvert at Avenue 144. A 60" culvert will be installed adjacent to the existing culvert at the road crossing at Avenue 144. This second culvert will allow the District to increase flows from upper Canal 2 (the "superhighway") to the Toledo Basin.
- 3. The Toledo Tie should be widened.

The Toledo Tie should be widened to ensure increased flows can be delivered from upper Canal 2 to the Toledo Basin (the "superhighway"), and that the water level fluctuations upstream of the gates to lower Canal 2 are minimized. Minimizing fluctuations in water level upstream of the flow control gates will provide a more constant water level to lower Canal 2.

4. The flow rate for lower Canal 2 will be controlled and measured in the existing structure with automation.

The existing gates will be automated for flow control. As indicated in the main report, this site is considered a "Phase 2" (medium priority) SCADA site. The varying flow and direction of flows in the Toledo Tie will cause the water level on the upstream side of this site to vary. Because of this, automation could be used to maintain a more constant flow rate through the gates. Additionally, the SCADA system will allow the District to remotely monitor and adjust the flow rate through the gates.

Some surveying of elevations is necessary to determine if a flume could be used downstream for flow <u>measurement</u>. But it is likely that the flow measurement will be done using the values of the water level difference across the gate, plus the gate opening.

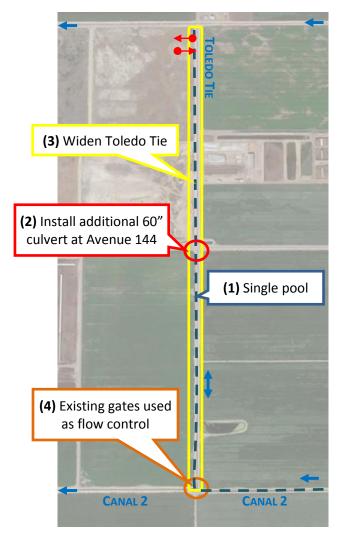


Figure A-37. Recommended structure and function at the intersection of Canal 2 and the Toledo Tie

The net result for operations will be:

- a) The lower Canal 2 flow rate will be re-started at this bifurcation point.
- b) The additional culvert and widened canal should allow high flows to flow from Canal 2 to the Toledo Basin without a significant change in water level between the Toledo Basin and lower Canal 2.
- c) The alterations should also allow water to flow from the Toledo Basin and/or Canal 3 to lower Canal 2.

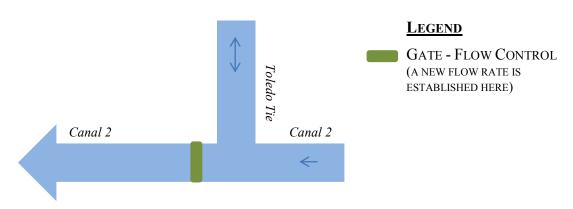


Figure A-38. New operation at the intersection of Canal 2 and the Toledo Tie

Toledo Tie (Canal 2), Canal 3 and the Inlet to the Toledo Basin

The flow rate into the downstream portion of Canal 3 (to the west of the Toledo Tie intersection) will be restarted. The water level in the Toledo Tie and Canal 3 (a shared pool) will be regulated with the Toledo Basin's northeast cell.

Current Operation

Present operation is depicted in Figure A-39 below.

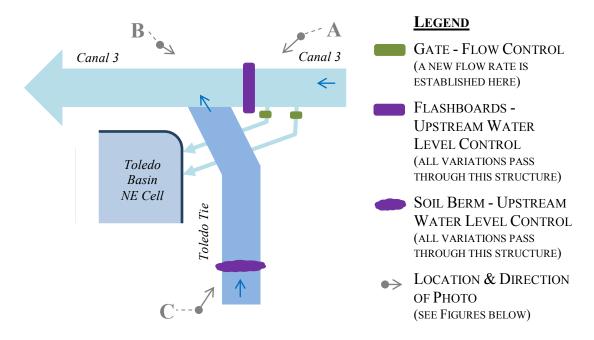


Figure A-39. Current operation at the intersection of the Toledo Tie, Canal 3, and the Toledo Basin

- 1. The variations in Canal 3 flow pass over a flashboard structure, continue down Canal 3, and eventually flow into the northwest cell of the Toledo Basin and/or Creighton Ranch. In other words, the flashboard check structure in Canal 3 is designed for manual upstream water level control.
- 2. The flow rate from Canal 3 into the northeast cell of the Toledo Basin is controlled by two separate flow control gates.
- 3. The variations in Toledo Tie (Canal 2) flow pass over a soil berm in the canal just downstream of the last turnout, flow into lower Canal 3, and eventually flow into the northwest cell of the Toledo Basin and/ or Creighton Ranch. In other words, the soil berm in the Toledo Tie is a manual upstream water level control structure.

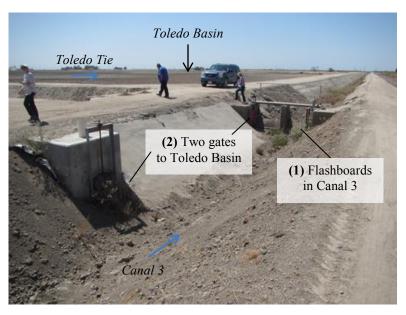


Figure A-40. Location A from Figure A-39. View toward SW of Toledo Basin from Canal 3. The end of the Toledo Tie is on the left.

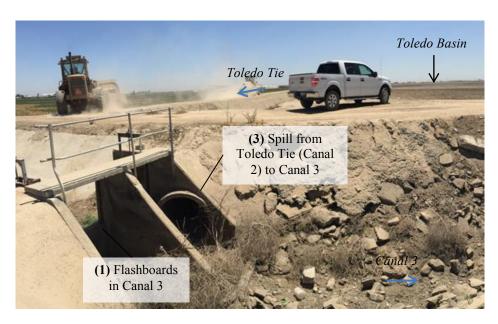


Figure A-41. Location B from Figure A-39. View toward SE from Canal 3 (Canal 3 flows left to right). Toledo Basin is in background on right; the end of the Toledo Tie is in background.



Figure A-42. Location C from Figure A-39. View toward NE from of soil berm in Toledo Tie (Canal 2) (Canal 3 flows right to left in background of photo).

The pools in the Toledo Tie and Canal 3 will be combined and the function of the existing Canal 3 structure will be switched, which will require a different structure. The Toledo Basin will maintain the water level in the new pool, which will also require new structures. Specifically,

1. The water level in Canal 3 will be maintained by a structure just upstream of the Toledo Tie/Canal 3 connection (recommendation: long-crested weir).

The flashboards in Canal 3 will be replaced with a long-crested weir downstream of the existing turnout for better water level control. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard and the drop available across upstream turnouts.

2. The Toledo Tie and Canal 3 (downstream of new long-crested weir) pools will be combined. A new culvert will be installed between the two.

The two pools will be combined and float. This will require a new culvert with minimal head loss to replace the existing culvert. This will allow lower Canal 2 and lower Canal 3 (as well as any grower turnouts in the pool) to all be supplied by the Toledo Basin.

3. The northeast cell of the Toledo Basin will be modified for water regulation, rather than infiltration.

To minimize infiltration losses in the northeast cell of the Toledo Basin, the floor and sides should be lined. The floor of the cell could be lined with a geomembrane covered

with soil. The sides could use a combination of geomembrane plus shotcrete to protect the sides from wave action. The Huesker Canal³ geomembrane is designed so that the shotcrete adheres to the geomembrane on slopes.

4. Pumps, water level sensors, a PLC, and related equipment will be installed to regulate the new Toledo Tie pool with the northeast cell of the Toledo Basin.

Pumps and water level sensors will be installed in the Toledo Tie pool and the northeast cell of the Toledo Basin. The pump(s) in the Toledo Tie pool will pump water from the pool to the Toledo Basin if the water level in the pool is too high. The pump(s) in the Toledo Basin will pump water from the Toledo Basin to the pool if the water level in the pool is too low. Together, the pumps should maintain a constant water level in the Toledo Tie pool. The water level in the Toledo Basin should be viewable remotely via SCADA. The actual control elevation will be dependent on the elevations of limiting structures (such as culverts in the pool).

5. The Toledo Basin should be modified to allow excess water to spill from the northeast cell to the other three cells should the water level in the northeast cell get too high.

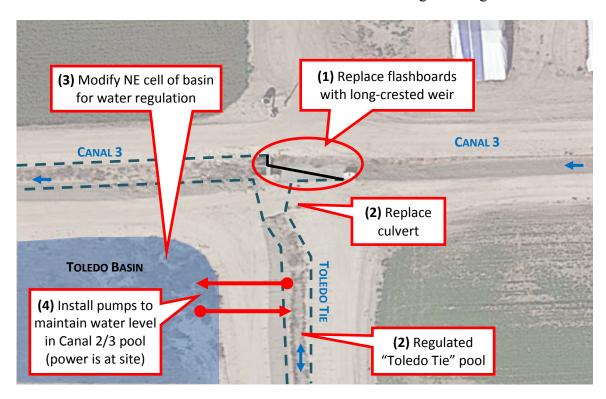


Figure A-43. Recommended structure and function changes at the intersection of Canal 2 (Toledo Tie), Canal 3, and the Toledo Basin.

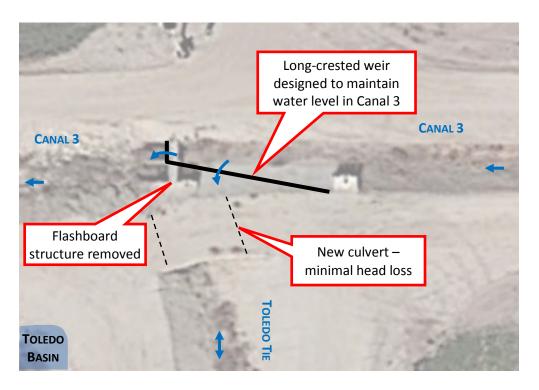


Figure A-44. Recommended structure layout at the intersection of Canal 2 (Toledo Tie), Canal 3, and the Toledo Basin.

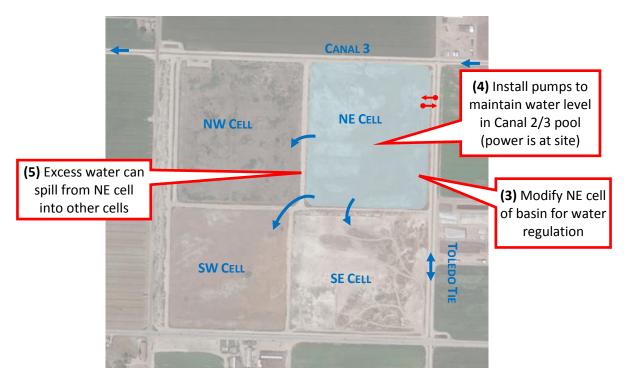


Figure A-45. Recommended structure and function changes to the Toledo Basin.

- a) The long-crested weir should always have some flow over it to provide flexibility in operation along upper Canal 3.
- b) The variable flow over the long-crested weir will be captured in the Toledo Basin.
- c) Combining the Toledo Tie (Canal 2) and Canal 3 pools will provide greater downstream acreage that the Toledo Basin can supply water to.
- d) The regulation of the Toledo Tie pool water level by the Toledo Basin will allow the District to provide greater flexibility to growers while preserving surface water supplies.

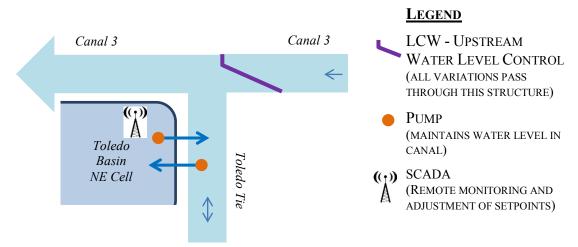


Figure A-46. New operation at the intersection of the Toledo Tie, Canal 3, and the Toledo Basin.

Canal 3 and the Outlet from the Toledo Basin

Canal 3 will no longer be regulated by the northwest cell of the Toledo Basin. Instead, Canal 3 will float with the end of Canal 2 (the Toledo Tie), which will be regulated by the northeast cell of the Toledo Basin. Because of this, the structure in Canal 3 adjacent to the northwest cell will be flow control.

Current Operation

Present operation is depicted in **Figure A-47** below.

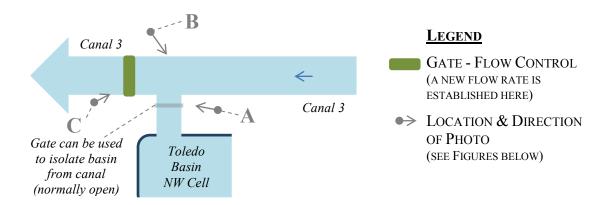


Figure A-47. Current operation at Canal 3 and the Toledo Basin northwest cell

Presently,

- 1. The flow rate into lower Canal 3 is controlled by one flow control gate and one flashboard bay.
- 2. The variations in Canal 3 flow are regulated with the northwest cell of the Toledo Basin. The basin "floats" with the Canal 3 pool, providing storage. A gate can be closed to isolate the basin from the canal; the gate is open during normal operation.

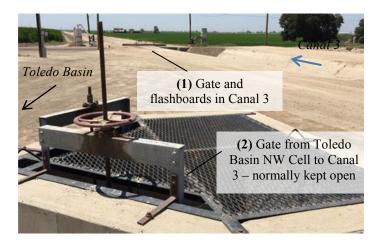


Figure A-48. Location A from Figure A-47. View east looking downstream in Canal 3. The Toledo Basin is located to the left (outside of image).



Figure A-49. Location B from Figure A-47. View SE looking at Toledo Basin outlet in Canal 3. The Toledo Basin is located to the background. Canal 3 flows left to right in image.

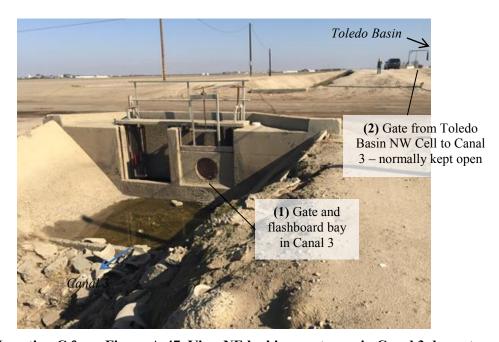


Figure A-50. Location C from Figure A-47. View NE looking upstream in Canal 3 downstream of check. The Toledo Basin is located to the right (outside of image).

The regulation point for the basin and the re-set of Canal 3 flow will be relocated upstream. This requires modification to the operation and some of the structures at this location. Specifically,

1. The gate between the NW cell of the Toledo Basin and Canal 3 should remain closed during normal operation.

The regulation point in the Toledo Basin will be relocated to the northeast cell. This increases the acreage downstream of the regulation point by including lower Canal 2. The northeast cell will be upgraded for canal regulation, with the other three cells optimized for groundwater recharge. Further, the flow down Canal 3 will now be reset at the northeast cell. Therefore, the northwest cell should no longer be used for irrigation flow regulation.

- 2. The water level in Canal 3 adjacent to the northwest cell of the Toledo Basin will float with the end of Canal 2 (the Toledo Tie), which will be regulated by the northeast cell of the Toledo Basin.
- 3. The structure just downstream of the Toledo Tie pool in Canal 3 will measure and control the flow rate into lower Canal 3. The structure will consist of flow control gates (recommendation: rectangular sluice gates).

The existing round sluice gate and flashboard structure will be replaced with rectangular sluice gates. They could be automated for flow control or could be manually operated. As indicated in the main report, this site is considered a "Phase 2" (medium priority) SCADA site. The pumps will keep a fairly constant water level upstream of the flow control gates, so even with manual control, the flow through those gates should remain fairly constant. However, automation is recommended for this site because it will allow the District to remotely monitor and adjust the flow rate through the gates.

Some surveying of elevations would be necessary to determine if a flume could be used downstream for flow <u>measurement</u>, but it is likely that the flow measurement will be done using the values of the water level difference across the gates, plus the gate openings.

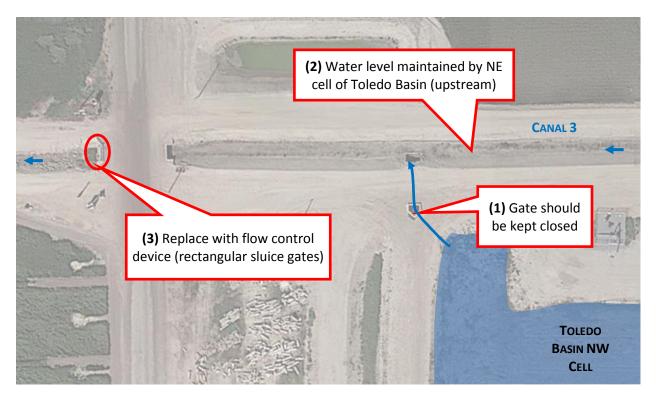


Figure A-51. Structure modifications at Canal 3 and the Toledo Basin northwest cell

- a) The Canal 3 flow rate will be re-started at this point, allowing the remainder of Canal 3 (downstream) to be operated as a very short canal.
- b) Buffering of varying flows will now occur upstream, utilizing the northeast cell of the Toledo Basin.
- c) The northwest cell (as well as the southern two cells) of the Toledo Basin will be used for groundwater recharge.

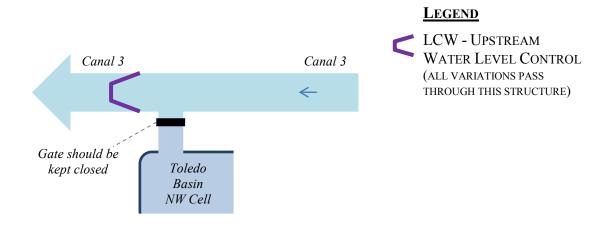


Figure A-52. New operation at Canal 3 and the Toledo Basin northwest cell

Canal 1 and Cross Ditch

The operation and structures at Canal 1 and the Cross Ditch will remain the same. However, they are explained below for clarity, as they are part of the proposed Toledo Basin system.

Operation

Present and future operation is depicted in **Figure A-53** below.

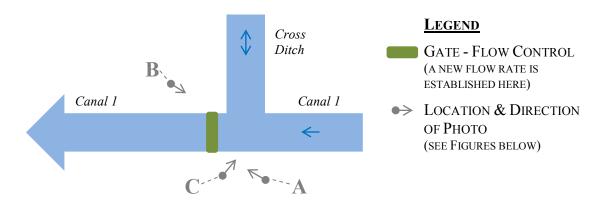


Figure A-53. Operation at the bifurcation of Canal 1 and the Cross Ditch

The operation of the existing structures will remain essentially the same. Presently,

- 1. The flow rate down Canal 1 is controlled by one flow control gate. The flow rate is re-started at this bifurcation point, allowing the remainder of Canal 1 (downstream) to be operated as a very short canal.
- 2. Variations in upper Canal 1 are buffered by the Cross Ditch (water can flow into or out of the Cross Ditch). Excess flows in the Cross Ditch flow into Canal 2 over flashboards and eventually flow into the Toledo Basin and/or Creighton Ranch.



Figure A-54. Location A from Figure A-53. View toward the NW, looking downstream along Canal 1.

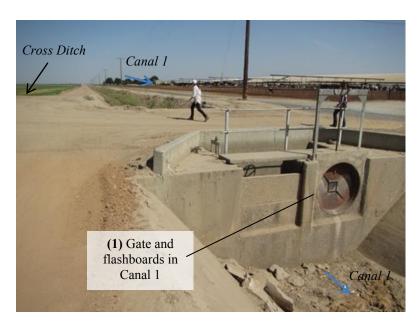


Figure A-55. Location B from Figure A-53. View toward east of Canal 1. Photo is taken just downstream of Canal 1 structure.



Figure A-56. Location C from Figure A-53. View toward north of the Cross Ditch at Canal 1 (Canal 1 flows right to left).

Function

The function of the existing structure at this location will remain the same. Specifically,

1. The flow rate for lower Canal 1 will be controlled and measured in the existing structure, just downstream of the road crossing of Canal 1.

The existing gate could be automated for flow control, or could be manually operated. As indicated in the main report, this site is considered a "Phase 2" (medium priority) SCADA site. The long-crested weir on the northern end of the Cross Ditch will keep a

fairly constant water level upstream of the flow control gate, so even with manual control, the flow through the gate should remain fairly constant. <u>However</u>, automation is recommended for this site because it will allow the District to remotely monitor and adjust the flow rate through the gate.

Some surveying of elevations would be necessary to determine if a flume could be used downstream for flow measurement, but it is likely that the flow measurement will be done using the values of the water level difference across the gate, plus the gate opening.

2. The Cross Ditch will continue to "float" with upper Canal 1. The Cross Ditch long-crested weir into Canal 2 will maintain the water level.

A long-crested weir will be installed in the Cross Ditch that flows into Canal 2. This design is discussed in the Canal 2/Cross Ditch section.

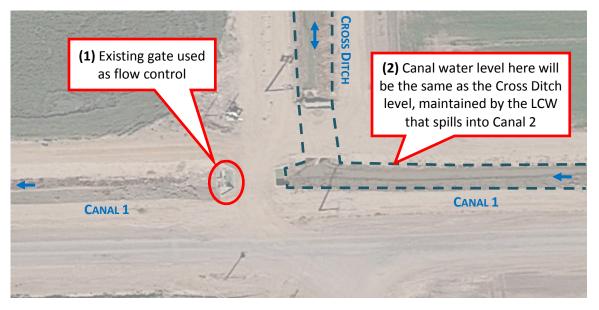


Figure A-57. Recommended structure and function at the intersection of Canal 1 and the Cross Ditch

Cross Ditch and Cole Ditch

The operation and structures at the bifurcation of Cross Ditch and Cole Ditch will remain the same. However, they are explained below for clarity, as they are part of the proposed Toledo Basin system.

Operation

Present and future operation is depicted in **Figure A-58** below.

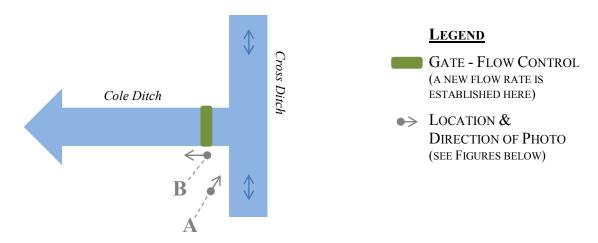


Figure A-58. Operation at the bifurcation of Cross Ditch and Cole Ditch

The operation of the existing structures will remain essentially the same. Presently,

- 1. The flow rate into Cole Ditch from Cross Ditch is controlled by one flow control gate.
- 2. The variations in Cross Ditch (and Canal 1) flow spill over a long-crested weir into Canal 2, and eventually flow into the Toledo Basin and/or Creighton Ranch.

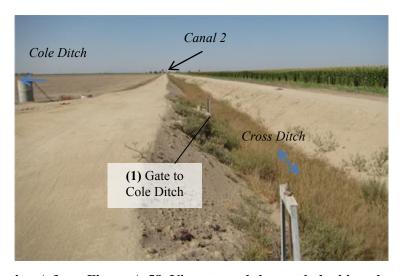


Figure A-59. Location A from Figure A-58. View toward the north, looking along the Cross Ditch towards Canal 2. The headworks gate to Cole Ditch is shown in the middle of the image. Cole Ditch is to the left of the image.



Figure A-60. Location B from Figure A-58. View toward the west, looking downstream Cole Ditch, just downstream of the headworks from the Cross Ditch.

Function

The functions of the existing structure at this location will remain the same. Specifically,

- 1. The flow rate for Cole Ditch will be controlled and measured in the existing structure.

 The existing gate could be automated for flow control or could be manually operated.

 This site is considered a low priority SCADA site. It is recommended that, for the time being, this location remain manually operated. The long-crested weir at the northern end of the Cross Ditch will keep a fairly constant water level upstream of the Cole Ditch gate, so even with manual control, the flow through the gate should remain fairly constant.

 However, automation would allow the District to remotely monitor and adjust the flow rate through the gates.
- 2. Cross Ditch is a single pool from Canal 1 to Canal 2.

 The Cross Ditch pool is maintained by flows from Canal 1 and Canal 2. Excess flows flow into lower Canal 2, and eventually flow into the Toledo Basin.

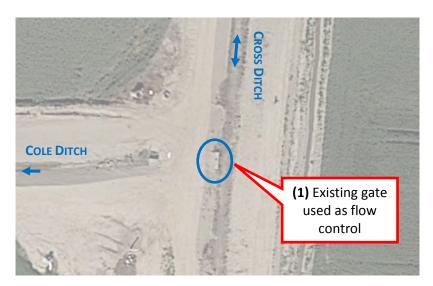


Figure A-61. Recommended structure and function at the intersection of Cole Ditch and the Cross Ditch

Attachment B Site-by-Site Details for Taylor Ditch Modifications

Taylor Ditch Modifications

Overview

The following figure shows the pertinent sites along Taylor Ditch. These sites are addressed one-by-one in this attachment.

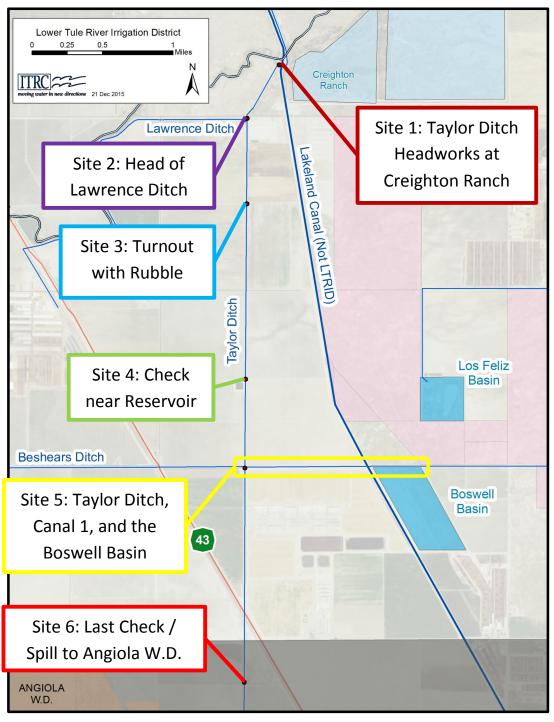


Figure B-1. Overview of pertinent sites along Taylor Ditch

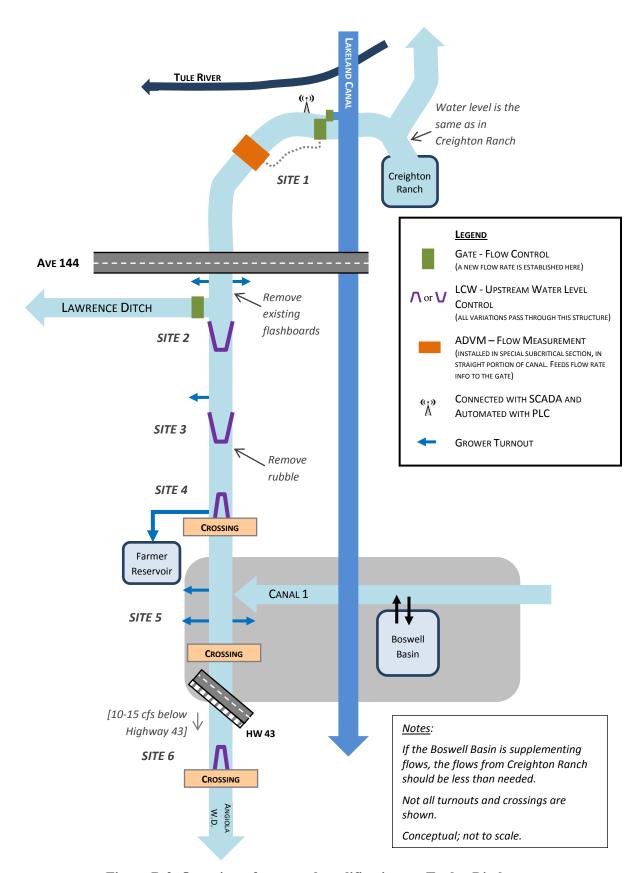


Figure B-2. Overview of proposed modifications to Taylor Ditch

Site 1: Taylor Ditch Headworks at Creighton Ranch

The flow rate entering Taylor Ditch from Creighton Ranch will be automatically measured and maintained.

Current Operation

Present operation is depicted in **Figure B-3** below.

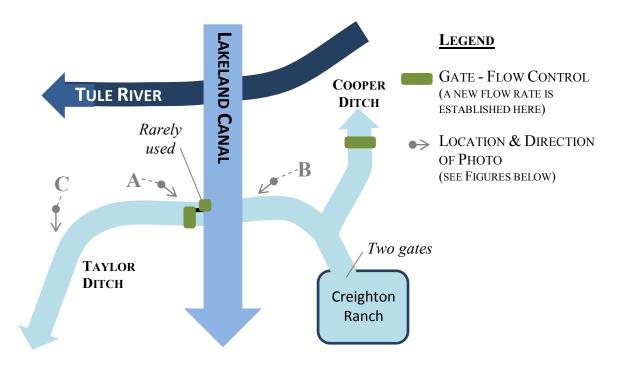


Figure B-3. Current operation at the head of Taylor Ditch

Presently,

- 1. The Creighton Ranch water level fluctuates upstream of the Taylor Ditch headgates. A siphon connects Creighton Ranch to the Taylor Ditch headgates under the Lakeland Canal.
- 2. The flow rate into Taylor Ditch from Creighton Ranch is controlled by one flow control gate.
- 3. The flow rate into or out of Taylor Ditch from or to the Lakeland Canal is controlled by one flow control gate. This gate is rarely used (only a few instances in the last 20 years).



Figure B-4. Location A from Figure B-3. Gates at head of Taylor Ditch.

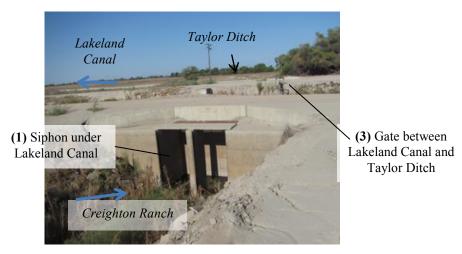


Figure B-5. Location B from Figure B-3. Creighton Ranch siphon under Lakeland Canal to Taylor Ditch headgate



Figure B-6. Location C from Figure B-3. Looking downstream Taylor Ditch from just downstream of the headgate.

The functions of the existing structures at the head of Taylor Ditch will remain the same. However, the structures used should be upgraded to provide remote monitoring and modification, as well as automated control. Specifically,

1. The flow rate into Taylor Ditch from Creighton Ranch will be maintained by an automated flow control gate.

The existing gate will be replaced with a newly automated flow control gate using a PLC (programmable logic controller) and SCADA. This site is considered a "Phase 1" (high priority) SCADA site; because the water level upstream of the gate fluctuates, the gate must be automated to maintain a constant flow rate into the Ditch. The flow rate will also be able to be remotely monitored and adjusted. The flow rate will be calculated two ways: (1) using the gate discharge equation (gate opening and head loss across the gate), and (2) using a downstream acoustic Doppler velocity meter (ADMV) (see item 2, below). The flow rate into Taylor Ditch should be less than needed so that the Boswell Basin can automatically supplement the deficit flow.

- 2. The flow rate in Taylor Ditch will be calculated with a secondary calculation from an acoustic Doppler velocity meter (ADVM) in the ditch, just downstream of the headworks. *The ADVM will be installed in a straight section with a specially-designed subcritical walled canal section.*
- 3. The gate to/from the Lakeland Canal and Taylor Ditch will be left as-is.

 The gate between the Lakeland Canal and Taylor Ditch will remain as-is, so that the gate can be manually opened, if desired.

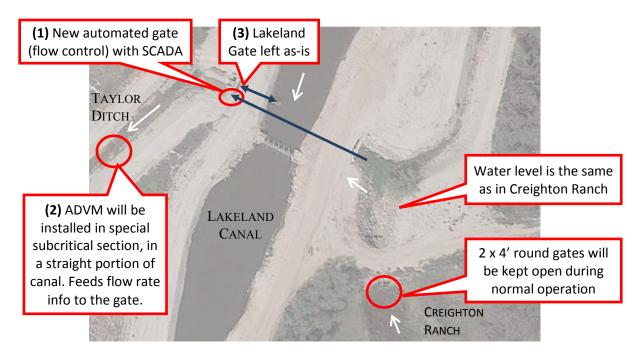


Figure B-7. Recommended structure and function changes at the bifurcation of Taylor Ditch and Creighton Ranch.

- 1. The flow control gate from Creighton Ranch will maintain a constant (but adjustable) flow rate down Taylor Ditch.
- 2. District personnel can remotely monitor and adjust the target flow rate.

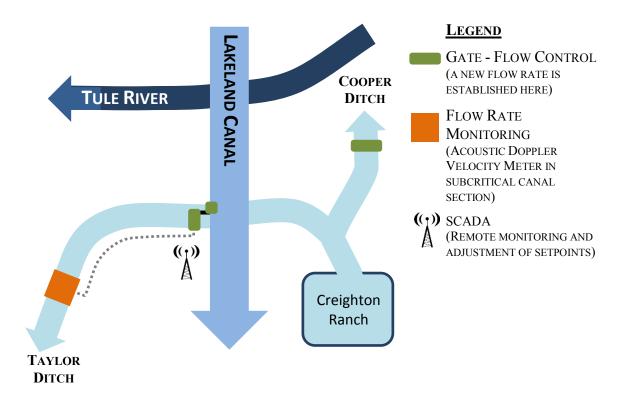


Figure B-8. New operation at the head of Taylor Ditch

Site 2: Head of Lawrence Ditch

The upstream water level control structure will be upgraded to provide better water level control in the ditch despite varying flows.

Current Operation

Present operation is depicted in **Figure B-9** below.

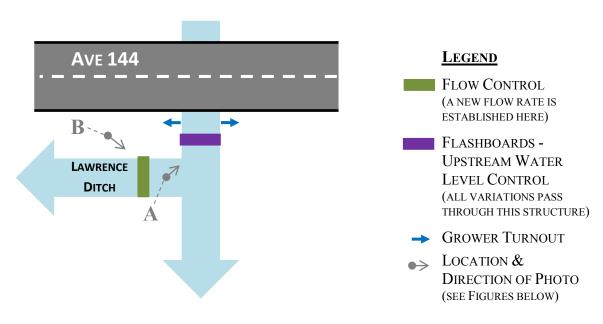


Figure B-9. Current operation at the bifurcation of Taylor Ditch and Lawrence Ditch

Presently,

- 1. Flashboards maintain the water level for the turnouts just downstream of Avenue 144.
- 2. A gate controls the flow at the head of Lawrence Ditch.

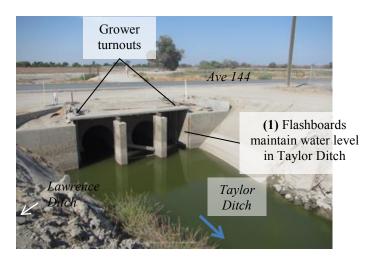


Figure B-10. Location A from Figure B-9. View to north of turnouts and flashboard bays on Taylor Ditch just south of Avenue 144.



Figure B-11. Location B from Figure B-9. View to SE of head of Lawrence Ditch. Taylor Ditch flows left to right in background.

The functions of the existing structures at the bifurcation of Taylor Ditch and Lawrence Ditch will remain the same. However, the structure in Taylor Ditch will be upgraded to provide better water level control despite varying flows and will be relocated downstream of the headworks of the Lawrence Ditch. Specifically,

1. The flashboards in Taylor Ditch, just downstream of the grower turnouts downstream of Avenue 144, should be removed.

The existing flashboard structure will be removed and replaced with a long-crested weir just downstream (see item 2).

2. A new water level control device (recommended: long-crested weir) will be installed in Taylor Ditch just downstream of the Lawrence Ditch headworks.

The long-crested weir will provide better water level control than the existing flashboards to the grower turnouts just downstream of Avenue 144 in Taylor Ditch. Additionally, by relocating the structure downstream of the Lawrence Ditch headworks, the long-crested weir will provide water level control on the upstream side of the Lawrence Ditch headworks flow control gate. This will provide a more constant flow rate through the Lawrence Ditch headworks flow control gate. A downstream facing long-crested weir (water flows out of the weir) is recommended for this site. The design of the length and crest height of the long-crested weir is given in the Design Details section below.

3. The gate on the Lawrence Ditch will continue to be used for flow control.

The existing gate could be automated for flow control or could be manually operated. This site is considered a low priority SCADA site. It is recommended that, for the time being, this location remain manually operated. The long-crested weir in Taylor Ditch (item 2, above) will keep a fairly constant water level upstream of the Lawrence Ditch gate, so even with manual control, the flow through the gate should remain fairly constant. However, automation would allow the District to remotely monitor and adjust the flow rate through the gates.

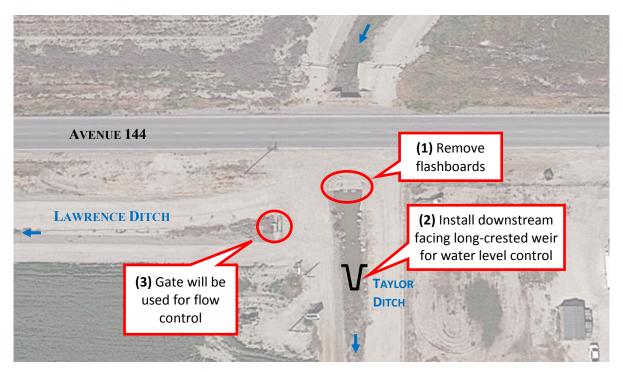


Figure B-12. Recommended structure and function changes at the bifurcation of Taylor Ditch and Lawrence Ditch

- a) The long-crested weir will provide a constant water level upstream of the grower turnouts and Lawrence Ditch gate.
- b) A constant flow rate can be delivered to the Lawrence Ditch.

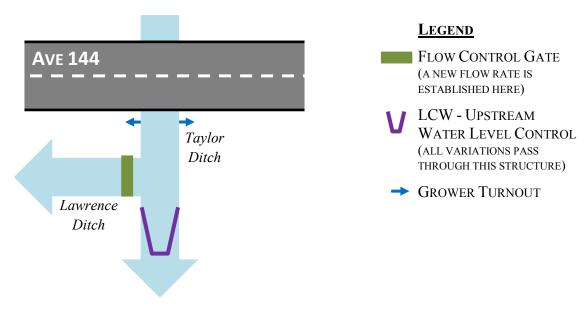


Figure B-13. New operation at the bifurcation of Taylor Ditch and Lawrence Ditch

Design Details - Long-Crested Weir

The long-crested weir should meet the following specifications:

- The long-crested weir should be located in the Taylor Ditch downstream of the Lawrence Ditch turnout
- The long-crested weir should be downstream facing (water flows <u>out of</u> the weir, rather than <u>into</u> the weir)
- Minimum weir length = 50'
- In the drawings below, the maximum allowable elevation has an assumed elevation of 100.00'; all other elevations are given in relation to this elevation. The maximum allowable elevation includes 0.4' of freeboard above the maximum flow rate of 60 CFS; a flow rate of approximately 137 CFS would cause the water level to exceed this maximum allowable elevation. The district must determine the "real world" elevation of this maximum allowable elevation (such as the top of the existing concrete structure downstream of Avenue 144).
- The top of the weir crest (a 2x6 board) should be 0.94' below the maximum allowable elevation.
- A 2x6 (1.5" x 5.5") board will sit on top of the weir structure for final weir crest adjustment. This means the top of the weir structure will be 0.94 + [5.5/12] = 1.40' below the maximum allowable elevation.
- There should be an 18" canal or slide gate at the downstream end of the weir to flush silt. The width of the weir at this end should be 40".
- There should be a catwalk from the canal bank to access sluice gate.

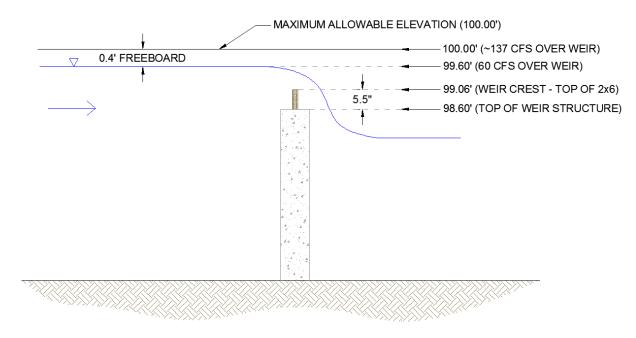


Figure B-14. Conceptual side view of long-crested weir at Site 2

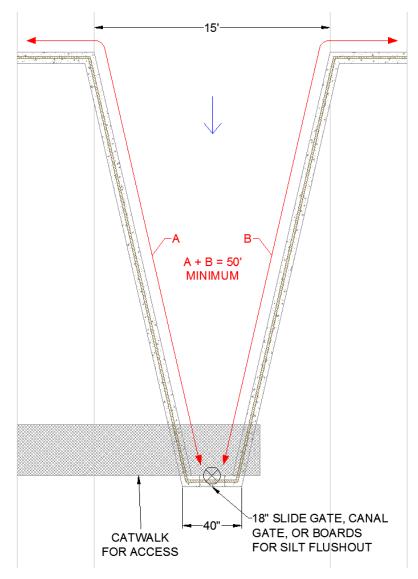


Figure B-15. Conceptual plan view of long-crested weir at Site 2

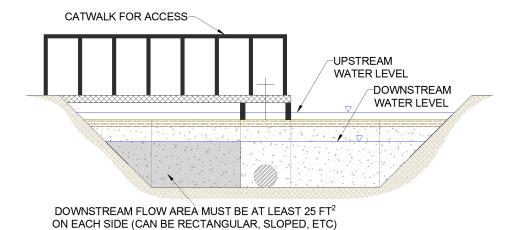


Figure B-16. Conceptual elevation view of long-crested weir at Site 2, looking upstream

Site 3: Turnout with Rubble

The upstream water level control structure will be upgraded to provide better water level control in the ditch despite varying flows.

Current Operation

Present operation is depicted in Figure B-17 below.

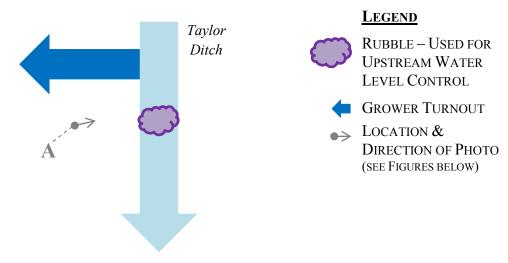


Figure B-17. Current operation of Taylor Ditch at Site 3

Presently,

1. Rubble (large pieces of concrete) has been thrown in the canal just downstream of a grower turnout to raise the water level in the canal at the turnout.

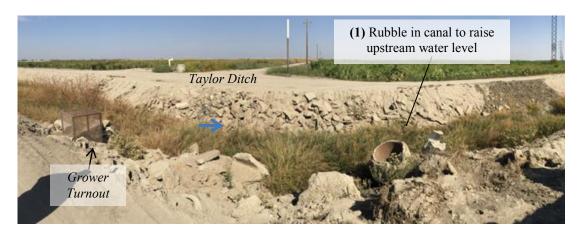


Figure B-18. Location A from Figure B-17. Rubble and turnout at Site 3 in Taylor Ditch.

The functions of the existing "structures" at Site 2 in Taylor Ditch will remain the same. However, the structures used should be upgraded to provide better control despite varying flows. Specifically,

- 1. Rubble will be removed from ditch.
- 2. A new structure just downstream of the grower turnout will control the water level in Taylor Ditch.

A long-crested weir will be installed in Taylor Ditch just downstream of the grower turnout. A long-crested weir will provide a much more constant upstream water level despite changing flows in the canal than the rubble. A downstream facing long-crested weir (water flows <u>out</u> of the weir) is recommended for this site. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard and the drop available across the grower's turnout.

3. A new metergate should be installed at the grower's turnout from the ditch.

The metergate should be a district-standard metergate (see suggestions for metergates in main report) that will provide flow measurement and control.

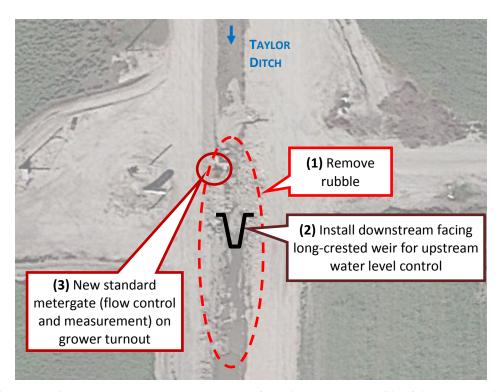


Figure B-19. Recommended structure and function changes at Site 3 in Taylor Ditch

- a) The long-crested weir will provide a constant water level at the grower turnout.
- b) The metergate will allow for accurate measurement of the flow through the grower's turnout.

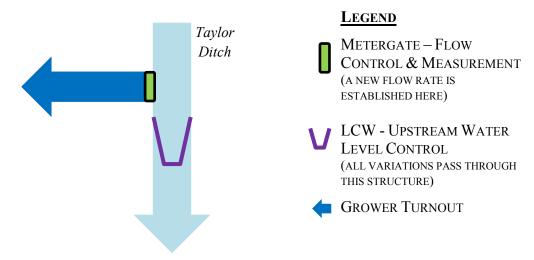


Figure B-20. New operation of Taylor Ditch at Site 3

Site 4: Check near Reservoir

The upstream water level control structure will be upgraded to provide better water level control in the ditch despite varying flows.

Current Operation

Present operation is depicted in Figure B-21 below.

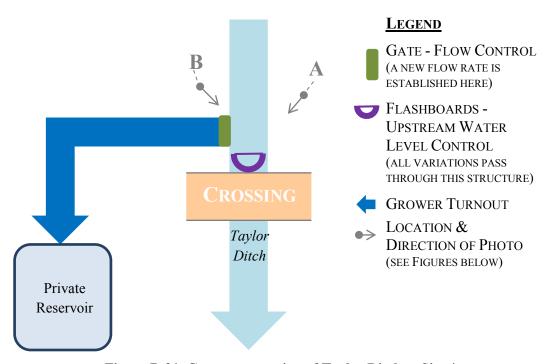


Figure B-21. Current operation of Taylor Ditch at Site 4

Presently,

- 1. The variations in Taylor Ditch flow pass over a corrugated metal flashboard structure, continue down Taylor Ditch, and eventually flow into Angiola Water District. In other words, the flashboard check structure in Taylor Ditch is designed for manual upstream water level control.
- 2. The flow rate from Taylor Ditch into a private reservoir is controlled by a manually operated flow control gate (turnout).



Figure B-22. Location A from Figure B-21. View to SW of check structure and turnout at Site 4 on Taylor Ditch. Private reservoir in background.



Figure B-23. Location B from Figure B-21. View to SE of check structure and turnout at Site 4 on Taylor Ditch.

The functions of the existing structure and turnout in Taylor Ditch at Site 4 will remain the same. However, the structure and turnout should be upgraded to provide better control despite varying flows (structure) and better flow measurement (turnout). Specifically,

1. A new structure just downstream of the reservoir turnout will control the water level in Taylor Ditch.

A long-crested weir will replace the existing flashboards in Taylor Ditch just downstream of the turnout. A long-crested weir will provide a more constant water level despite changing flows in the canal than the existing flashboards. An upstream facing long-

crested weir (water flows <u>into</u> the weir) is recommended for this site. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard and the drop available across the turnout.

2. A new metergate should be installed at the grower's turnout from the ditch.

The metergate should be a district-standard metergate (see suggestions for metergates in main report) that will provide flow measurement and control.

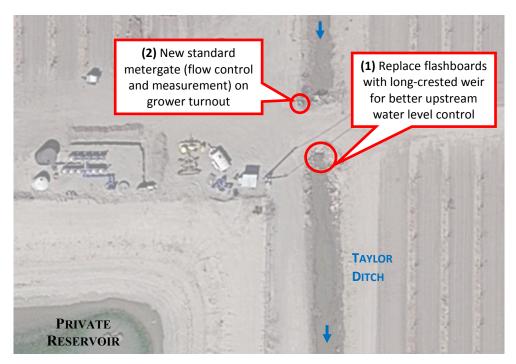


Figure B-24. Recommended structure and function changes at Site 4 in Taylor Ditch



Figure B-25. Recommended structure layout at Site 4 in Taylor Ditch



Figure B-26. Example design for long-crested weir at Site 4 in Taylor Ditch (upstream facing)

- a) The long-crested weir will provide a constant water level at the grower turnout.
- b) The metergate will allow for accurate measurement of the flow through the grower's turnout.

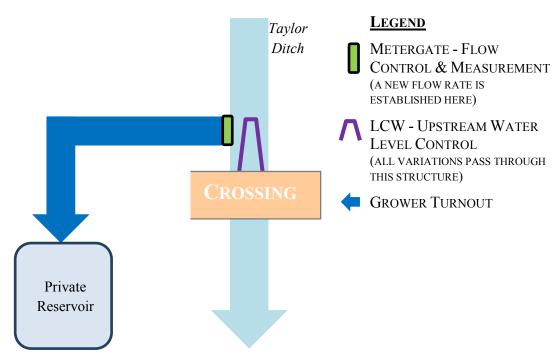


Figure B- 27. Current operation of Taylor Ditch at Site 4

Site 5: Taylor Ditch, Canal 1, and the Boswell Basin

Site 5 can be divided into two sub-sites: (a) the intersection of Taylor Ditch and Canal 1, and (b) the intersection of the Boswell Basin and Canal 1. These two sub-sites are shown in the figure below. For clarity, these two sub-sites are used to describe current operation.



Figure B-28. Sites 5a and 5b

Current Operation: Site 5A: Taylor Ditch at Canal 1

Present operation is depicted in **Figure B-29** below.

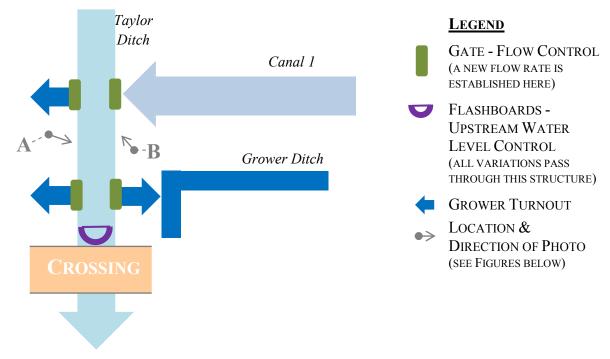


Figure B-29. Current operation of Taylor Ditch at Site 5a

Presently,

- 1. The variations in Taylor Ditch flow pass over a corrugated metal flashboard structure, continue down Taylor Ditch, and eventually flow into Angiola Water District. In other words, the flashboard check structure in Taylor Ditch is designed for manual upstream water level control.
- 2. There are three grower turnouts off of Taylor Ditch just upstream of the flashboard structure.
- 3. The end of Canal 1 is to the east of Taylor Ditch. Canal 1 can make deliveries to Taylor Ditch in the pool upstream of the flashboard structure through an existing slide gate.

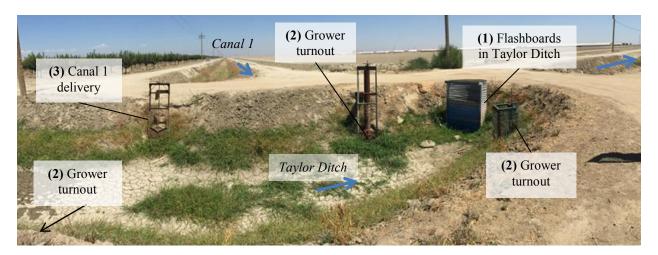


Figure B-30. Location A from Figure B-29. View to east of structures and turnouts in Taylor Ditch at Canal 1 intersection.

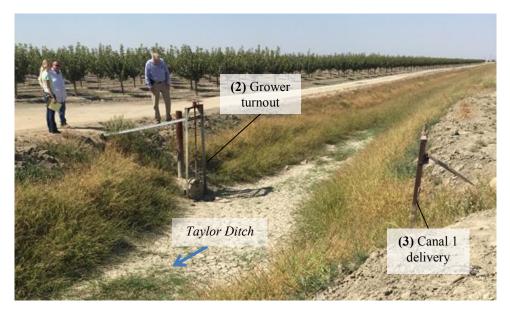


Figure B-31. Location B from Figure B-29. View to SW of structures in Taylor Ditch at Canal 1 intersection.

Current Operation: Site 5B: Taylor Ditch at Canal 1

Present operation is depicted in Figure B-32 below.

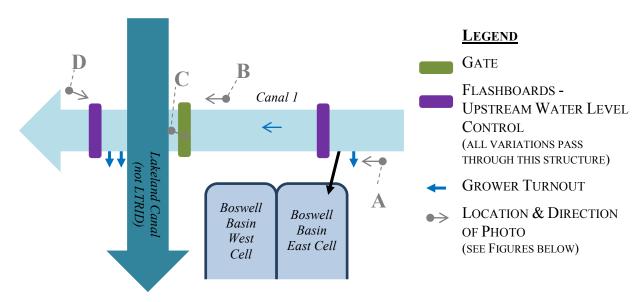


Figure B-32. Current operation of Canal 1 at Boswell Basin (Site 5b)

Presently,

- 1. Water can be delivered to the Boswell Basin's eastern cell for infiltration through a metergate in Canal 1.
- 2. A gate is located just upstream of the siphon in Canal 1 under the Lakeland Canal.
- 3. A flashboard check structure is located in Canal 1 just downstream of two turnouts and the Lakeland Canal.



Figure B-33. Location A from Figure B-32. View to west of Boswell Basin and Canal 1 at upstream end of Boswell Basin. Canal 1 flows away from photographer. Lakeland Canal flows right to left in background of image.



Figure B-34. Location B from Figure B-32. View to west of Canal 1 at downstream end of Boswell Basin. Boswell Basin is to left of image. Canal 1 flows under Lakeland Canal. Lakeland Canal flows right to left.

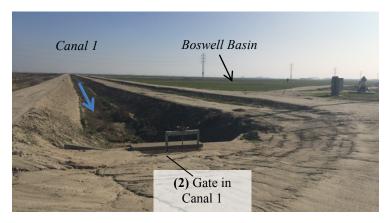


Figure B-35. Location C from Figure B-32. View to SE of Canal 1 at downstream end of Boswell Basin. Boswell Basin is on right. Canal 1 flows under Lakeland Canal behind the photographer.

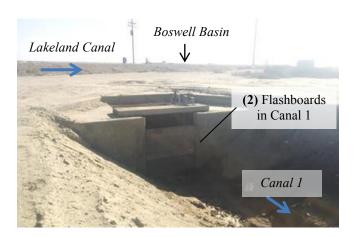


Figure B-36. Location D from Figure B-32. View to E of Canal 1 just downstream of Lakeland Canal. Boswell Basin is on far side of Lakeland Canal in background.

Proposed Modifications

There are five options for improved delivery to the downstream end of Taylor Ditch. These options are explained below, along with <u>very general estimated costs</u>.

The Boswell Basin could be used (via Canal 1) to supplement flows into the Taylor Ditch. There are five options for modification for the Taylor Ditch at the Canal 1 intersection:

1. Install an upstream facing long-crested weir in the Taylor Ditch. The long-crested weir would maintain an upstream water level in the Taylor Ditch.

Install metergates on the turnouts in the pool.

Flows in Taylor Ditch would not be supplemented by the Boswell Basin.



Figure B-37. Layout of option 1 for the Site 5 on the Taylor Ditch

Approximate Cost: The cost of a long-crested weir varies significantly depending on design.

2. Install an upstream facing long-crested weir in the Taylor Ditch. The long-crested weir would maintain an upstream water level in the Taylor Ditch.

Install metergates on the turnouts in the pool.

Install in/out capability to the Boswell Basin.

Sometimes deliberately deliver the correct flow rate from Canal 1, rather than from the Creighton Ranch.

Install a SCADA-connected flow measurement device in Taylor Ditch downstream of the intersection of Taylor Ditch with Canal 1.

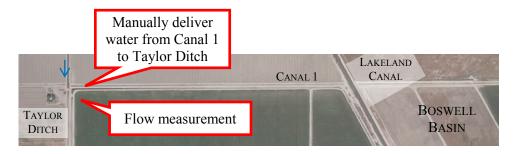


Figure B-38. Layout of option 2 for the Site 5 on the Taylor Ditch Approximate Cost: \$160,000 + LCW cost¹

3. Pipe Canal 1 from the Lakeland Canal to Taylor Ditch. Have automatic control of the pool next to the Boswell Basin (in/out capability in the Boswell Basin) and an automatic valve on the downstream end of the pipe, to maintain a water level in Taylor Ditch. The banks would need to be built up near the Boswell Basin.

Install a flow control gate in Taylor Ditch at the Canal 1 intersection and install metergates on the turnouts in the pool.

Install a SCADA-connected flow measurement device in Taylor Ditch downstream of the intersection of Taylor Ditch with Canal 1.

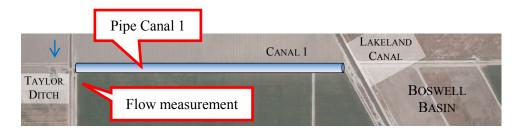


Figure B-39. Layout of option 3 for the Site 5 on the Taylor Ditch

Approximate Cost: \$660,000

4. Install two downstream water level gates in Canal 1 to maintain the water level in Taylor Ditch where Canal 1 meets Taylor Ditch. AVIS or AVIO gates could be used, rather than PLCs, because of the small size and remote location of the sites. The banks would likely need to be built up in Canal 1 between the Boswell Basin and Taylor Ditch.

Install in/out capability to the Boswell Basin.

-

¹ The cost of a long-crested weir varies significantly depending on design.

Install a flow control gate in Taylor Ditch at the Canal 1 intersection and install metergates on the turnouts in the pool.

Install a SCADA-connected flow measurement device in Taylor Ditch downstream of the intersection of Taylor Ditch with Canal 1.

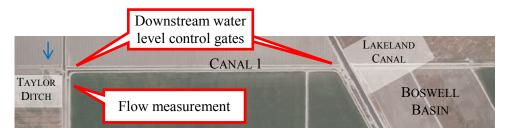


Figure B-40. Layout of option 4 for the Site 5 on the Taylor Ditch

Approximate Cost: \$460,000

5. Use pool storage in Taylor Ditch upstream of Canal 1. Sense the water level in the pool and adjust flows from the Boswell Basin.

Install in/out capability to the Boswell Basin.

Install a SCADA-connected flow measurement device in Taylor Ditch downstream of the intersection of Taylor Ditch with Canal 1.

This option would require automating the turnouts in the Taylor Ditch pool.

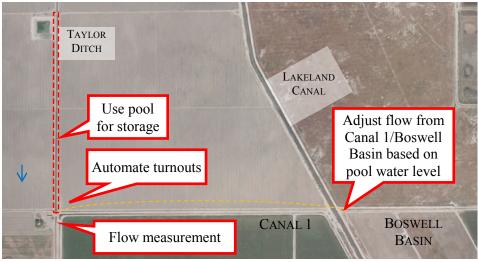


Figure B-41. Layout of option 5 for the Site 5 on the Taylor Ditch This option is not recommended.

The net result for operation will depend on the option selected.

Site 6: Last Check/Spill to Angiola W.D.

A new structure will maintain the water level in the canal despite varying flows.

Current Operation

Present operation is depicted in Figure B-42 below.

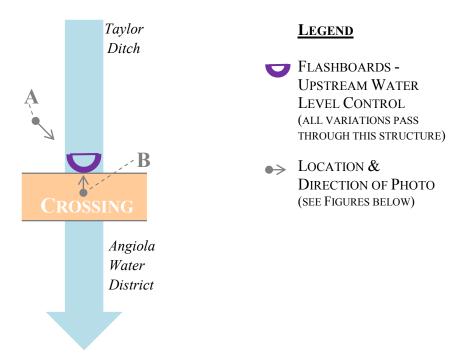


Figure B-42. Current operation of Taylor Ditch at the last check (Site 6)

Presently,

1. The variations in Taylor Ditch flow (either deliveries or spill) pass over a corrugated metal flashboard structure and flow into Angiola Water District. In other words, the flashboard check structure in Taylor Ditch is designed for manual upstream water level control.



Figure B-43. Location A from Figure B-42. View to SE of check structure at end of Taylor Ditch.

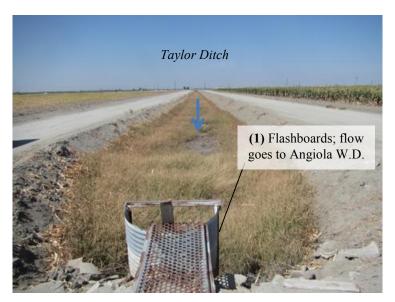


Figure B-44. Location B from Figure B-42. View to north of check structure at end of Taylor Ditch.

Proposed Modifications

The function of the existing structure in Taylor Ditch at Site 6 will remain the same. However, the structure should be upgraded to provide better control despite varying flows. Specifically, 1. A new structure will control the water level in Taylor Ditch.

A long-crested weir will be installed at the end of Taylor Ditch. A long-crested weir will provide a more constant water level than the existing flashboards despite changing flows in the canal. An upstream facing long-crested weir (water flows into the weir) is recommended for this site. The design of the length and crest height of the long-crested weir will require some survey information regarding freeboard and the drop available across any upstream turnouts.

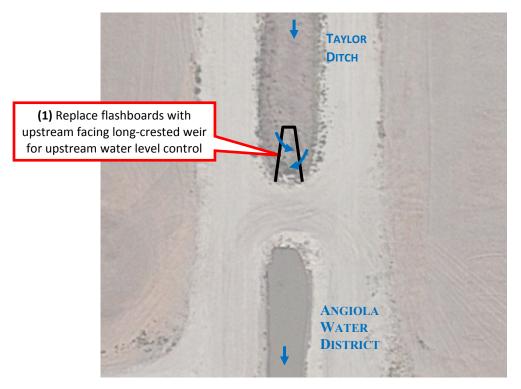


Figure B-45. Recommended structure and function changes at end of Taylor Ditch



Figure B-46. Example design for long-crested weir at end of Taylor Ditch (upstream facing)

The net result for operations will be:

a) The long-crested weir will provide a constant water level upstream.

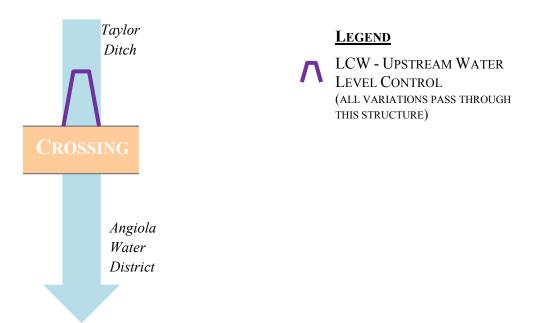


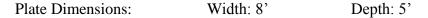
Figure B- 47. New operation of the end of Taylor Ditch (Site 6)

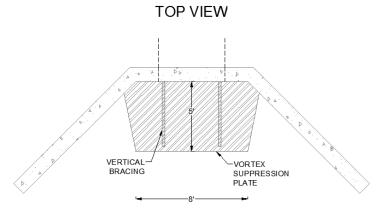
Attachment C Highway 99 Culvert Vortex Plate Details

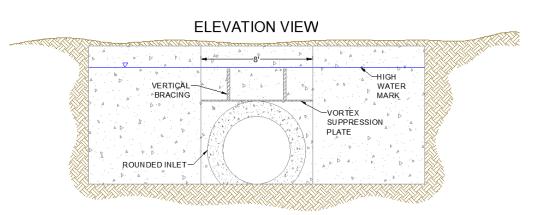
Overview

Dimensions for a vortex suppression plate on the upstream side of each culvert were calculated; these dimensions are based on field surveys during non-flow conditions. As such, these dimensions are estimates. However, they should improve the performance of the system and minimize vortexing.

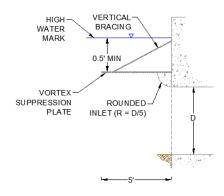
Canal 1





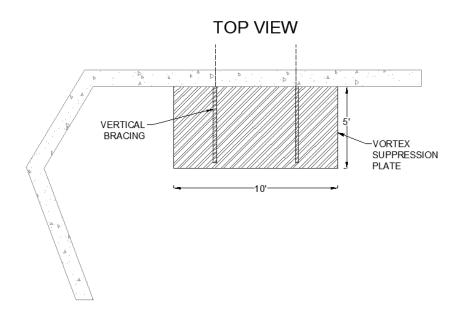


SIDE VIEW

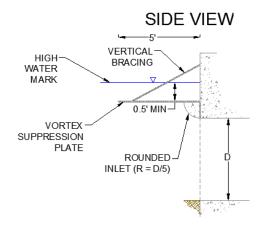


Canal 2

Plate Dimensions: Width: 10' Depth: 5'

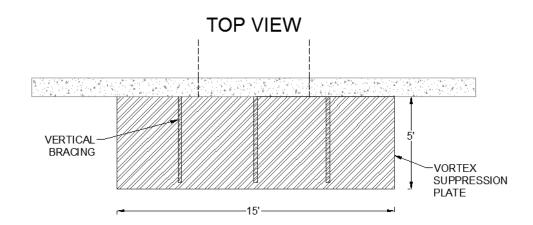


VERTICAL VERTICAL VERTICAL VERTICAL VERTICAL VERTICAL VORTEX SUPPRESSION PLATE ROUNDED INLET

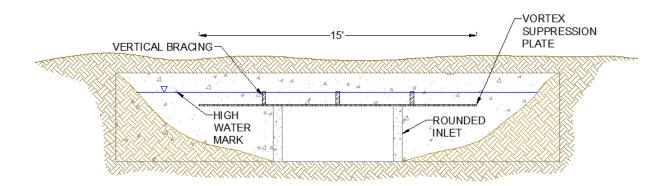


Canal 3 Highway 99

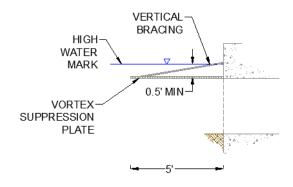
Plate Dimensions: Width: 15' Depth: 5'



ELEVATION VIEW



SIDE VIEW

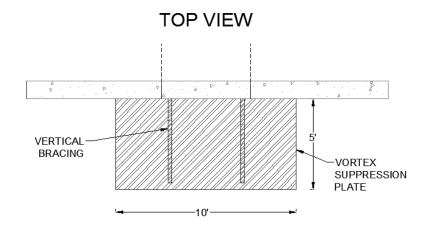


Canal 3 Road Crossing

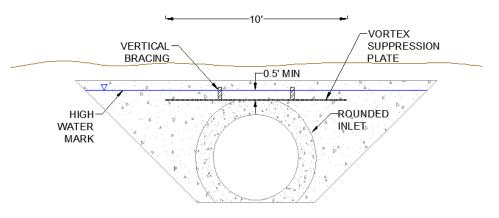
Plate Dimensions:

Width: 10'

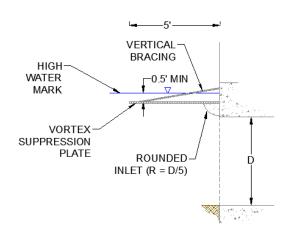
Depth: 5'



ELEVATION VIEW



SIDE VIEW



Attachment D Metergate Design



IRRIGATION TRAINING & RESEARCH CENTER

California Polytechnic State University San Luis Obispo, CA 93407-0730

Phone: (805) 756-2434 FAX: (805) 756-2433 www.itrc.org

Practical Guide for Metergates

by Dr. Charles Burt and Dr. Daniel Howes Rev June 30, 2015

Background

This document contains brief instructions on the use of special round canal gates called "metergates" for flow measurement. A metergate differs from a traditional canal gate turnout because it has a hole in the top of the pipe attached to a stilling well downstream of the gate so that the downstream water level can be measured.

Metergates have been used since the early 1900's for flow measurement in addition to on-off control. Recent research conducted by the authors at the Irrigation Training and Research Center has shown that the existing tables for "Armco"-type metergates, published after the 1950's, provide good accuracy for flow measurement (if measurements are made correctly).

Armco-type metergates include round gates from Fresno Valve and Casting (101), Waterman (C-10), and X-CAD (model unknown) gates. In order to properly use these gates, a hole (5/8 to 3/4 inch in diameter) must be drilled in the pipe 12 inches downstream of the back face of the gate (or at the top of a corrugation as close to 12 inches as possible). This hole must be attached to a stilling well at least 6 inches in diameter that protrudes up to the elevation of the top of the gate frame.

Figure 1 shows a common metergate design drawing.

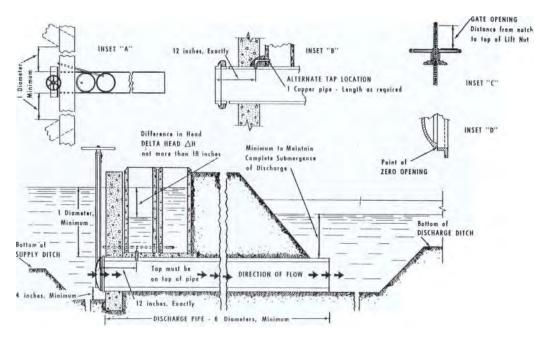


Figure 1. Metergate drawing used by various manufacturers, USBR, etc.

ITRC Research

ITRC evaluated the calibration of a variety of Armco-type round and square gates to determine if published "metergate" calibration tables are accurate. These gates were installed at the ITRC gate calibration facility (**Figure 2**). The gate calibration facility is set up so that the turnout gate is perpendicular to the main supply channel flow, which is typical in field installations.



Figure 2. ITRC gate calibration facility

Summary of ITRC Research Results

- 1) A high level of accuracy (+/-5%) was found if all of the following conditions are met:
 - a. Gate opening range: 20% < Gate Opening < 75%
 - b. Upstream submergence > 0.5D (where D is the gate diameter)
 - c. Stilling well location was 4" to 12" downstream of the face of the gate
- 2) The distance downstream of the gate at which the stilling well is located (as long as it is within the 4" to 12" range) does not have a significant effect on the flow rate obtained using the tables **unless** the gate is **open** more than 70-75% (percent of fully open).

- 3) The preliminary evaluation of tangential supply channel flow velocity did not seem to have a significant impact on the flow through the turnout gates. Supply channel velocities up to 1.9 feet per second (fps) were examined in this evaluation.
- 4) Higher uncertainty (error) occurred at smaller gate openings.
- 5) Optimum range of operation for the highest accuracy was an opening between 20% and 75% under most conditions. Smaller gate openings seemed to be more problematic than larger gate openings.
- 6) One issue that is not discussed here but was apparent was the submergence (water level) in the supply canal above the turnout pipeline. Care should be taken to ensure that the water level upstream of the top of the turnout pipe remains above $(0.5 \times \text{gate diameter})$. The USBR standard is $(1 \times \text{gate diameter})$.

Correction for Stilling Well 4" from Gate

Standard flow tables are based on a stilling well located 12" downstream of the back of the gate. Stilling well measurements were made at multiple locations downstream of the gate to analyze the effects of stilling well location. It was found that, at gate openings less than 70% open, there was **minimal** impact on the change in head from any stilling well closer than 12" to the gate. Once the gate reached an opening of 70% or greater, the ΔH measurement measured at the closer stilling wells (e.g., at 4") began to vary depending on gate size resulting in more significant error.

On average, at gate openings above 75%, the flow rate for a 4" stilling well was 8%-10% greater than the value shown on a 12" stilling well-based table. This adjustment could be applied in the case where gates must be opened more than 75%.

Practical Details

Figure 3 shows one recommended configuration for a metergate. There are some significant differences between **Figures 1** and **3**. With metergates, "the devil is in the details". These are discussed on the next few pages.

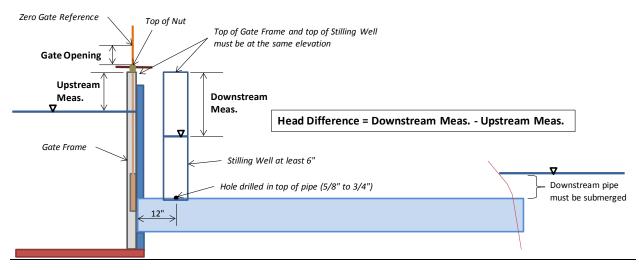


Figure 3. ITRC recommendation for proper metergate installation. These have been improved by Glenn Colusa ID with pre-cast concrete structures.

Practical Detail #1 – The pipe downstream of the metergate needs to be full. The water level needs to rise to some measurable level in the downstream stilling well.

Practical Detail #2 – Sufficient upstream submergence is needed. The required water level in the canal, above the top of the pipe, must be at least ½ of the gate (or pipe) diameter. In other words, if there is a 12" pipe, the water level in the supply canal needs to be at least 6" above the top of the pipe.

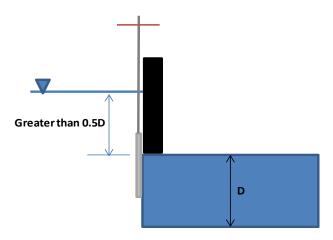


Figure 4. Recommended upstream submergence above the gate to ensure accurate flow measurement

Practical Detail #3 – All of the calibration charts require knowledge of the **gate opening**, as measured by the shaft opening. The "zero" gate opening must be properly determined and marked on the gate shaft. This is not a trivial detail. Specific points are:

- 1. All measurements of gate opening, as well as the initial marking, must be made after the gate stem has been lifted (opened). This is because there is some "slop" or movement between the shaft and the gate itself.
- 2. The gate stem will move up some distance before the gate plate itself reaches the bottom of the pipe. The charts depend on knowing the gate <u>opening</u>, not the movement from the gate seating position. The gate must be closed beyond the bottom of the pipe to seal off completely. That sealed position is not the "zero" position.
- 3. There must be some specific way to measure the shaft position when the bottom of the gate just barely clears the bottom of the pipe in other words, when there is a "zero opening". This is fairly easy to set and measure if the canal is full. The gate is opened until a narrow strip of paper can be inserted into the crack. **Figure 5** shows photos taken at San Luis Canal Company of a customized tool that is used to detect the actual gate opening, but a similar device can be used to detect the initial "cracking (zero) open" position.



Figure 5. Special tool to detect actual gate opening

4. The shaft needs to be marked in a clear manner so that operators know where the "zero" opening is for the gate when they open the gate. **Figure 6** shows a properly cut notch. It has a sharp bottom edge that was cut with a grinding wheel so that the bottom of the cut is at the same elevation as the top of the bushing. Notice from the color on the shaft that the shaft can be lowered from this position to properly seat the gate.

The operator will measure from the bottom of cut to the top of the bushing, when the gate is open, to determine the gate opening. This is always measured after an "uplift" action.

Practical Detail #4 – The stilling well needs to have sufficient diameter to dampen the turbulence, and so that operators can see into it. ITRC recommends a stilling well of 6" – 8" diameter, with an access hole of about 5/8" or 3/4" diameter.



Figure 6. Proper cut in shaft to mark the "zero" opening



Figure 7. Stilling well is located the correct distance downstream of the gate, but is so small that there will be tremendous surging (up/down movement), and operators cannot see the water surface

Practical Detail #5 – The stilling well does not need to be centered over the access hole in the top of the discharge pipe. In general, it is good to have the stilling well close to the gate frame/bulkhead, so that it can be supported.

Practical Detail #6 – Make it easy to measure the difference in head (between the water level in the canal, and the water level in the stilling well). In other words, use the same datum (elevation) for both measurements. Figure 8 shows a stilling well with the top correctly placed at the same elevation as the gate frame, and with a proper diameter. The top of the stilling well should be at the same elevation as the top of the gate frame (where the bottom of the nut rests), or have the same elevation as another reference point. Then the upstream measurement should be taken from the top of the gate frame to the water level. The downstream measurement should be taken from the top of the stilling well to the water level. The head difference is the difference between the upstream and downstream water levels.



Figure 8. Stilling well installed on an existing discharge pipe. It is constructed of PVC pipe that is too thin for long life, but it serves as an example of the correct diameter, position, and height.



Figure 9. An old type of dual-stilling well commonly found in Central California irrigation districts. One stilling well was connected to the canal, and the second was directly over the discharge pipe. The idea of measuring down into both stilling wells from the same center point was good, but the top of the stilling well was so close to the ground surface that road maintenance quickly filled these stilling wells with dirt. Also, the side connection between the canal stilling well and the canal itself was too difficult to clean.



Figure 10. This stilling well is properly located, but it has too small a diameter. The operator also needs to know the elevation difference between the top of the stilling well and the gate frame, which requires an extra computation to determine the difference in head across the gate.



Figure 11. Correct height of stilling well to match top of gate frame. However, the diameter is too small. Steel pipe material is good



Figure 12. Large diameter stilling well, with cover to minimize having it fill with dirt from the road. Strong concrete, with the rim of the stilling well at the same elevation as the bulkhead top.

The tables on the next few pages show the key measurements needed to properly use a metergate. The gate opening should be measured from the top of the gate opening nut to a zero gate opening reference. As mentioned previously, the zero gate opening reference should be marked with a grinder at the gate opening nut on the shaft when the gate is just open enough to breach the bottom of the pipe.

The Glenn-Colusa ID Configuration

Glenn-Colusa ID (GCID) worked with Briggs (a local pre-cast concrete structure company near Willows, CA) to incorporate the ITRC recommendations into a pre-cast structure. The following figures illustrate their solution, which appears to be excellent.



Figure 13. GCID metergate at Briggs



Figure 14. Pre-cast metergate ready for transport



Figure 15. Installation of GCID metergate



Figure 16. Final concrete for GCID metergate, showing downstream pre-cast outlet box

Table 1. Approximate cost for GCID metergate installation

18" X 6' H-Metergate with precast concrete ta	ailbox					
1). MATERIAL COST	QUANTITY			UNIT	COST/UNIT	COST
STILLING WELL 12" X 6' H W/ LID	1			EA	\$340	\$340
PRE/FAB 6' H BRIGG'S (metergate box)	1			EA	\$470	\$470
PLYWOOD				EA	\$1	\$0
SNAP TIES				YD	\$1	\$0
PIPE (18"PLASTIC)	25			Ft.	\$11	\$278
GATE 18" 5' FRAME	1			EA	\$1,270	\$1,270
CONCRETE	3			YD	\$105	\$315
METER BOX 5' H (tailbox)	1			EA	\$550	\$550
					TOTAL COST =	\$3,223
2). LABOR COST	QUANTITY	HRS/JOB	COST/HR	UNIT	COST/UNIT	COST
					TOTAL COST =	\$650
3). EQUIPMENT COST	QUANTITY	HRS/JOB	COST/HR*	UNIT	COST/UNIT	COST
BACKHOE			\$25.00	P/H		\$0
EXCAVATOR	1	\$1.00	\$50.00	P/H		\$50
LONG REACH			\$50.00	P/H		\$0
TRUCK	1	\$12.00	\$25.00	P/H		\$300
TRANSPORT	1	\$1.00	\$44.00	P/H		\$44
CRANE			\$50.00	P/H		\$0
PICKUPS	1	\$4.00	\$5.50	P/H		\$22
D-6 DOZER			\$35.00	P/H		\$0
D-4 DOZER			\$25.00	P/H		\$0
MISC.(WELDERS,PUMPS,GENERATORS)	1	\$4.00	\$8.00	P/H		\$32
					TOTAL COST =	\$448
					TOTAL HOURS =	22
					TOTAL =	\$4,321

ITRC Water Measurement Tables for ROUND (Armco-Type) Gates on Round Pipes

	ITRC Wate	er Measu	rement 1	Γables –	12" Arn	nco-Typ	oe Gate,	_				ack of G	ate [Blu	ie center	represe	nts best	accurac	y range]
ΔH	0.040	0.00	0.40	0.47	0.04	0.05	0.00		Gate Ope			0.50	0.50	0.07	0.75	0.00	0.00	4.00
(feet)	0.042	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	0.83	0.92	1.00
0.08	0.07	0.16	0.25	0.34	0.42	0.48	0.55	0.61	0.67	0.73	0.79	0.85	0.97	1.10	1.20	1.27	1.32	1.34
0.10	0.08	0.18	0.28	0.38	0.47	0.54	0.61	0.68	0.75	0.81	0.89	0.96	1.09	1.23	1.34	1.42	1.47	1.50
0.13	0.09	0.20	0.31	0.42	0.51	0.59	0.67	0.74	0.82	0.89	0.97	1.05	1.19	1.35	1.46	1.56	1.61	1.64
0.15	0.09	0.21	0.33	0.45	0.55	0.64	0.72	0.80	0.88	0.96	1.05	1.13	1.28	1.46	1.58	1.68	1.74	1.77
0.17	0.10	0.23	0.36	0.49	0.59	0.68	0.77	0.86	0.94	1.03	1.12	1.21	1.37	1.56	1.69	1.80	1.86	1.89
0.19	0.10	0.24	0.38	0.52	0.63	0.72	0.82	0.91	1.00	1.09	1.19	1.28	1.46	1.66	1.79	1.91	1.98	2.01
0.21	0.11	0.25	0.40	0.54	0.66	0.76	0.87	0.96	1.06	1.15	1.25	1.35	1.53	1.74	1.89	2.01	2.08	2.12
0.23	0.12	0.26	0.42	0.57	0.69	0.80	0.91	1.00	1.11	1.20	1.31	1.42	1.61	1.83	1.98	2.11	2.19	2.22
0.25	0.12	0.28	0.44	0.60	0.72	0.84	0.95	1.05	1.16	1.26	1.37	1.48	1.68	1.91	2.07	2.21	2.28	2.32
0.27	0.13	0.29	0.45	0.62	0.75	0.87	0.99	1.09	1.20	1.31	1.43	1.54	1.75	1.99	2.16	2.30	2.38	2.41
0.29	0.13	0.30	0.47	0.64	0.78	0.90	1.02	1.13	1.25	1.36	1.48	1.60	1.82	2.06	2.24	2.38	2.47	2.50
0.31	0.14	0.31	0.49	0.67	0.81	0.94	1.06	1.17	1.29	1.41	1.53	1.66	1.88	2.14	2.32	2.47	2.55	2.59
0.33	0.14	0.32	0.50	0.69	0.84	0.97	1.09	1.21	1.34	1.45	1.58	1.71	1.94	2.21	2.39	2.55	2.64	2.68
0.35	0.14	0.33	0.52	0.71	0.86	1.00	1.13	1.25	1.38	1.50	1.63	1.76	2.00	2.27	2.46	2.63	2.72	2.76
0.38	0.15	0.34	0.53	0.73	0.89	1.03	1.16	1.28	1.42	1.54	1.68	1.81	2.06	2.34	2.54	2.70	2.80	2.84
0.40	0.15	0.35	0.55	0.75	0.91	1.05	1.19	1.32	1.46	1.58	1.73	1.86	2.12	2.40	2.61	2.78	2.87	2.92
0.42	0.16	0.36	0.56	0.77	0.93	1.08	1.22	1.35	1.49	1.62	1.77	1.91	2.17	2.47	2.67	2.85	2.95	2.99
0.46	0.16	0.37	0.59	0.81	0.98	1.13	1.28	1.42	1.57	1.70	1.86	2.00	2.28	2.59	2.80	2.99	3.09	3.14
0.50	0.17	0.39	0.62	0.84	1.02	1.18	1.34	1.48	1.64	1.78	1.94	2.09	2.38	2.70	2.93	3.12	3.23	3.28
0.54	0.18	0.41	0.64	0.88	1.06	1.23	1.40	1.54	1.70	1.85	2.02	2.18	2.47	2.81	3.05	3.25	3.36	3.41
0.58	0.19	0.42	0.66	0.91	1.10	1.28	1.45	1.60	1.77	1.92	2.10	2.26	2.57	2.92	3.16	3.37	3.49	3.54
0.63	0.19	0.44	0.69	0.94	1.14	1.32	1.50	1.66	1.83	1.99	2.17	2.34	2.66	3.02	3.27	3.49	3.61	3.67
0.67	0.20	0.45	0.71	0.97	1.18	1.37	1.55	1.71	1.89	2.06	2.24	2.42	2.75	3.12	3.38	3.60	3.73	3.79
0.71	0.20	0.46	0.73	1.00	1.22	1.41	1.60	1.76	1.95	2.12	2.31	2.49	2.83	3.22	3.49	3.71	3.84	3.90
0.75	0.21	0.48	0.75	1.03	1.25	1.45	1.64	1.82	2.00	2.18	2.38	2.56	2.91	3.31	3.59	3.82	3.96	4.02
0.79	0.22	0.49	0.77	1.06	1.29	1.49	1.69	1.87	2.06	2.24	2.44	2.63	2.99	3.40	3.68	3.93	4.06	4.13
0.83	0.22	0.50	0.79	1.09	1.32	1.53	1.73	1.91	2.11	2.30	2.50	2.70	3.07	3.49	3.78	4.03	4.17	4.23
0.92	0.23	0.53	0.83	1.14	1.39	1.60	1.82	2.01	2.22	2.41	2.63	2.83	3.22	3.66	3.97	4.22	4.37	4.44
1.00	0.24	0.55	0.87	1.19	1.45	1.67	1.90	2.10	2.31	2.52	2.74	2.96	3.36	3.82	4.14	4.41	4.57	4.64
1.08	0.25	0.57	0.91	1.24	1.51	1.74	1.97	2.18	2.41	2.62	2.86	3.08	3.50	3.98	4.31	4.59	4.75	4.83
1.17	0.26	0.60	0.94	1.29	1.56	1.81	2.05	2.26	2.50	2.72	2.96	3.20	3.63	4.13	4.47	4.77	4.93	5.01
1.25	0.27	0.62	0.97	1.33	1.62	1.87	2.12	2.34	2.59	2.81	3.07	3.31	3.76	4.27	4.63	4.93	5.11	5.19
1.33	0.28	0.64	1.00	1.37	1.67	1.93	2.19	2.42	2.67	2.91	3.17	3.42	3.88	4.41	4.78	5.09	5.27	5.36
1.42	0.29	0.66	1.04	1.42	1.72	1.99	2.26	2.50	2.75	3.00	3.27	3.52	4.00	4.55	4.93	5.25	5.44	5.52
1.50	0.30	0.68	1.07	1.46	1.77	2.05	2.32	2.57	2.83	3.08	3.36	3.63	4.12	4.68	5.07	5.40	5.59	5.68
1.58	0.30	0.69	1.09	1.50	1.82	2.11	2.39	2.64	2.91	3.17	3.45	3.73	4.23	4.81	5.21	5.55	5.75	5.84
1.67	0.31	0.71	1.12	1.54	1.87	2.16	2.45	2.71	2.99	3.25	3.54	3.82	4.34	4.93	5.35	5.70	5.90	5.99
1.75	0.32	0.73	1.15	1.57	1.91	2.21	2.51	2.77	3.06	3.33	3.63	3.92	4.45	5.06	5.48	5.84	6.04	6.14
1.83	0.33	0.75	1.18	1.61	1.96	2.27	2.57	2.84	3.13	3.41	3.71	4.01	4.55	5.18	5.61	5.97	6.18	6.28
1.92	0.34	0.76	1.20	1.65	2.00	2.32	2.63	2.90	3.20	3.48	3.80	4.10	4.66	5.29	5.73	6.11	6.32	6.42
2.00	0.34	0.78	1.23	1.68	2.05	2.37	2.68	2.96	3.27	3.56	3.88	4.19	4.76	5.41	5.86	6.24	6.46	6.56
2.08	0.35	0.80	1.26	1.72	2.09	2.42	2.74	3.03	3.34	3.63	3.96	4.27	4.85	5.52	5.98	6.37	6.59	6.69
2.17	0.36	0.81	1.28	1.75	2.13	2.46	2.79	3.09	3.41	3.70	4.04	4.36	4.95	5.63	6.10	6.49	6.72	6.83
2.25	0.36	0.83	1.31	1.79	2.17	2.51	2.84	3.14	3.47	3.78	4.11	4.44	5.04	5.73	6.21	6.62	6.85	6.96
2.33	0.37	0.84	1.33	1.82	2.21	2.56	2.90	3.20	3.53	3.84	4.19	4.52	5.14	5.84	6.33	6.74	6.98	7.09
2.42	0.38	0.86	1.35	1.85	2.25	2.60	2.95	3.26	3.60	3.91	4.26	4.60	5.23	5.94	6.44	6.86	7.10	7.21
2.50	0.38	0.87	1.38	1.88	2.29	2.65	3.00	3.31	3.66	3.98	4.34	4.68	5.32	6.04	6.55	6.98	7.22	7.33
2.58	0.39	0.89	1.40	1.91	2.33	2.69	3.05	3.37	3.72	4.05	4.41	4.76	5.40	6.14	6.66	7.09	7.34	7.45
2.67	0.40	0.90	1.42	1.94	2.36	2.73	3.10	3.42	3.78	4.11	4.48	4.84	5.49	6.24	6.76	7.20	7.46	7.57
2.75	0.40	0.91	1.44	1.97	2.40		iti∂r 1 5Tr	aining a	and Res		Center	4.91	5.58	6.34	6.87	7.32	7.57	7.69
2.83	0.41	0.93	1.46	2.00	2.44	2.82	3.19	3.53	-1 ³ 3 ⁸⁹	4.24	4.62	4.98	5.66	6.43	6.97	7.43	7.69	7.81

ΔΗ	IT	RC Wa	ter Me	asuren	nent Ta	bles -	18" A	rmco-	Type (Gate, S		Well Lo			s of Ba	ck of G	ate [B	lue cei	nter rep	oresen	ts best	accura	acy ran	ge]
(feet)	0.042	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	0.83	0.92	1.00	1.08	1.17	1.25	1.33	1.42	1.50
0.04	0.07	0.16	0.25	0.35	0.44	0.52	0.61	0.68	0.75	0.81	0.87	0.93	1.05	1.17	1.29	1.40	1.54	1.67	1.81	1.95	2.05	2.14	2.17	2.17
0.06	0.08	0.20	0.31	0.43	0.54	0.64	0.74	0.84	0.92	1.00	1.07	1.14	1.29	1.43	1.58	1.72	1.88	2.05	2.22	2.39	2.51	2.62	2.66	2.66
0.08	0.10	0.23	0.36	0.50	0.62	0.74	0.86	0.96	1.06	1.15	1.24	1.31	1.49	1.65	1.82	1.98	2.18	2.36	2.57	2.76	2.90	3.02	3.07	3.07
0.10	0.11	0.25	0.40	0.56	0.70	0.83	0.96	1.08	1.19	1.29	1.38	1.47	1.67	1.85	2.04	2.22	2.43	2.64	2.87	3.09	3.24	3.38	3.43	3.43
0.13	0.12	0.28	0.44	0.61	0.76	0.91	1.05	1.18	1.30	1.41	1.51	1.61	1.83	2.03	2.23	2.43	2.66	2.89	3.14	3.38	3.55	3.70	3.76	3.76
0.15	0.13	0.30	0.48	0.66	0.82	0.98	1.13	1.28	1.40	1.52	1.63	1.73	1.97	2.19	2.41	2.62	2.88	3.12	3.39	3.65	3.84	4.00	4.06	4.06
0.17	0.14	0.32	0.51	0.70	0.88	1.05	1.21	1.36	1.50	1.63	1.75	1.85	2.11	2.34	2.58	2.80	3.08	3.34	3.63	3.90	4.10	4.27	4.34	4.34
0.19	0.15	0.34	0.54	0.75	0.93	1.11	1.28	1.45	1.59	1.73	1.85	1.97	2.24	2.48	2.74	2.97	3.26	3.54	3.85	4.14	4.35	4.53	4.60	4.61
0.21 0.23	0.15 0.16	0.36 0.37	0.57 0.60	0.79 0.82	0.98 1.03	1.17 1.23	1.35 1.42	1.52 1.60	1.68 1.76	1.82 1.91	1.95 2.05	2.07 2.17	2.36 2.47	2.62 2.74	2.88 3.02	3.13 3.29	3.44 3.61	3.74 3.92	4.06 4.25	4.36 4.58	4.58 4.81	4.78 5.01	4.85 5.08	4.85 5.09
0.25	0.17	0.37	0.62	0.86	1.03	1.28	1.48	1.67	1.84	2.00	2.14	2.27	2.58	2.87	3.16	3.43	3.77	4.09	4.44	4.78	5.02	5.23	5.31	5.32
0.23	0.17	0.33	0.65	0.90	1.12	1.34	1.54	1.74	1.91	2.08	2.23	2.36	2.69	2.98	3.29	3.57	3.92	4.26	4.62	4.98	5.23	5.44	5.53	5.54
0.29	0.18	0.42	0.67	0.93	1.16	1.39	1.60	1.80	1.99	2.16	2.31	2.45	2.79	3.10	3.41	3.71	4.07	4.42	4.80	5.16	5.42	5.65	5.74	5.74
0.31	0.19	0.44	0.70	0.96	1.20	1.44	1.66	1.87	2.06	2.23	2.39	2.54	2.89	3.20	3.53	3.84	4.21	4.57	4.97	5.35	5.62	5.85	5.94	5.95
0.33	0.19	0.45	0.72	0.99	1.24	1.48	1.71	1.93	2.12	2.30	2.47	2.62	2.98	3.31	3.65	3.96	4.35	4.72	5.13	5.52	5.80	6.04	6.13	6.14
0.35	0.20	0.46	0.74	1.02	1.28	1.53	1.76	1.99	2.19	2.38	2.55	2.70	3.07	3.41	3.76	4.09	4.48	4.87	5.29	5.69	5.98	6.23	6.32	6.33
0.38	0.21	0.48	0.76	1.05	1.32	1.57	1.82	2.05	2.25	2.44	2.62	2.78	3.16	3.51	3.87	4.20	4.61	5.01	5.44	5.86	6.15	6.41	6.50	6.51
0.40	0.21	0.49	0.78	1.08	1.36	1.62	1.87	2.10	2.31	2.51	2.69	2.86	3.25	3.61	3.98	4.32	4.74	5.15	5.59	6.02	6.32	6.58	6.68	6.69
0.42	0.22	0.50	0.81	1.11	1.39	1.66	1.91	2.16	2.37	2.58	2.76	2.93	3.33	3.70	4.08	4.43	4.86	5.28	5.74	6.17	6.48	6.75	6.86	6.87
0.46	0.23	0.53	0.84	1.17	1.46	1.74	2.01 2.10	2.26	2.49	2.70	2.90	3.08	3.50	3.88	4.28	4.65	5.10	5.54	6.02	6.47	6.80 7.10	7.08	7.19	7.20
0.50 0.54	0.24 0.25	0.55 0.57	0.88 0.92	1.22 1.27	1.52 1.59	1.82 1.89	2.10	2.36 2.46	2.60 2.71	2.82 2.94	3.03 3.15	3.21 3.34	3.65 3.80	4.05 4.22	4.47 4.65	4.85 5.05	5.33 5.55	5.79 6.02	6.28 6.54	6.76 7.04	7.10	7.40 7.70	7.51 7.82	7.52 7.83
0.58	0.26	0.60	0.95	1.31	1.65	1.96	2.26	2.55	2.81	3.05	3.27	3.47	3.94	4.38	4.83	5.24	5.75	6.25	6.79	7.30	7.67	7.70	8.11	8.12
0.63	0.26	0.62	0.99	1.36	1.70	2.03	2.34	2.64	2.91	3.16	3.38	3.59	4.08	4.53	5.00	5.43	5.96	6.47	7.02	7.56	7.94	8.27	8.40	8.41
0.67	0.27	0.64	1.02	1.41	1.76	2.10	2.42	2.73	3.00	3.26	3.49	3.71	4.22	4.68	5.16	5.61	6.15	6.68	7.25	7.81	8.20	8.54	8.67	8.68
0.71	0.28	0.66	1.05	1.45	1.81	2.16	2.50	2.81	3.10	3.36	3.60	3.82	4.35	4.82	5.32	5.78	6.34	6.89	7.48	8.05	8.45	8.81	8.94	8.95
0.75	0.29	0.68	1.08	1.49	1.87	2.23	2.57	2.89	3.19	3.46	3.71	3.93	4.47	4.96	5.47	5.95	6.53	7.09	7.70	8.28	8.70	9.06	9.20	9.21
0.79	0.30	0.69	1.11	1.53	1.92	2.29	2.64	2.97	3.27	3.55	3.81	4.04	4.59	5.10	5.62	6.11	6.70	7.28	7.91	8.51	8.94	9.31	9.45	9.46
0.83	0.31	0.71	1.14	1.57	1.97	2.35	2.71	3.05	3.36	3.64	3.91	4.15	4.71	5.23	5.77	6.27	6.88	7.47	8.11	8.73	9.17	9.55	9.70	9.71
0.92	0.32	0.75	1.19	1.65	2.06	2.46	2.84	3.20	3.52	3.82	4.10	4.35	4.94	5.49	6.05	6.57	7.21	7.83	8.51	9.15	9.62	10.02	10.17	10.18
1.00	0.34	0.78	1.25	1.72	2.15	2.57	2.97	3.34	3.68	3.99	4.28	4.54	5.16	5.73	6.32	6.86	7.53	8.18	8.89 9.25	9.56	10.04	10.46	10.62	10.64
1.08 1.17	0.35 0.36	0.81 0.84	1.30 1.35	1.79 1.86	2.24	2.67 2.78	3.09 3.20	3.48 3.61	3.83 3.97	4.15 4.31	4.45 4.62	4.73 4.91	5.37 5.58	5.96 6.19	6.58 6.83	7.15 7.41	7.84 8.14	8.52 8.84	9.60	9.95 10.33	10.45 10.85	10.89 11.30	11.05 11.47	11.07 11.49
1.17	0.37	0.87	1.39	1.92	2.33	2.78	3.32	3.73	4.11	4.46	4.78	5.08	5.77	6.41	7.06	7.41	8.42	9.15	9.93	10.55	11.23	11.70	11.47	11.49
1.33	0.39	0.90	1.44	1.99	2.49	2.97	3.42	3.86	4.25	4.61	4.94	5.25	5.96	6.62	7.30	7.93	8.70	9.45	10.26	11.04	11.60	12.08	12.26	12.28
1.42	0.40	0.93	1.49	2.05	2.56	3.06	3.53	3.98	4.38	4.75	5.09	5.41	6.15	6.82	7.52	8.17	8.97	9.74	10.58	11.38	11.96	12.45	12.64	12.66
1.50	0.41	0.96	1.53	2.11	2.64	3.15	3.63	4.09	4.51	4.89	5.24	5.56	6.32	7.02	7.74	8.41	9.23	10.02	10.88	11.71	12.30	12.81	13.01	13.03
1.58	0.42	0.98	1.57	2.17	2.71	3.23	3.73	4.20	4.63	5.02	5.39	5.72	6.50	7.21	7.95	8.64	9.48	10.30	11.18	12.03	12.64	13.17	13.36	13.38
1.67	0.43	1.01	1.61	2.22	2.78	3.32	3.83	4.31	4.75	5.15	5.53	5.86	6.67	7.40	8.16	8.86	9.73	10.56	11.47	12.34	12.97	13.51	13.71	13.73
1.75	0.44	1.03	1.65	2.28	2.85	3.40	3.92	4.42	4.87	5.28	5.66	6.01	6.83	7.58	8.36	9.08	9.97	10.83	11.75	12.65	13.29	13.84	14.05	14.07
1.83	0.45	1.06	1.69	2.33	2.92	3.48	4.01	4.52	4.98	5.40	5.79	6.15	6.99	7.76	8.56	9.29			12.03					14.40
1.92	0.46	1.08	1.73		2.98	3.56	4.11	4.62	5.09	5.53	5.93	6.29	7.15	7.93	8.75	9.50							14.70	14.72
2.00 2.08	0.47 0.48	1.10 1.13	1.76 1.80	2.43 2.48	3.05 3.11	3.63 3.71	4.19 4.28	4.72 4.82	5.20 5.31	5.64 5.76	6.05 6.18	6.42 6.56	7.30 7.45	8.10 8.27	8.94 9.12	9.71 9.91	10.66 10.88	11.57	12.57	13.52	14.20 14.50			15.04 15.35
2.06	0.48	1.15	1.84	2.53	3.17	3.71	4.36	4.92	5.41	5.88	6.30	6.69	7.60	8.44	9.30	10.10	11.09						15.63	15.66
2.25	0.50	1.17	1.87	2.58	3.23	3.85	4.45	5.01	5.52	5.99	6.42	6.81	7.75	8.60	9.48		11.30				15.07	15.69		15.95
2.33	0.51	1.19	1.91	2.63	3.29	3.93	4.53	5.10	5.62	6.10	6.54	6.94	7.89	8.75	9.65	10.49			13.57		15.34			16.25
2.42	0.52	1.21	1.94	2.68	3.35	3.99	4.61	5.19	5.72	6.21	6.65	7.06	8.03	8.91	9.82	10.67	11.71	12.72	13.81	14.86	15.61	16.26	16.51	16.53
2.50	0.53	1.23	1.97	2.72	3.41	4.06	4.69	5.28	5.82	6.31	6.77	7.18	8.16	9.06	9.99	10.85	11.91	12.94	14.05	15.12	15.88			16.82
2.58	0.54	1.26	2.01	2.77	3.46	4.13	4.77	5.37	ri5gatio		infing	añð⁰R	es e ai	ch²€e	niget 6	11.03			14.28		16.14			17.09
2.67	0.55	1.28	2.04	2.81	3.52	4.20	4.84	5.45	6.01	6.52	6.99	D-742	8.43	9.36	10.32	11.21		13.36		15.61	16.40	17.09		17.37
2.75	0.56	1.30	2.07	2.85	3.57	4.26	4.92	5.54	6.10	6.62			8.56	9.50	10.48		12.50							17.64
2.83	0.56	1.31	2.10	2.90	3.63	4.33	4.99	5.62	6.19	6.72	7.20	7.65	8.69	9.65	10.64	11.56	12.68	13.77	14.96	16.09	16.91	17.61	17.88	17.90

			П	RC W	ater M	easur	ement	Tables	s – <u>24</u>	" Arm	ico-Ty	/pe G	ate, St	_					Back of	f Gate	[Blue	cente	r repre	sents	best a	ccura	cy ran	ge]		
ΔH (feet)	0.042	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	pening 0.83	0.92	1.00	1.08	1.17	1.25	1.33	1.42	1.50	1.58	1.67	1.75	1.83	1.92	2.00
(feet) 0.04	0.042	0.08	0.13	0.17	0.21	0.23	0.29	0.95	1.05	1.14	1.23	1.31	1.49	1.65	1.81	1.96	2.14	2.32	2.45	2.57	2.71	2.85	3.01	3.16	3.30	3.51	3.68	3.71	3.77	3.57
0.04	0.12	0.27	0.43	0.60	0.75	0.89	1.03	1.17	1.29	1.40	1.51	1.61	1.82	2.02	2.22	2.40	2.63	2.84	3.00	3.14	3.32	3.49	3.68	3.87	4.04	4.30	4.51	4.54	4.62	4.37
0.08	0.14	0.31	0.50	0.69	0.86	1.03	1.19	1.35	1.49	1.62	1.74	1.85	2.10	2.33	2.56	2.78	3.03	3.28	3.46	3.63	3.84	4.03	4.25	4.47	4.67	4.97	5.20	5.24	5.34	5.04
0.10	0.15	0.35	0.56	0.77	0.96	1.15	1.33	1.51	1.66	1.81	1.95	2.07	2.35	2.61	2.87	3.10	3.39	3.67	3.87	4.06	4.29	4.51	4.76	4.99	5.22	5.56	5.82	5.86	5.97	5.64
0.13	0.17	0.39	0.61	0.84	1.06	1.26	1.46	1.65	1.82	1.98	2.13	2.27	2.58	2.86	3.14	3.40	3.71	4.02	4.24	4.44	4.70	4.94	5.21	5.47	5.72	6.09	6.37	6.42	6.54	6.18
0.15	0.18	0.42	0.66	0.91	1.14	1.36	1.58	1.78	1.97	2.14	2.30	2.45	2.78	3.09	3.39	3.67	4.01	4.34	4.58	4.80	5.07	5.33	5.63	5.91	6.17	6.57	6.88	6.93	7.06	6.67
0.17	0.19	0.44	0.71	0.97	1.22	1.46	1.69	1.91	2.10	2.29	2.46	2.62	2.98	3.30	3.63	3.93	4.29	4.64	4.90	5.13	5.43	5.70	6.02	6.32	6.60	7.03	7.36	7.41	7.55	7.13
0.19	0.20	0.47	0.75	1.03	1.29	1.55	1.79	2.02	2.23	2.43	2.61	2.78	3.16	3.50	3.85	4.17	4.55	4.92	5.20	5.44	5.75	6.05	6.38	6.70	7.00	7.45	7.81	7.86	8.01	7.56
0.21 0.23	0.22	0.50 0.52	0.79	1.09 1.14	1.36 1.43	1.63 1.71	1.89 1.98	2.13	2.35	2.56 2.68	2.75 2.89	2.93 3.07	3.33 3.49	3.69 3.87	4.05 4.25	4.39 4.61	4.80 5.03	5.19 5.44	5.48 5.74	5.74 6.02	6.07 6.36	6.38	6.73 7.05	7.06 7.41	7.38 7.74	7.86 8.24	8.23 8.63	8.29 8.69	8.44 8.85	7.97 8.36
0.25	0.23	0.54	0.83	1.19	1.49	1.71	2.07	2.33	2.58	2.80	3.02	3.21	3.65	4.04	4.23	4.81	5.25	5.68	6.00	6.28	6.64	6.98	7.37	7.74	8.08	8.61	9.01	9.08	9.24	8.74
0.23	0.25	0.57	0.90	1.24	1.55	1.86	2.15	2.43	2.68	2.92	3.14	3.34	3.79	4.21	4.62	5.01	5.47	5.92	6.24	6.54	6.92	7.27	7.67	8.05	8.41	8.96	9.38	9.45	9.62	9.09
0.29	0.26	0.59	0.94	1.29	1.61	1.93	2.23	2.52	2.78	3.03	3.26	3.47	3.94	4.37	4.80	5.20	5.67	6.14	6.48	6.79	7.18	7.54	7.96	8.36	8.73	9.30	9.74	9.80	9.98	9.43
0.31	0.26	0.61	0.97	1.33	1.67	2.00	2.31	2.61	2.88	3.13	3.37	3.59	4.08	4.52	4.96	5.38	5.87	6.36	6.71	7.03	7.43	7.81	8.24	8.65	9.04	9.62	10.08	10.15	10.33	9.77
0.33	0.27	0.63	1.00	1.38	1.72	2.06	2.38	2.69	2.97	3.24	3.48	3.71	4.21	4.67	5.13	5.55	6.07	6.56	6.93	7.26	7.67	8.06	8.51	8.93	9.33	9.94	10.41	10.48	10.67	10.09
0.35	0.28	0.65	1.03	1.42	1.78	2.12	2.46	2.78	3.07	3.34	3.59	3.82	4.34	4.81	5.29	5.72	6.25	6.77	7.14	7.48	7.91	8.31	8.77	9.21	9.62	10.25	10.73	10.80	11.00	10.40
0.38	0.29	0.67	1.06	1.46	1.83	2.19	2.53	2.86	3.16	3.43	3.69	3.93	4.46	4.95	5.44	5.89	6.43	6.96	7.35	7.70	8.14	8.55	9.02	9.47	9.90				11.32	10.70
0.40	0.30	0.69	1.09	1.50	1.88	2.25	2.60	2.94	3.24	3.53	3.79	4.04	4.59	5.09	5.59	6.05	6.61	7.15	7.55	7.91	8.36	8.79	9.27	9.73	10.17	10.83		11.42	11.63	10.99
0.42	0.31	0.70	1.12	1.54	1.93	2.30	2.67	3.01	3.33	3.62	3.89	4.15	4.71	5.22	5.73	6.21	6.78	7.34	7.75	8.11	8.58	9.02	9.51	9.99	10.44	11.11	11.64	11.72	11.93	11.28
0.46 0.50	0.32	0.74 0.77	1.17 1.22	1.61 1.69	2.02	2.42	2.80	3.16 3.30	3.49 3.64	3.80 3.96	4.08 4.26	4.35 4.54	4.94 5.16	5.47 5.72	6.01	6.51	7.11 7.43	7.70 8.04	8.12 8.48	8.51 8.89	9.00 9.40	9.46 9.88	9.98 10.42	10.47	10.94 11.43		12.20	12.29 12.84		11.83 12.35
0.54	0.35	0.80	1.27	1.75	2.11	2.63	3.04	3.44	3.79	4.13	4.44	4.73	5.37	5.95	6.54	7.08	7.43	8.37	8.83	9.25	9.78	10.28	10.42		11.43	12.17	13.27		13.61	12.33
0.54	0.36	0.83	1.32	1.82	2.28	2.73	3.15	3.56	3.94	4.28	4.61	4.91	5.57	6.17	6.78	7.35	8.03	8.68	9.16	9.60	10.15	10.67			12.35	13.15	13.77	13.87	14.12	13.34
0.63	0.37	0.86	1.37	1.88	2.36	2.82	3.27	3.69	4.07	4.43	4.77	5.08	5.76	6.39	7.02	7.61	8.31	8.99	9.49	9.94		11.04				13.61			14.62	13.81
0.67	0.39	0.89	1.41	1.95	2.44	2.91	3.37	3.81	4.21	4.58	4.92	5.24	5.95	6.60	7.25	7.85	8.58	9.28	9.80			11.41					14.72		15.10	14.26
0.71	0.40	0.92	1.46	2.01	2.51	3.00	3.48	3.93	4.34	4.72	5.08	5.41	6.14	6.80	7.47	8.10	8.84	9.57	10.10	10.58	11.18	11.76	12.40	13.02	13.61	14.49	15.17	15.28	15.56	14.70
0.75	0.41	0.94	1.50	2.06	2.59	3.09	3.58	4.04	4.46	4.86	5.22	5.56	6.31	7.00	7.69	8.33	9.10	9.85	10.39	10.89	11.51	12.10	12.76	13.40	14.00	14.91	15.61	15.72	16.01	15.13
0.79	0.42	0.97	1.54	2.12	2.66	3.18	3.67	4.15	4.58	4.99	5.37	5.71	6.49	7.19	7.90	8.56		10.12		11.18				13.77				16.15	16.45	15.54
0.83	0.43	0.99	1.58	2.18	2.73	3.26	3.77	4.26	4.70	5.12	5.50	5.86	6.66	7.38	8.11	8.78			10.95					14.12			16.46		16.88	15.95
0.92	0.45	1.04	1.66	2.28	2.86	3.42	3.95 4.13	4.47 4.67	4.93 5.15	5.37	5.77 6.03	6.15	6.98 7.29	7.74 8.08	8.50	9.21		10.88	11.49 12.00		12.72 13.29		14.11	14.81 15.47	15.48 16.17	16.48 17.22	17.26 18.03		17.70 18.49	16.73 17.47
1.00 1.08	0.47	1.13	1.73	2.38	3.11	3.72	4.13	4.86	5.36	5.84	6.28	6.42 6.69	7.59	8.41	8.88 9.24	10.01		11.83			13.83				16.83				19.24	18.18
1.17	0.43	1.13	1.87	2.57	3.23	3.86	4.46	5.04	5.57	6.06	6.51	6.94	7.87	8.73	9.59	10.39		12.28	12.45		14.35				17.46	18.60		19.61	19.97	18.87
1.25	0.53	1.22	1.94	2.66	3.34	3.99	4.62	5.22	5.76	6.27	6.74	7.18	8.15	9.04	9.93			12.71						17.30		19.25	20.15		20.67	19.53
1.33	0.55	1.26	2.00	2.75	3.45	4.12	4.77	5.39	5.95	6.47	6.96	7.42	8.42	9.33	10.26	11.11		13.13	13.85	14.51	15.34	16.13	17.02	17.87	18.67	19.88	20.81	20.96	21.35	20.17
1.42	0.56	1.30	2.06	2.84	3.56	4.25	4.92	5.56	6.13	6.67	7.18	7.64	8.68	9.62	10.57	11.45	12.51	13.53	14.28	14.96	15.82	16.63	17.54	18.42	19.24	20.49	21.46	21.61	22.00	20.79
1.50	0.58	1.33	2.12	2.92	3.66	4.37	5.06	5.72	6.31	6.87	7.39	7.87	8.93	9.90		11.78	12.87	13.92	14.70	15.40	16.28	17.11	18.05	18.95	19.80	21.09	22.08	22.24	22.64	21.40
1.58	0.59	1.37	2.18	3.00	3.76	4.49	5.20	5.87	6.48	7.06	7.59	8.08	9.17	10.17	11.18	12.10		14.31			1	17.58	18.54	19.47	20.34	21.66	22.68		23.26	21.98
1.67	0.61	1.41	2.24	3.08	3.86	4.61	5.33	6.03	6.65	7.24	7.79	8.29	9.41	10.44	11.47	12.42		14.68	15.49	16.23	17.16	18.03	19.03	19.97	20.87	22.23	23.27	23.44	23.87	22.55
1.75 1.83	0.63	1.44 1.48	2.29	3.15 3.23	3.95 4.04	4.72 4.83	5.46 5.59	6.17 6.32	6.82	7.42 7.59	7.98 8.17	8.50 8.70	9.64 9.87	10.69 10.95	11.75 12.03			15.04						20.47			23.85	24.02	24.46	23.11 23.65
1.92																												25.13		
2.00			2.45				5.84			7.93																		25.67		
2.08			2.50				5.96			8.09																				25.22
2.17	0.70	1.60	2.55	3.51		5.25		6.87	7.58	8.25	8.88	9.45	10.73	11.90	13.07	14.16	15.47	16.73	17.66	18.50	19.56	20.56	21.69	22.77	23.80	25.34	26.53	26.72	27.21	25.72
2.25	0.71	1.63	2.60	3.58	4.48	5.35	6.20	7.00	7.73	8.41	9.05	9.63	10.94	12.13	13.32	14.43	15.76	17.05	18.00	18.85	19.93	20.95	22.11	23.21	24.25	25.82	27.04	27.23	27.73	26.21
2.33	0.72	1.66	2.65	3.64		5.45		7.13	7.87	8.56	9.21	9.81	11.14	12.35	13.57	14.69	16.05	17.37	18.33	19.20	20.30	21.34	22.51	23.63	24.69	26.30	27.54	27.73	28.24	26.69
2.42	0.73		2.69	3.71		5.55		7.26	8.01	8.72	9.37	9.98	11.33	12.57	13.81	14.95	16.33	17.67	18.65	19.54	20.66	21.71	22.91	24.05	25.13	26.76	28.02	28.22	28.74	27.16
2.50			2.74				6.53	7.38	8.15	8.87	9.53	10.16	11.53	12.78	14.04	15.21	16.61	17.98	18.97	19.87	21.01	22.09	23.30	24.46	25.56	27.22	28.50	28.71	29.23	27.62
2.58			2.78			5.74		7.50	8.28	9.01	9.69 0.0rr	gatio	n Tra	i <mark>ning</mark>	and I	RESE	iţch C	ente	19.29	20.20	21.36	22.45	23.69	24.87	25.98	27.67	28.97	29.18	29./1	27.62 28.08 28.53
2.67 2.75	0.77 0.78	1.78	2.83			5.83	6.74	7.62	8.41	9.16	10.00	10.49	12.00	13.20	D ₁ 150	15./1	17.16	18.56	19.59	20.53	22.70	22.81	24.07	25.27	26.40	28.11	29.44	29.65	30.19	28.53
2.75			2.07	4.01	5.03	6.01	6.95	7.74	8.67	9.44	10.00	10.03	12.09	13.41	14.73	16.93	17.42	19 14	20.20	21 16	22.04	23.10	24.44	26.04	27 21	28.33	30 34	30.11	31.12	29.41
2.00	0.80	1.03	2.32	4.01	5.05	0.01	0.55	7.00	0.07	J.44	10.13	10.61	12.27	15.01	14.53	10.19	17.03	13.14	20.20	21.10	22.37	25.51	24.01	20.04	27.21	20.50	30.34	30.30	31.12	23.41

Preliminary Tables for **Round Gates on Round Pipes**

Discharge Values in CFS

These tables are from the original ARMCO Flow Measurement Tables and will be replaced as these gate sizes are tested by ITRC

Armco-Type Metergate Tables - Preliminary

8-inch Round Gate

Head	Net Gate Opening (feet)													
Difference	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.54	0.58	0.63	0.67	
(feet)							Discharge							
0.08	0.27	0.32	0.38	0.42	0.46	0.51	0.55	0.57	0.59	0.61	0.62	0.63	0.64	
0.10	0.30	0.36	0.42	0.46	0.51	0.56	0.60	0.63	0.65	0.68	0.70	0.71	0.71	
0.13	0.32	0.39	0.46	0.50	0.56	0.61	0.67	0.69	0.72	0.75	0.77	0.78	0.78	
0.15	0.35	0.42	0.49	0.54	0.60	0.66	0.72	0.75	0.78	0.81	0.83	0.84	0.85	
0.17	0.37	0.44	0.52	0.58	0.64	0.70	0.76	0.80	0.83	0.86	0.89	0.90	0.91	
0.19	0.39	0.46	0.54	0.61	0.67	0.74	0.80	0.84	0.88	0.92	0.94	0.96	0.97	
0.21	0.41	0.49	0.57	0.64	0.70	0.77	0.85	0.89	0.93	0.96	1.00	1.01	1.02	
0.23	0.42	0.51	0.60	0.66	0.74	0.81	0.88	0.93	0.97	1.01	1.04	1.06	1.07	
0.25	0.44	0.53	0.62	0.70	0.76	0.84	0.92	0.97	1.02	1.06	1.09	1.11	1.12	
0.27	0.46	0.55	0.64	0.72	0.79	0.87	0.95	1.01	1.06	1.10	1.13	1.15	1.16	
0.29	0.47	0.57	0.67	0.74	0.82	0.90	0.99	1.05	1.10	1.14	1.18	1.20	1.21	
0.31	0.49	0.59	0.69	0.77	0.85	0.93	1.02	1.08	1.14	1.18	1.22	1.24	1.26	
0.33	0.50	0.60	0.71	0.79	0.88	0.96	1.05	1.12	10.18	1.22	1.26	1.28	1.30	
0.35	0.52	0.62	0.73	0.82	0.90	0.99	1.08	1.15	1.22	1.26	1.30	1.33	1.34	
0.38	0.53	0.64	0.75	0.84	0.92	1.02	1.11	1.19	1.25	1.30	1.34	1.37	1.38	
0.40	0.54	0.65	0.76	0.86	0.95	1.04	1.14	1.22	1.29	1.34	1.38	1.41	1.42	
0.42	0.56	0.67	0.78	0.88	0.97	1.07	1.17	1.25	1.32	1.37	1.42	1.44	1.46	
0.46	0.58	0.70	0.81	0.91	1.01	1.12	1.22	1.31	1.38	1.44	1.49	1.52	1.54	
0.50	0.60	0.72	0.84	0.95	1.06	1.17	1.27	1.36	1.44	1.50	1.55	1.58	1.60	
0.54	0.62	0.75	0.87	0.99	1.10	1.22	1.32	1.42	1.50	1.56	1.61	1.65	1.67	
0.58	0.64	0.77	0.90	1.03	1.15	1.26	1.37	1.47	1.55	1.62	1.67	1.71	1.74	
0.63	0.66	0.80	0.94	1.06	1.19	1.31	1.42	1.53	1.61	1.68	1.73	1.77	1.80	
0.67	0.68	0.82	0.96	1.10	1.22	1.35	1.47	1.58	1.66	1.73	1.79	1.83	1.86	
0.71	0.70	0.85	1.00	1.13	1.26	1.39	1.52	1.62	1.71	1.78	1.84	1.88	1.92	
0.75	0.72	0.87	1.02	1.16	1.30	1.43	1.56	14.67	1.76	1.84	1.89	1.94	1.97	
0.79	0.74	0.90	1.05	1.19	1.33	1.47	1.60	1.72	1.81	1.89	1.94	1.99	2.02	
0.83	0.76	0.92	1.08	1.22	1.37	1.51	1.64	1.76	1.85	1.94	1.99	2.04	2.08	
0.92	0.79	0.96	1.13	1.28	1.44	1.58	1.72	1.85	1.94	2.03	2.09	2.14	2.18	
1.00	0.83	1.01	1.18	1.34	1.50	1.66	1.80	1.93	2.03	2.12	2.18	2.24	2.27	
1.08	0.86	1.05	1.23	1.40	1.56	1.72	1.87	2.01	2.12	2.21	2.29	2.33	2.37	
1.17	0.89	1.09	1.28	1.45	1.62	1.79	1.94	2.08	2.20	2.29	2.36	2.42	2.46	
1.25	0.92	1.13	1.32	1.50	1.68	1.85	2.01	2.16	2.27	2.37	2.44	2.50	2.54	
1.33	0.95	1.16	1.37	1.55	1.73	1.91	2.08	2.23	2.35	2.45	2.52	2.58	2.62	
1.42	0.98	1.20	1.41	1.60	1.78	1.97	2.14	2.30	2.42	2.52	2.60	2.66	2.71	
1.50	1.01	1.23	1.45	1.64	1.84	2.03	2.20	2.36	2.49	2.60	2.68	2.74	2.79	

Irrigation Training and Research Center

Armco-Type Metergate Tables - Preliminary

15-inch Round Gate

Head									Net Gat	e Opening	(feet)							
Difference	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	0.83	0.92	1.00	1.08	1.17	1.25
(feet)			I	I .		I	ı	ı	Dis	charge (cf	s)	ı		I	I		I	l
0.08	0.46	0.57	0.66	0.75	0.83	0.91	0.98	1.07	1.14	1.30	1.43	1.58	1.71	1.84	1.94	2.04	2.13	2.18
0.10	0.51	0.62	0.73	0.83	0.92	1.02	1.09	1.19	1.27	1.44	1.59	1.75	1.90	2.05	2.17	2.29	2.38	2.43
0.13	0.55	0.67	0.79	0.91	1.00	1.11	1.19	1.30	1.38	1.57	1.74	1.91	2.08	2.24	2.38	2.51	2.62	2.67
0.15	0.59	0.72	0.85	0.98	1.08	1.19	1.28	1.39	1.49	1.68	1.87	2.06	2.24	2.41	2.57	2.72	2.83	2.90
0.17	0.63	0.77	0.90	1.04	1.15	1.27	1.37	1.48	1.59	1.79	1.99	2.20	2.39	2.58	2.75	2.90	3.03	3.09
0.19	0.67	0.81	0.95	1.10	1.22	1.34	1.45	1.57	1.48	1.89	2.11	2.33	2.54	2.73	2.91	3.07	3.22	3.28
0.21	0.70	0.85	1.00	1.15	1.28	1.41	1.53	1.65	1.76	1.99	2.22	2.45	2.68	2.87	3.07	3.24	3.40	3.46
0.23	0.73	0.89	1.05	1.20	1.33	1.48	1.60	1.73	1.84	2.09	2.33	2.57	2.81	3.01	3.21	3.40	3.57	6.64
0.25	0.76	3.93	1.09	1.25	1.38	1.54	1.67	1.80	1.92	2.18	2.43	2.69	2.93	3.14	3.35	3.54	3.73	3.81
0.27	0.79	0.97	1.13	1.29	1.43	1.60	1.73	1.87	2.00	2.27	2.53	2.80	3.05	3.27	3.49	3.68	3.88	3.97
0.29	0.82	1.00	1.17	1.33	1.48	1.65	1.79	1.94	2.08	2.36	2.63	2.90	3.17	3.39	3.62	3.82	4.01	4.11
0.31	0.85	1.03	1.21	1.37	1.53	1.70	1.85	2.01	2.15	2.44	2.72	3.00	3.28	3.51	3.75	3.96	4.14	4.25
0.33	0.88	1.06	1.25	1.41	1.58	1.75	1.91	2.07	1.22	2.52	2.81	3.10	3.39	3.63	3.87	4.09	4.27	4.39
0.35	0.91	1.09	1.29	1.45	1.63	1.80	1.97	2.13	2.29	2.60	2.90	3.20	3.49	3.74	3.99	4.21	4.40	4.53
0.38	0.93	1.12	1.32	1.49	1.68	1.85	2.03	2.19	2.36	2.68	2.98	3.29	3.59	3.85	4.10	4.33	4.53	4.67
0.40	0.95	1.15	1.35	1.53	1.73	1.90	2.09	2.25	2.42	2.75	3.06	3.38	3.69	3.96	4.21	4.45	4.65	4.80
0.42	0.97	1.18	1.38	1.57	1.77	1.95	2.14	2.31	2.48	2.82	3.14	3.47	3.79	4.06	2.32	4.57	4.77	4.92
0.46	1.01	1.23	1.44	1.64	1.85	2.05	2.24	2.43	2.60	2.96	3.30	3.63	3.97	4.26	4.54	4.79	5.00	5.14
0.50	1.05	1.28	1.50	1.71	1.93	2.14	2.34	2.54	2.72	3.09	3.44	3.79	4.15	4.44	4.74	5.00	5.22	5.36
0.54	1.09	1.33	1.56	1.78	2.01	2.23	2.44	2.64	2.83	3.22	3.58	3.95	4.32	4.62	4.93	5.20	5.43	5.58
0.58	1.13	1.38	1.62	1.85	2.09	2.31	2.53	2.74	2.93	3.34	3.72	4.10	4.48	4.79	5.11	5.40	5.64	5.79
0.63	1.17	1.42	1.68	1.92	2.16	2.39	2.62	2.84	3.03	3.46	2.85	4.25	4.64	4.96	5.29	5.59	5.84	5.99
0.67	1.21	1.46	1.73	1.98	2.23	2.47	2.71	2.93	3.13	3.57	2.98	4.39	4.79	5.13	5.47	5.78	6.03	6.19
0.71	1.24	1.50	1.78	2.04	2.30	2.55	2.79	3.02	3.23	3.68	4.10	4.52	4.93	5.29	5.64	5.95	6.22	6.38
0.75	1.27	1.54	1.83	2.10	2.37	2.62	2.87	3.11	3.33	3.79	4.22	4.65	5.07	5.44	5.80	6.12	6.40	6.56
0.79	1.30	1.58	1.88	2.16	2.43	2.69	2.95	3.19	3.42	3.89	4.34	4.78	5.21	5.59	5.96	6.29	6.58	6.74
0.83	1.33	1.62	1.93	2.22	2.49	2.76	3.03	3.27	3.51	3.99	4.45	4.91	5.35	5.73	6.11	6.46	6.75	6.92
0.92	1.39	1.70	2.03	2.32	2.61	2.90	3.17	3.43	3.68	4.18	4.66	5.14	5.61	6.01	6.41	6.77	7.07	7.26
1.00	1.45	1.78	2.12	2.42	2.73	3.03	3.31	3.59	3.84	4.37	4.87	5.37	5.86	6.29	6.70	7.07	7.39	7.59
1.08	1.50	1.85	2.21	2.52	2.84	3.15	3.45	3.73	4.00	4.55	5.07	5.59	6.10	6.54	6.97	7.36	7.69	7.89
1.17	1.55	1.92	2.29	2.62	2.95	2.37	3.58	3.87	4.15	4.72	5.26	5.80	6.34	6.79	7.24	7.64	7.98	8.19
1.25	1.60	1.99	2.37	2.71	3.05	3.38	3.70	4.01	4.30	4.88	5.44	6.00	6.56	7.03	7.49	7.91	8.26	8.47
1.33	1.65	2.05	2.45	2.80	3.15	3.49	3.82	4.14	4.44	5.04	5.62	6.20	6.77	7.26	7.73	8.17	8.53	8.75
1.42	1.70	2.11	2.52	2.89	3.25	3.60	3.94	4.27	4.57	5.20	5.80	6.39	6.98	7.48	7.97	8.42	8.80	9.02
1.50	1.75	2.17	2.59	2.97	3.34	3.70	4.05	4.39	4.70	5.35	5.96	6.58	7.18	7.69	8.20	8.66	9.05	9.28

Head									et Gate (pening (feet)								
Difference	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	0.83	0.92	1.00	1.08	1.17	1.25	1.33
(feet)	0.127	0.22	0.25	0.23	0.00	0.00	0	0.10		arge (cfs)	0.07	0.70	0.00	0.52	2.00	2.00		1.10	2.00
0.08	0.49	0.59	0.70	0.79	0.89	0.97	1.05	1.14	1.22	1.37	1.53	1.68	1.83	1.96	2.10	2.24	2.35	2.43	2.47
0.10	0.55	0.66	0.77	0.88	0.98	1.08	1.16	1.27	1.36	1.52	1.70	1.87	2.04	2.19	2.34	2.50	2.63	2.72	2.78
0.13	0.59	0.72	0.84	0.96	1.07	1.18	1.27	1.39	1.48	1.66	1.86	2.04	2.22	2.39	2.56	2.74	2.89	2.98	3.05
0.15	0.63	0.77	0.90	1.03	1.15	1.27	1.37	1.49	1.59	1.79	1.99	2.20	2.40	2.57	2.76	2.96	3.12	3.23	3.31
0.17	0.67	0.82	0.96	1.10	1.23	1.35	1.46	1.59	1.69	1.91	2.12	2.34	2.56	2.74	2.94	3.16	3.31	3.46	3.54
0.19	0.71	0.86	1.02	1.16	1.30	1.43	1.54	1.68	1.79	2.02	2.25	2.48	2.71	2.91	3.11	3.33	3.50	3.66	3.75
0.21	0.75	0.90	1.07	1.21	1.36	1.50	1.62	1.76	1.89	2.13	2.37	2.61	2.85	3.08	3.28	3.50	3.68	3.85	3.95
0.23	0.78	0.94	1.12	1.26	1.42	1.57	1.69	1.84	1.98	2.23	2.49	2.74	2.99	3.23	3.44	3.67	3.86	4.03	4.14
0.25	0.81	0.98	1.16	1.31	1.48	1.64	1.76	1.92	2.06	2.33	2.60	2.86	3.12	3.37	3.59	3.83	4.04	4.20	4.33
0.27	0.84	1.02	1.20	1.36	1.54	1.70	1.84	2.00	2.14	2.43	2.71	2.98	3.25	3.51	3.74	3.99	4.20	4.37	4.51
0.29	0.87	1.06	1.24	1.41	1.59	1.75	1.91	2.08	2.22	2.52	2.81	3.09	3.37	3.64	3.88	4.14	4.36	4.53	4.69
0.31	0.90	1.09	1.28	1.46	1.64	1.81	1.98	2.15	2.30	2.61	2.91	3.20	3.49	3.77	4.02	4.28	4.52	4.69	4.86
0.33	0.93	1.12	1.32	1.51	1.69	1.87	2.05	2.22	2.38	2.69	3.00	3.31	3.61	3.89	4.15	4.42	4.67	4.85	5.02
0.35	0.96	1.15	1.36	1.56	1.74	1.93	2.11	2.29	2.45	2.77	3.09	3.41	3.72	4.01	4.28	4.56	4.81	5.00	5.18
0.38	0.99	1.18	1.40	1.61	1.79	1.99	2.17	2.36	2.52	2.85	3.18	3.51	3.83	4.13	4.40	4.69	4.95	5.15	5.32
0.40	1.02	1.21	1.44	1.65	1.84	2.04	2.23	2.42	2.59	2.93	3.27	3.61	3.94	4.24	4.52	4.82	5.09	5.29	5.46
0.42	1.04	1.24	1.48	1.69	1.89	2.09	2.29	2.48	2.66	3.01	3.36	3.70	4.04	4.35	4.64	4.95	5.22	5.43	5.59
0.46	1.08	1.30	1.55	1.76	1.98	2.19	2.40	2.60	2.79	3.16	3.52	3.88	4.24	4.56	4.87	5.19	5.47	5.69	5.85
0.50	1.12	1.36	1.61	1.83	2.07	2.28	2.50	2.71	2.91	3.30	3.68	4.05	4.42	4.76	5.08	5.42	5.71	5.94	6.10
0.54	1.16	1.41	1.67	1.90	2.15	2.37	2.60	2.82	3.03	3.43	3.83	4.21	4.60	4.96	5.29	5.64	5.95	6.18	6.35
0.58	1.20	1.46	1.73	1.97	2.23	2.46	2.70	2.93	3.14	3.56	3.97	4.37	4.77	5.15	5.49	5.85	6.18	6.41	6.59
0.63	1.24	1.51	1.79	2.04	2.31	2.55	2.80	3.04	3.25	3.69	4.11	4.53	4.94	5.33	5.68	6.06	6.39	6.64	6.82
0.67	1.28	1.56	1.85	2.11	2.39	2.63	2.89	3.14	3.36	3.81	4.25	4.68	5.11	5.50	5.87	6.26	6.60	6.86	7.05
0.71	1.31	1.60	1.90	2.18	2.46	2.71	2.98	3.24	3.46	3.93	4.38	4.82	5.26	5.67	6.05	6.45	6.81	7.07	7.27
0.75	1.34	1.64	1.95	2.24	2.53	2.79	3.07	3.33	3.56	4.04	4.51	4.96	5.41	5.83	6.23	6.64	7.01	7.27	7.48
0.79	1.37	1.68	2.00	2.30	2.60	2.87	3.15	3.42	3.66	4.15	4.63	5.10	5.56	5.99	6.40	6.83	7.20	7.47	7.68
0.83	1.40	1.72	2.05	2.36	2.67	2.95	3.23	3.51	3.75	4.26	4.75	5.23	5.71	6.15	6.56	7.00	7.39	7.67	7.88
0.92	1.46	1.80	2.15	2.48	2.80	3.09	3.39	3.68	3.93	4.46	4.98	5.48	5.98	6.45	6.88	7.34	7.74	8.04	8.26
1.00	1.52	1.88	2.25	2.59	2.92	3.23	3.54	3.84	4.11	4.66	5.20	5.73	6.25	6.74	7.19	7.66	8.09	8.40	8.63
1.08	1.58	1.96	2.34	2.69	3.04	3.36	3.68	4.00	4.28	4.85	5.41	5.96	6.50	7.01	7.48	7.98	8.41	8.74	8.98
1.17	1.64	2.04	2.43	2.79	3.15	3.49	3.82	4.15	4.44	5.03	5.61	6.19	6.75	7.28	7.76	8.27	8.73	9.07	9.32
1.25	1.70	2.11	2.51	2.89	3.26	3.61	3.96	4.29	4.60	5.21	5.81	6.40	6.99	7.54	8.04	8.56	9.04	9.39	9.65
1.33	1.76	2.18	2.59	2.99	3.37	3.73	4.09	4.43	4.75	5.38	6.00	6.61	7.22	7.79	8.30	8.85	9.34	9.70	9.96
1.42	1.81	2.25	2.67	3.08	3.48	3.84	4.22	4.57	4.90	5.55	6.19	6.82	7.44	8.03	8.56	9.13	9.63	10.00	10.27
1.50	1.86	2.31	2.75	3.16	3.58	3.95	4.34	4.70	5.04	5.71	6.37	7.01	7.65	8.25	8.80	9.39	9.90	10.28	10.56

Head													ite Ope	ning (fe	et)								
Difference	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	0.83	0.92	1.00	1.08	1.17	1.25	1.33	1.42	1.50	1.58	1.67
(feet)	0.127	0.22	0.20	0.25	0.00	0.00	0	01.10	0.00	0.00	0.07		ischarg		2.00	2.00		1.10	2.00		2.00	2.00	
0.08	0.58	0.73	0.86	0.96	1.10	1.21	1.32	1.43	1.54	1.75	1.92	2.12	2.29	2.48	2.66	2.84	3.01	3.16	3.31	3.44	3.57	3.68	3.71
0.10	0.66	0.81	0.96	1.09	1.23	1.35	1.42	1.60	1.72	1.95	2.16	2.37	2.56	2.77	2.98	3.18	3.37	3.54	3.71	3.86	4.01	4.14	4.19
0.13	0.72	0.88	1.04	1.18	1.35	1.47	1.61	1.74	1.88	2.12	2.35	2.58	2.79	3.03	3.25	3.47	3.69	3.88	4.06	4.23	4.39	4.52	4.61
0.15	0.77	0.95	1.11	1.27	1.44	1.58	1.72	1.87	2.02	2.27	2.52	2.77	3.00	3.26	3.50	3.73	3.95	4.18	3.36	4.55	4.71	4.86	4.97
0.17	0.82	1.01	1.18	1.36	1.53	1.68	1.83	1.99	2.15	2.42	2.69	2.95	3.21	3.48	3.73	3.97	4.20	4.46	4.66	4.85	5.02	5.20	5.31
0.19	0.87	1.07	1.25	1.44	1.62	1.78	1.94	2.11	2.27	2.56	2.86	3.13	3.42	3.69	3.96	4.21	4.45	4.72	4.95	5.15	5.33	5.53	5.65
0.21	0.91	1.12	1.31	1.51	1.70	1.87	2.04	2.21	2.38	2.70	3.02	3.31	3.62	3.89	4.18	4.45	4.70	4.97	5.21	5.43	5.63	5.83	5.95
0.23	0.95	1.17	1.37	1.58	1.78	1.96	2.13	2.31	2.49	2.84	3.16	3.49	3.80	4.08	4.39	4.66	4.95	5.21	5.46	5.70	5.91	6.13	6.24
0.25	0.99	1.22	1.43	1.65	1.85	2.04	2.22	2.41	2.60	2.96	3.30	3.64	3.96	4.26	4.58	4.86	5.16	5.44	5.70	5.95	6.17	6.41	6.52
0.27	1.03	1.27	1.49	1.71	1.92	2.12	2.31	2.51	2.71	3.08	3.44	3.79	4.12	4.44	4.77	5.06	5.37	5.66	5.94	6.20	6.43	6.68	6.80
0.29	1.07	1.31	1.54	1.77	1.99	2.19	2.40	2.61	2.82	3.20	5.56	3.93	4.28	4.60	4.95	5.25	5.57	5.88	6.16	6.43	6.67	6.92	7.08
0.31	1.10	1.35	1.59	1.83	2.06	2.26	2.49	2.70	2.92	3.31	3.68	4.07	4.43	4.76	5.13	5.44	5.77	6.09	6.38	6.65	6.90	7.15	7.32
0.33	1.13	1.39	1.64	1.88	2.12	2.33	2.57	2.79	3.02	3.42	3.80	4.20	4.57	4.92	5.29	5.62	5.96	6.29	6.58	6.87	7.12	7.38	7.56
0.35	1.16	1.43	1.69	1.93	2.18	2.40	2.65	2.88	3.12	3.52	3.92	4.33	4.71	5.07	5.45	5.79	6.14	6.48	6.78	7.08	7.34	7.61	7.79
0.38	1.19	1.47	1.73	1.98	2.24	2.47	2.73	2.96	3.21	3.62	4.04	4.46	4.85	5.22	5.61	5.96	6.32	6.67	6.98	7.29	7.56	7.84	8.02
0.40	1.22	1.51	1.77	2.03	2.30	2.54	2.80	3.04	3.29	3.72	4.16	4.58	4.99	5.36	6.76	6.13	6.50	6.85	7.18	7.50	7.77	8.05	8.25
0.42	1.25	1.55	1.81	2.08	2.36	2.61	2.87	3.12	3.37	3.82	4.26	4.70	5.12	5.50	5.91	6.29	6.66	7.03	7.36	7.69	7.97	8.26	8.46
0.46	1.31	1.61	1.89	2.18	2.48	2.74	3.02	3.28	3.53	1.01	4.47	4.93	5.36	5.77	6.20	6.59	6.98	7.37	7.72	8.06	8.36	8.66	8.87
0.50	1.37	1.67	1.97	2.28	2.59	2.86	3.15	3.42	3.69	4.19	4.67	5.15	5.60	6.04	6.48	6.89	7.30	7.70	8.06	8.41	8.73	9.05	9.26
0.54	1.42	1.73	2.05	2.38	2.69	2.98	3.28	3.56	3.85	4.36	4.86	5.37	5.84	6.28	6.76	7.17	7.60	8.02	8.40	8.76	9.10	9.44	9.65
0.58	1.47	1.79	2.12	2.47	2.79	3.09	3.40	3.70	3.99	4.53	5.05	5.57	6.06	6.51	7.01	7.45	7.89	8.32	8.72	9.10	9.43	9.78	10.02
0.63	1.52	1.85	2.19	2.56	2.89	3.20	3.52	3.82	4.13	4.68	5.22	5.76	6.26	6.74	7.25	7.70	8.16	8.61	9.02	9.42	9.76	10.12	10.37
0.67	1.57	1.91	2.26	2.65	2.98	3.30	3.63	3.94	4.26	4.83	5.39	5.95	6.46	6.96	7.48	7.95	8.43	8.88	9.31	9.72	10.08	10.44	10.70
0.71	1.61	1.97	2.33	2.73	3.07	3.40	3.74	4.06	4.39	4.98	5.55	6.13	6.66	7.17	7.70	8.19	8.69	9.15	9.60	10.01	10.40	10.76	11.03
0.75	1.65	2.02	2.40	2.80	3.16	3.50	3.85	4.18	4.52	5.13	5.71	6.31	6.86	7.38	7.92	8.43	8.95	9.42	9.88	10.30	10.70	11.08	11.34
0.79	1.69	2.07	2.47	2.87	3.25	3.60	3.96	4.30	4.65	5.27	5.87	6.49	7.06	7.59	8.14	8.67	9.20	9.69	10.15	10.59	11.00	11.40	11.65
0.83	1.73	2.12	2.54	2.94	3.34	3.70	4.07	4.42	4.77	5.41	6.03	6.65	7.25	7.79	8.36	8.90	9.44	9.95	10.41	10.88	11.28	11.69	11.96
0.92	1.81	2.22	2.67	3.08	3.50	3.87	4.28	4.63	5.00	5.67	6.31	6.97	7.60	8.16	8.76	9.32	9.88	10.42	10.91	11.44	11.82	12.24	12.53
1.00	1.88	2.32	2.79	3.22	3.66	4.04	4.47	4.84	5.22	5.92	6.59	7.29	7.93	8.53	9.16	9.74	10.32	10.89	11.41	11.93	12.34	12.79	13.10
1.08	1.95	2.42	2.91	3.36	3.81	4.21	4.64	5.04	5.44	6.17	6.87	7.60	8.26	8.88	9.55	10.13	10.76	11.33	11.88	12.40	12.86	13.32	13.65
1.17	2.02	2.52	3.02	3.49	3.95	4.38	4.81	5.23	5.64	6.40	7.13	7.89	8.57	9.21	9.90	10.52	11.16	11.77	12.32	12.87	13.33	13.82	14.17
1.25	2.08	2.61	3.12	3.61	4.09	4.53	4.97	5.41	5.84	6.62	7.38	8.15	8.86	9.53	10.24	10.88	11.53	12.18	12.74	13.30	13.80	14.30	14.65
1.33	2.14	2.70	3.22	3.73	4.22	4.67	5.13	5.58	6.03	6.84	7.62	8.41	9.15	9.85	10.58	11.23	11.90	12.56	13.16	13.72	14.25	14.78	15.13
1.42	2.20	2.78	3.32	3.84	4.35	4.81	5.29	5.75	6.22	7.05	7.85	8.67	9.43	10.15	10.90	11.58	12.27	12.94	13.58	14.14	14.69	15.24	15.59
1.50	2.26	2.86	3.41	3.95	4.47	4.95	5.45	5.92	6.40	7.25	8.08	8.93	9.70	10.44	11.22	11.92	12.64	13.32	13.98	14.56	15.11	15.68	16.05

33 2.50 70 7.86
70 7 86
58 8.77
40 9.59
.15 10.32
.88 11.04
.56 11.74
.16 12.40
.68 13.00
.18 13.55
.68 14.05
.18 14.52
.67 14.98
.15 15.44
.61 15.90
.07 16.36
.52 16.82
.95 17.26
.77 18.10
.55 18.90
.30 19.65
.04 20.40
.74 21.12
.42 21.82 .08 22.52
.08 22.52 .72 23.17
.34 23.80
.95 24.40
.12 25.58
.23 26.72
.30 27.80
.32 28.85
.32 29.86
.30 30.84
.25 31.80
.15 32.70
7. 33. 33. 33. 33. 33. 33. 33. 33. 33. 3

Difference 0.17 0.21 0.25 0.29 0.33 0.38 0.42 0.46 0.50 0.58 0.67 0.75 0.83 0.92 1.09 1.05 1.70 1.25 1.70 1.25 1.30 1.05 1.67 1.83 2.00 2.17 2.33 2.50 2.67 2.83 3.84 2.06 2.17 2.38 3.84 2.06 2.17 2.38 3.84 2.06 2.17 2.38 3.84 2.06 2.17 2.38 3.84 2.15 2.18 2
Check
0.08
0.13
0.15
0.17
0.19
0.21 1.50 1.89 2.28 2.63 3.00 3.37 3.76 4.07 4.35 5.04 5.55 6.30 6.85 7.42 8.02 8.56 9.09 9.61 10.18 11.13 12.16 13.10 13.88 14.60 15.21 15.76 16.17 16.54 16.00 10.20
0.23
0.25
0.27
0.29
0.31
1.86
1.035
0.48
0.40
0.42
0.46
0.50
0.54
0.58
0.63
0.67 2.61 3.29 3.97 4.59 5.23 5.91 6.57 7.23 7.76 8.97 10.09 11.24 12.26 13.28 14.35 15.32 16.25 17.20 18.21 19.92 21.75 23.45 24.84 26.13 27.20 28.13 28.85 29.55 30.071 2.69 3.38 4.08 4.72 5.39 6.09 6.77 7.45 8.00 9.25 10.40 11.59 12.63 13.68 14.79 15.79 16.74 17.72 18.77 20.54 22.42 24.15 25.60 26.95 28.05 29.00 29.75 30.45 31.08 14.79 15.79 16.74 17.72 18.77 16.74 17.72 18.77 18
0.71 2.69 3.38 4.08 4.72 5.39 6.09 6.77 7.45 8.00 9.25 10.40 11.59 12.63 13.68 14.79 15.79 16.74 17.72 18.77 20.54 22.42 24.15 25.60 26.95 28.05 29.00 29.75 3.0.45 31.
0.75 2.76 3.47 4.19 4.85 5.55 6.27 6.97 7.60 8.23 9.52 10.70 11.93 13.00 14.08 15.21 16.25 17.23 18.23 19.31 21.15 23.07 24.85 26.33 27.73 28.85 29.84 30.62 31.35 31.25 12.25
0.79 2.83 3.56 4.30 4.98 5.70 6.44 7.16 7.87 8.45 9.78 11.00 12.26 13.37 14.47 15.63 16.68 17.70 18.73 19.84 21.72 23.70 15.55 27.05 28.47 29.63 30.65 31.45 32.20 32.
0.83 2.90 3.65 4.41 5.11 5.85 6.61 7.35 8.07 8.67 10.03 11.28 12.58 13.71 14.83 16.03 17.10 18.17 19.21 20.35 22.27 24.30 26.20 27.75 29.20 30.40 31.45 32.25 33.05 33.
0.92 3.05 3.82 4.60 5.36 6.13 6.92 7.70 8.46 9.10 10.52 11.82 13.18 14.37 15.55 16.81 17.93 19.05 20.14 21.33 23.35 25.47 27.45 29.10 30.60 31.85 32.95 33.80 34.65 35.
1.00 3.16 3.98 4.79 5.61 6.40 7.23 8.05 8.85 9.51 10.99 12.35 13.78 15.01 16.25 17.58 18.74 19.90 21.05 22.30 24.40 26.62 18.70 30.40 32.00 33.30 34.45 35.35 36.20 36.
1.08 3.28 4.14 4.98 5.85 6.67 7.52 8.39 9.22 9.89 11.44 12.85 14.35 15.62 16.93 18.30 19.53 20.72 21.92 23.22 25.40 27.75 29.87 31.65 33.32 34.65 35.85 36.80 37.68 38.
1.17 3.39 4.29 5.16 6.06 6.91 7.81 8.70 9.56 10.26 11.88 13.33 14.88 16.21 17.58 18.99 20.25 21.50 22.75 24.10 26.35 28.80 31.00 32.85 34.60 35.98 37.20 38.18 39.10 39.
1.25 3.50 4.43 5.34 6.27 7.15 8.08 9.00 9.89 10.62 12.30 13.80 15.40 16.78 18.19 19.64 20.95 22.24 23.54 24.93 27.30 29.80 32.10 34.00 35.80 37.25 28.50 39.50 40.45 41.
1.33 3.61 4.56 5.51 6.48 7.39 8.34 9.29 10.22 10.98 12.69 14.27 15.90 17.33 18.78 20.29 54.65 22.98 24.30 25.75 28.20 30.75 33.15 35.10 36.95 38.45 29.80 40.80 41.80 42.80
1.42 3.72 4.69 5.68 6.68 7.62 8.60 9.58 10.54 11.32 13.08 14.70 16.39 17.86 19.34 20.92 22.32 23.69 25.05 26.55 29.03 31.70 34.15 36.20 38.10 39.60 41.10 42.05 43.10 43.
1.50 3.82 4.82 5.85 6.87 7.84 8.85 9.86 10.84 11.64 13.45 15.12 16.88 18.39 19.89 21.54 22.97 24.36 25.78 27.33 29.85 32.63 35.15 37.25 39.20 40.75 42.30 43.25 44.35 45.25

ITRC Water Measurement Tables for **RECTANGULAR Gates on Round Pipes**

Discharge Values in CFS

		r	TRC W	ater M	easurei	ment Ta	ables -	18" Re	ectang	ular Ga	<u>te,</u> Still	_	ell Loca			f Back	of Gate [Blue cei	nter repr	esents b	est accu	racy rang	ge]	
ΔΗ	0.042	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67		0.83	0.92	1.00	1.08	1.17	1.25	1.33	1.42	1.50
(feet)	0.02	0.05	0.00	0.42	0.40	0.22	0.20	0.24	0.40	0.46	0.53		ischar		1.01	4.47	4.24	4.54	4.74	4.02	2.07	2.24	2.26	2.20
0.04 0.06	0.02 0.02	0.05 0.06	0.09 0.11	0.13 0.16	0.18 0.22	0.23 0.28	0.28 0.35	0.34 0.42	0.40 0.49	0.46 0.56	0.52 0.64	0.58 0.71	0.72 0.88	0.86 1.05	1.01 1.24	1.17 1.43	1.34 1.64	1.51 1.85	1.71 2.10	1.92 2.36	2.07 2.54	2.21 2.70	2.26 2.77	2.28 2.79
0.08	0.02	0.07	0.12	0.19	0.25	0.33	0.40	0.48	0.56	0.65	0.73	0.82	1.01	1.21	1.43	1.65	1.89	2.13	2.43	2.72	2.93	3.12	3.20	3.22
0.10	0.03	0.08	0.14	0.21	0.28	0.37	0.45	0.54	0.63	0.72	0.82	0.92	1.13	1.36	1.60	1.85	2.11	2.39	2.71	3.04	3.28	3.49	3.58	3.60
0.13 0.15	0.03 0.03	0.08	0.15 0.16	0.23 0.25	0.31 0.34	0.40 0.43	0.49 0.53	0.59 0.63	0.69 0.74	0.79 0.86	0.90 0.97	1.01 1.09	1.24 1.34	1.49 1.61	1.75 1.89	2.02 2.19	2.32 2.50	2.61 2.82	2.97 3.21	3.33 3.60	3.59 3.88	3.82 4.13	3.92 4.24	3.95 4.26
0.13	0.03	0.09	0.10	0.25	0.34	0.45	0.53	0.68	0.74	0.80	1.04	1.16	1.44	1.72	2.02	2.19	2.67	3.02	3.43	3.85	4.15	4.13	4.24	4.26
0.19	0.04	0.10	0.18	0.28	0.38	0.49	0.60	0.72	0.84	0.97	1.10	1.23	1.52	1.82	2.15	2.48	2.84	3.20	3.64	4.08	4.40	4.68	4.80	4.84
0.21	0.04	0.11	0.19	0.29	0.40	0.52	0.64	0.76	0.89	1.02	1.16	1.30	1.60	1.92	2.26	2.61	2.99	3.37	3.83	4.30	4.63	4.94	5.06	5.10
0.23	0.04	0.11	0.20	0.31	0.42	0.54	0.67	0.79	0.93	1.07	1.22	1.36	1.68	2.01	2.37	2.74 2.86	3.14 3.28	3.54 3.70	4.02 4.20	4.51 4.71	4.86 5.08	5.18 5.41	5.31 5.55	5.35 5.58
0.25	0.04	0.12	0.21	0.34	0.44	0.57	0.70	0.86	1.01	1.12	1.32	1.42	1.83	2.10	2.48	2.98	3.41	3.85	4.20	4.71	5.28	5.63	5.77	5.81
0.29	0.04	0.13	0.23	0.35	0.48	0.61	0.75	0.90	1.05	1.21	1.37	1.54	1.90	2.27	2.68	3.09	3.54	3.99	4.54	5.09	5.48	5.84	5.99	6.03
0.31	0.05	0.13	0.24	0.36	0.49	0.63	0.78	0.93	1.09	1.25	1.42	1.59	1.97	2.35	2.77	3.20	3.66	4.13	4.70	5.27	5.68	6.05	6.20	6.24
0.33 0.35	0.05 0.05	0.13 0.14	0.24 0.25	0.37 0.38	0.51 0.52	0.65 0.67	0.80	0.96 0.99	1.12 1.16	1.30 1.33	1.47 1.51	1.64 1.69	2.03	2.43 2.50	2.86 2.95	3.30 3.41	3.78 3.90	4.27 4.40	4.85 5.00	5.44 5.61	5.86 6.04	6.24 6.44	6.41 6.60	6.45 6.65
0.38	0.05	0.14	0.25	0.38	0.54	0.67	0.85	1.02	1.19	1.37	1.56	1.74	2.09	2.57	3.03	3.50	4.01	4.53	5.14	5.77	6.22	6.62	6.79	6.84
0.40	0.05	0.15	0.27	0.41	0.55	0.71	0.88	1.04	1.23	1.41	1.60	1.79	2.21	2.65	3.12	3.60	4.12	4.65	5.29	5.93	6.39	6.81	6.98	7.03
0.42	0.05	0.15	0.27	0.42	0.57	0.73	0.90	1.07	1.26	1.45	1.64	1.84	2.27	2.71	3.20	3.69	4.23	4.77	5.42	6.08	6.55	6.98	7.16	7.21
0.46	0.06	0.16	0.29	0.44	0.60	0.77	0.94	1.12	1.32	1.52	1.72	1.93	2.38	2.85	3.35	3.87	4.44	5.00	5.69	6.38	6.87	7.32	7.51	7.56
0.50 0.54	0.06 0.06	0.16 0.17	0.30 0.31	0.46 0.48	0.62 0.65	0.80 0.83	0.98 1.03	1.17 1.22	1.38 1.43	1.59 1.65	1.80 1.87	2.01 2.10	2.49 2.59	2.97 3.09	3.50 3.65	4.05 4.21	4.63 4.82	5.23 5.44	5.94 6.18	6.66 6.93	7.18 7.47	7.65 7.96	7.84 8.16	7.90 8.22
0.58	0.06	0.18	0.32	0.49	0.67	0.86	1.06	1.27	1.49	1.71	1.94	2.17	2.69	3.21	3.78	4.37	5.00	5.65	6.42	7.20	7.75	8.26	8.47	8.53
0.63	0.07	0.18	0.33	0.51	0.70	0.90	1.10	1.31	1.54	1.77	2.01	2.25	2.78	3.32	3.92	4.52	5.18	5.84	6.64	7.45	8.03	8.55	8.77	8.83
0.67	0.07	0.19	0.35	0.53	0.72	0.92	1.14	1.36	1.59	1.83	2.08	2.32 2.40	2.87	3.43	4.05	4.67	5.35	6.04	6.86	7.69	8.29	8.83	9.06	9.12
0.71	0.07	0.20	0.36	0.54	0.74	0.95	1.17	1.40	1.64 1.69	1.89	2.14	2.40	2.96 3.04	3.54 3.64	4.17 4.29	4.82 4.96	5.51 5.67	6.22 6.40	7.07 7.28	7.93 8.16	8.55 8.79	9.10 9.37	9.34 9.61	9.40 9.67
0.79	0.07	0.21	0.38	0.57	0.78	1.01	1.24	1.48	1.73	2.00	2.26	2.53	3.13	3.74	4.41	5.09	5.83	6.58	7.47	8.38	9.03	9.62	9.87	9.94
0.83	0.08	0.21	0.39	0.59	0.81	1.03	1.27	1.52	1.78	2.05	2.32	2.60	3.21	3.84	4.52	5.22	5.98	6.75	7.67	8.60	9.27	9.87	10.13	10.20
0.92	0.08	0.22	0.41	0.62	0.84	1.08	1.33	1.59	1.87	2.15	2.43	2.73	3.37	4.03	4.74	5.48	6.27	7.08	8.04	9.02	9.72	10.36	10.62	10.69
1.00 1.08	0.08 0.09	0.23 0.24	0.42 0.44	0.65 0.67	0.88 0.92	1.13 1.18	1.39 1.45	1.66 1.73	1.95 2.03	2.24 2.33	2.54 2.65	2.85 2.96	3.52 3.66	4.20 4.38	4.96 5.16	5.72 5.96	6.55 6.82	7.39 7.69	8.40 8.74	9.42 9.81	10.15 10.57	10.82 11.26	11.09 11.55	11.17 11.62
1.17	0.09	0.25	0.46	0.70	0.95	1.22	1.50	1.79	2.10	2.42	2.75	3.08	3.80	4.54	5.35	6.18	7.08	7.98	9.07	10.18	10.97	11.68	11.98	12.06
1.25	0.09	0.26	0.47	0.72	0.99	1.27	1.56	1.86	2.18	2.51	2.84	3.18	3.93	4.70	5.54	6.40	7.33	8.26	9.39	10.53	11.35	12.09	12.40	12.49
1.33	0.10	0.27	0.49	0.75	1.02	1.31	1.61	1.92	2.25	2.59	2.94	3.29	4.06	4.86	5.72	6.61	7.57	8.53	9.70	10.88	11.72	12.49	12.81	12.90
1.42 1.50	0.10 0.10	0.28 0.28	0.50 0.52	0.77 0.79	1.05 1.08	1.35 1.39	1.66 1.71	1.98 2.03	2.32 2.39	2.67 2.75	3.03 3.11	3.39 3.49	4.18 4.31	5.00 5.15	5.90 6.07	6.81 7.01	7.80 8.02	8.80 9.05	10.00 10.29	11.21 11.54	12.09 12.44	12.87 13.25	13.20 13.59	13.29 13.68
1.58	0.10	0.29	0.53	0.81	1.11	1.42	1.75	2.09	2.45	2.82	3.20	3.58	4.42	5.29	6.24	7.20	8.24	9.30	10.57	11.86	12.78	13.61	13.96	14.05
1.67	0.11	0.30	0.55	0.83	1.14	1.46	1.80	2.14	2.52	2.90	3.28	3.68	4.54	5.43	6.40	7.39	8.46	9.54	10.85	12.16	13.11	13.96	14.32	14.42
1.75	0.11	0.31	0.56	0.85	1.17	1.50	1.84	2.20	2.58	2.97	3.36	3.77	4.65	5.56	6.56	7.57	8.67	9.78	11.11	12.46	13.43	14.31	14.68	14.77
1.83 1.92	0.11 0.11	0.31 0.32	0.57 0.59	0.87 0.89	1.19 1.22	1.53 1.57	1.89 1.93	2.25 2.30	2.64 2.70	3.04 3.11	3.44 3.52	3.85 3.94	4.76 4.87	5.69 5.82	6.71 6.86	7.75 7.92	8.87 9.07	10.01 10.23	11.37 11.63	12.76 13.04	13.75 14.06	14.65 14.97	15.02 15.36	15.12 15.46
2.00	0.12	0.33	0.60	0.91	1.25	1.60	1.97	2.35	2.76	3.17	3.60	4.03	4.97	5.95	7.01	8.09	9.27	10.45	11.88	13.32	14.36	15.30	15.69	15.79
2.08	0.12	0.34	0.61	0.93	1.27	1.63	2.01	2.40	2.81	3.24	3.67	4.11	5.07	6.07	7.15	8.26	9.46	10.67	12.13	13.60	14.66	15.61	16.01	16.12
2.17	0.12	0.34	0.62	0.95	1.30	1.67	2.05	2.44	2.87	3.30	3.74	4.19	5.18	6.19	7.29	8.42	9.64	10.88	12.37	13.87	14.95	15.92	16.33	16.44
2.25	0.12	0.35	0.64	0.97	1.32	1.70 1.73	2.09	2.49	2.92	3.36	3.81	4.27	5.27	6.31	7.43	8.58 8.74	9.83 10.01	11.09 11.29	12.60 12.83	14.13 14.39	15.23 15.51	16.22 16.52	16.64 16.95	16.75 17.06
2.33 2.42	0.13	0.36	0.66	1.00	1.37	1.76	2.13	2.54	3.03	3.49	3.95	4.33	5.47	6.54	7.70	8.90	10.01	11.49	13.06	14.59	15.78	16.32	17.25	17.36
2.50	0.13	0.37	0.67	1.02	1.39	1.79	2.20	2.63		igatio			ng 18 e				10.36	11.69	13.28	14.90	16.05	17.10	17.54	17.66
2.58	0.13	0.37	0.68	1.04	1.42	1.82	2.24	2.67									10.53	11.88	13.50	15.14	16.32	17.38	17.83	17.95
2.67	0.14	0.38	0.69	1.05	1.44	1.85	2.27	2.71	3.18	3.66	4.15	4.65		6.87	8.09	9.34	10.70	12.07	13.72	15.39	16.58	17.66	18.12	18.24
2.75 2.83	0.14 0.14	0.39	0.70 0.71	1.07 1.09	1.46 1.48	1.88 1.91	2.31 2.34	2.75 2.80	3.23 3.28	3.72 3.78	4.22 4.28	4.72 4.79	5.83 5.92	6.97 7.08	8.22 8.34	9.49 9.63	10.87 11.03	12.26 12.44	13.93 14.14	15.62 15.86	16.84 17.09	17.94 18.21	18.40 18.67	18.52 18.80
2.83	0.14	0.39	0.71	1.09	1.48	1.91	2.34	2.80	5.28	5./8	4.28	4.79	5.92	7.08	0.34	9.03	11.03	12.44	14.14	15.80	17.09	10.21	10.07	10.80

			ITRO) Wate	er Me	easure	ement	Tabl	es – <u>2</u>	24"	Rect	ang	ular	Gate		ng We				f Back	of Gat	e [Blu	e cente	er repr	esents	best a	ccurac	y rang	e]	
ΔΗ	0.042	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42	0.46	0.50	0.58	0.67	0.75	0.83		1.00		1.17	1.25	1.33	1.42	1.50	1.58	1.67	1.75	1.83	1.92	2.00
(feet)	0.0.2		100	10	0.2 .	10.20	0.20	0.00	0.00	01.12	01.10	0.00	0.00	0.01	00		harge (1100		0			1.00	1.00					
0.04	0.04	0.07	0.12	0.18	0.25	0.31	0.38	0.44	0.52	0.60	0.68	0.76	0.93	1.11	1.30	1.49	1.68	1.86	2.06	2.25	2.45	2.65	2.87	3.08	3.28	3.70	3.89	4.05	4.06	4.07
0.06	0.04	0.08				0.38				0.73		0.93	1.14	1.36	1.60	1.83	2.06	2.28	2.52	2.75	3.00	3.25	3.51	3.77	4.02	4.54	4.76	4.96	4.97	4.98
0.08	0.05	0.09								0.85	0.96			1.57	1.84	2.11	2.38	2.64	2.91	3.18	3.47	3.75	4.06	4.36	4.64	5.24	5.50	5.73	5.74	5.75
0.10	0.06		0.19				0.60					1.20		1.76	2.06	2.36	2.66	2.95	3.25	3.55	3.88	4.20	4.54	4.87	5.19	5.85	6.15	6.41	6.42	6.43
0.13 0.15	0.06	0.11	0.21			0.54 0.59			0.90 0.97		1.18 1.27			1.93 2.08	2.26 2.44	2.59 2.80	2.91 3.14	3.23 3.49	3.56 3.85	3.89 4.20	4.25 4.59	4.60 4.96	4.97 5.37	5.33 5.76	5.69 6.14	6.41 6.93	6.73 7.27	7.02 7.58	7.03 7.59	7.04 7.61
0.13	0.07	0.12				0.63						1.52	1.87	2.23	2.60	2.99	3.36	3.73	4.11	4.49	4.90	5.31	5.74	6.16	6.57	7.41	7.77	8.10	8.12	8.13
0.17	0.07	0.13				0.66			1.10			1.61	_	2.36	2.76	3.17	3.56	3.96	4.36	4.77	5.20	5.63	6.09	6.53	6.97	7.86	8.24	8.59	8.61	8.62
0.21	0.08					0.70			1.16		1.52			2.49	2.91	3.34	3.76	4.17	4.60	5.02	5.48	5.93	6.41	6.89	7.34	8.28	8.69	9.06	9.07	9.09
0.23	0.08	0.15	0.28	0.43	0.58	0.73	0.89	1.04	1.22	1.41	1.59	1.78	2.19	2.61	3.05	3.50	3.94	4.37	4.82	5.27	5.75	6.22	6.73	7.22	7.70	8.68	9.11	9.50	9.52	9.53
0.25	0.09	0.16		0.45	0.61	0.77	0.93	1.09	1.28	1.47	1.66	1.86	2.29	2.73	3.19	3.66	4.12	4.57	5.04	5.50	6.00	6.50	7.03	7.54	8.05	9.07	9.52	9.92	9.94	9.96
0.27	0.09	0.17				0.80			1.33		1.73			2.84	3.32	3.81	4.28	4.75	5.24	5.73	6.25	6.77	7.31	7.85	8.37	9.44	9.91	10.33	10.35	10.37
0.29	0.10		0.32			0.83			1.38		1.80			2.95	3.45	3.95	4.45	4.93	5.44	5.94	6.49	7.02	7.59	8.15	8.69	9.80	10.28		10.74	10.76
0.31	0.10	0.18				0.86			1.43		1.86		2.56	1	3.57	4.09	4.60	5.11	5.63	6.15	6.71	7.27	7.86	8.43	8.99	10.14	10.64		11.11	11.13
0.33	0.10									1.70	1.92		_	3.15	3.68	4.23	4.75	5.27	5.82	6.35	6.93	7.51	8.11	8.71	9.29	10.47	10.99		11.48	11.50
0.35 0.38	0.11	0.19				0.91	1.11		1.52 1.56		1.98 2.04	2.22		3.25	3.80 3.91	4.36 4.48	4.90 5.04	5.44 5.59	6.00 6.17	6.55 6.74	7.15 7.35	7.74 7.96	8.36 8.61	8.98 9.24	9.58 9.85		11.33 11.66	11.81 12.15	12.17	11.85 12.20
0.30	0.11	0.20							1.61		2.09			3.43	4.01	4.61	5.18	5.75	6.34	6.92	7.55	8.18	8.84	9.49	10.12		11.98			12.53
0.42	0.11	0.21			0.78							2.40	2.96	3.52	4.12	4.73	5.31	5.90	6.50	7.10	7.75	8.39	9.07	9.74	10.39		12.29	12.81	12.83	12.86
0.46	0.12										2.25			3.69	4.32	4.96	5.57	6.18	6.82	7.45	8.13	8.80	9.51	10.21	10.89		12.89	13.44	13.46	
0.50	0.13	0.23	0.42	0.64	0.86	1.09	1.31	1.54	1.80	2.08	2.35	2.63	3.24	3.86	4.51	5.18	5.82	6.46	7.12	7.78	8.49	9.19	9.94	10.67	11.38	12.83	13.46	14.03	14.06	14.08
0.54	0.13	0.24			0.89	1.13	1.37	1.60	1.88	2.16	2.45	2.74	3.37	4.01	4.70	5.39	6.06	6.72	7.42	8.10	8.84	9.57	10.34	11.10	11.84	13.35	14.01	14.61	14.63	14.66
0.58	0.14	0.25			0.93		1.42	1.66			2.54			4.17	4.87	5.59	6.29	6.98	7.70	8.40	9.17	9.93	10.73	11.52	12.29		14.54		15.18	15.21
0.63	0.14		0.47			1.21			2.02					4.31	5.04	5.79	6.51	7.22	7.97	8.70	9.49	10.28		11.93			15.05	15.69		15.75
0.67	0.14	0.26				1.25			2.08 2.15		2.72			4.45	5.21 5.37	5.98	6.72 6.93	7.46	8.23	8.98 9.26	9.80	10.61 10.94	11.47		13.14		15.55		16.23	16.26
0.71	0.15	+	_			_	1.61			2.54	2.80	3.22	3.97	4.59	5.53	6.16	7.13	7.69 7.91	8.48 8.73	9.53		11.26	11.83 12.17	12.70 13.07	13.54 13.93	15.27 15.71	16.02 16.49	16.70 17.19	17.22	16.76 17.25
0.73	0.13	0.29				1.37			2.27				4.07	4.72	5.68	6.51	7.13	8.13	8.97	9.79		11.57	12.17		14.32		16.94			17.72
0.83	0.16					1.40			2.33		3.04			4.98	5.82	6.68	7.52	8.34	9.20	10.05	10.96		12.83		14.69		17.38	18.12		18.18
0.92	0.17		0.57			1.47			2.44			3.57		5.22	6.11	7.01	7.88	8.75	9.65	10.54	11.50		13.45		15.41		18.23		19.03	19.07
1.00	0.18	0.32	0.59	0.90	1.21	1.53	1.86	2.18	2.55	2.94	3.33	3.72	4.58	5.45	6.38	7.32	8.23	9.14	10.08	11.00	12.01	13.00	14.05	15.09	16.09	18.14	19.04	19.85	19.88	19.92
1.08	0.18		0.61			1.60			2.66		3.46		4.77	5.68	6.64	7.62	8.57	9.51		11.45				15.70			19.82	20.66		20.73
1.17	0.19		0.64			1.66			2.76		3.59			5.89	6.89	7.91	8.89	9.87		11.89				16.30			20.57	21.44		21.51
1.25	0.20	0.36				1.72		2.43		3.28		4.16	5.12	6.10	7.13	8.18	9.20	10.21		12.30		14.53	15.71	16.87	17.99		21.29	22.19	22.23	22.27
1.33	0.20	0.37				1.77 1.83			2.95 3.04		3.84 3.96	4.30		6.30 6.49	7.37 7.59	8.45 8.71	9.51 9.80	10.55 10.87		12.71 13.10	13.87 14.29		16.23	17.42 17.96	18.58		21.99 22.66	22.92 23.62	22.95	23.00 23.71
1.42 1.50	0.21				1.49				3.13		4.08			6.68	7.81	8.97	10.08	11.19		13.48		15.47			19.13		23.32	24.31		
1.58	0.22							2.74		3.69		4.69	5.76		8.03	9.21	10.36			13.85		16.36			20.25		23.96		25.01	25.06
1.67	0.23	0.42		1	1.57	_	2.40	2.81		3.79	4.30	4.81	5.91	7.04	8.24	9.45	10.63	11.79	13.01	14.21	15.50	16.78	18.14	19.48	20.77	23.42	24.58	25.62	25.66	25.71
1.75							2.46								8.44	9.68					15.89									
1.83																					16.26									
1.92																					16.62									
2.00																					16.98									
2.08	0.26	0.47	0.85	1.30	1.75	2.22	2.68	3.14	3.68	4.24	4.80	5.37	6.61	7.87	9.21	10.57	11.88	13.19	14.54	15.88	17.33	18.76	20.28	21.78	23.22	26.18	27.48	28.65	28.69	28.75
2.17 2.25	0.26	0.48	0.87	1.33	1.79	2.20	2.73	3.20	3./6	4.32	4.90	5.48	6.74	8 19	9.39	10.78	12.12	13.45	14.83	16.20	17.68 18.01	19.14	21.09	22.21	24.14	20.70	28.03	29.21	29.20	29.32
2.33	0.27	0.49	0 90	1 38	1 86	2 34	2 84	3 32	3 90	4 49	5.08	5 69	6 99	8 33	9 75	11 18	12 58	13 95	15 39	16.81	18 34	19.86	21 47	23.05	24 58	27 71	29 08	30.32	30 37	30.42
2.42	0.27	0.50	0.92	1.40	1.89	2.39	2.89	3.38	3.97	4.56	5.17	5.79	7.12	8.48	9.92	11.38	12.80	14.20	15.66	17.11	18.67	20.21	21.85	23.45	25.01	28.20	29.60	30.85	30.90	30.96
2.50	0.28	0.51	0.93	1.43	1.92	2.43	2.94	3.44	4.03	4.64	5.26	5.89	7.24	8.62	10.09	11.58	13.02	14.44	15.93	17.40	18.99	20.56	22.22	23.85	25.44	28.68	30.11	31.38	31.43	31.49
2.58	0.28	0.52	0.95	1.45	1.95	2.47	2.99	3.50	4.10	4.72	5.35	5.9 b	r iga t	<u>&i}</u> 2	ralinir	g_1	13.88°	94.68	4ent	17.69	18.67 18.99 19.30	20.90	22.59	24.25	25.86	29.16	30.60	31.90	31.95	32.01
2.67	0.29	0.53	0.96	1.47	1.98	2.51	3.03	3.55	4.17	4.80	5.43	6.08	7.48	8.91	10.42	147.98	P13.44	14.92	16.45	17.97	19.61	21.23	22.95	24.64	26.28	29.62	31.09	32.41	32.46	32.52
2.75	0.29	0.54	0.98	1.50	2.01	2.55	3.08	3.61	4.23	4.87	5.52	6.18	7.59	9.04	10.58	12.14	13.65	15.15	16.71	18.25	19.91	21.56	23.30	25.02	26.68	30.08	31.57	32.91	32.97	33.03
2.83	0.30	0.54	0.99	1.52	2.04	2.58	3.13	3.66	4.29	4.94	5.60	6.27	7.71	9.18	10.74	12.32	13.86	15.38	16.96	18.52	20.21	21.88	23.65	25.39	27.08	30.53	32.05	33.41	33.46	33.52

Attachment E Overview of Current Well Flow Meter Options



moving water in new directions

IRRIGATION TRAINING & RESEARCH CENTER

California Polytechnic State University San Luis Obispo, CA 93407-0730

Phone: (805) 756-2434 FAX: (805) 756-2433 www.itrc.org

TECHNICAL MEMORANDUM

Date: August 24, 2015

To: Dan Vink, LTRID, dvink@ltrid.org

Eric Limas, LTRID, <u>elimas@ltrid.com</u> Kenny Phelps, LTRID <u>kphelps@ltrid.org</u>

From: Stuart Styles, ITRC, sstyles@calpoly.edu

Sierra Layous, ITRC, slayous@calpoly.edu

Subject: Overview of Flow Meter Options for Pipelines

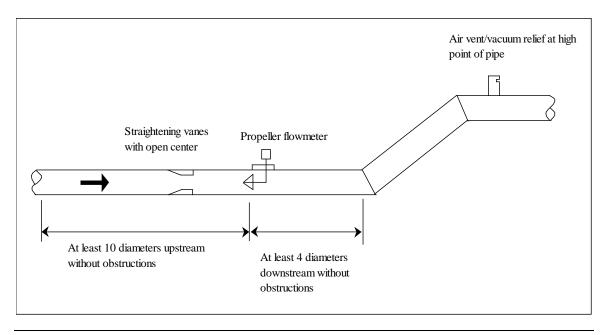
During a site visit to Lower Tule River Irrigation District (LTRID), ITRC was asked to provide information about options for flow meters on farmers' wells. This memo summarizes four of the most popular and currently available products:

- 1. Netafim Octave Ultrasonic Water Meter (very new but seems to be gaining popularity especially with growers)
- 2. McCrometer McMag3000 Magnetic Meter (brand new, still not much information on this)
- 3. Seametrics Ag2000 Magnetic Meter (Several water districts have adopted this unit as a standard. Main issue is battery life at about 2 years)
- 4. McCrometer McPropeller Meter (still the number one way to measure water in a pipeline)

We are seeing all of these types of units being installed at well pumps. There are several issues with measuring in pipelines. The first is that there must be a full-pipe. This can be done with a gooseneck or an elbow on the discharge of the pipe.



The second issue is turbulence and the number of diameters of pipe upstream of the meter required to have an accurate reading. The typical recommendation is to have 10 diameters upstream. However, this number can be decreased based on the manufacturers recommendation or from using flow conditioners. There are several types of flow conditioners. The most common is the straightening vanes. In order to decrease the number of diameters required, the manufacturer must have the documentation that less than 10 diameters can be used.



Netafim Octave Ultrasonic Water Meter

In Appendix A, installation examples of the Octave Ultrasonic Water Meter can be found.



Available Sizes	2", 3", 4", 6", 8", 10", 12"
Accuracy	± 1.5% from factory
Batteries	2x D batteries
	10-15 year life expectancy
	5 year warranty
	Not serviceable – <u>replace entire unit when battery dies</u>
Output	Pulse or 4-20mA
Configuration	5D upstream (pump), 2D upstream (valve, elbow), 2D downstream

Meter Size	Flow Rate (GPM)							
Meter Size	Min*	Max						
2"	0.5	250						
3"	1	500						
4"	1.5	1000						
6"	3	1,600						
8"	5	2,800						
10"	14	5,500						
12"	14	5,500						

^{*}Meter can read to lower flows with 5% accuracy (see meter literature for range)

Display:



McCrometer Mc Mag³⁰⁰⁰ Magnetic Meter

In Appendix B there are requirements for installing the meter on straight pipe.



Available Sizes	4", 6", 8", 10", 12"
Accuracy	\pm 2% factory default calibration; \pm 1% with custom factory
	calibration
Batteries	3x D batteries
	5 year guaranteed battery life
	Batteries are field replaceable by user
	External power optional
Output	Pulse or 4-20mA
Configuration	3D upstream, 1D downstream

Meter Size	Flow Rate (GPM)							
Wielei Size	Min	Max						
4"	40	600						
6"	90	1,350						
8"	150	2,350						
10"	240	3,700						
12"	350	5,300						

Seametrics Ag2000 Magnetic Meter

In Appendix D, installation examples and recommendations of the Seametrics Ag2000 Meter can be found. Also in Appendix D is a technical memo from Seametrics that provides diagrams for flow meter installation on straight run.



Available Sizes	3", 4", 6", 8", 10", 12"
Accuracy	+/- 1% of reading for flow between 10% to 100% of max flow +/- 2%
	of reading for flow from cutoff to 10% of max flow
Batteries	2x D batteries
	2.5 year standard battery life; 5 year with extended battery life option
	Batteries are field replaceable by user
	External power optional
Output	Pulse or 4-20mA
Configuration	2D upstream, 1D downstream

Meter Size	Flow Rate (GPM)		
Wieter Size	Min	Max	
3"	7.5	700	
4"	12	1,000	
6"	32	2,400	
8"	60	4,400	
10"	95	7,000	
12"	130	10,000	

McCrometer McPropeller Meter

In Appendix C there are installation instructions and suggestions for the McPropeller Meter as well as information on the McCrometer Flow Straightener. Also in Appendix C is information on the McSpaceSaver Flow Meter, which conists of a McPropeller Meter and a McCrometer Flow Straightener.



Available Sizes	2"- 24"
Accuracy	± 2% factory default calibration
Batteries	Not battery powered
Output	
Configuration	5-10 D upstream, 1-2 D downstream

Meter Size	Flow Rate (GPM)		
Meter Size	Min	Max	
2"	40	250	
2.5"	40	250	
3"	40	250	
4"	50	600	
6"	90	1200	
8"	100	1500	
10"	125	1800	
12"	150	2500	
14"	250	3000	
16"	275	4000	
18"	400	5000	
20"	475	6000	
24"	700	8500	

Automatic Meter Reading (AMR)

AMR is an emerging technology in the water meter field. A number of large cities have adopted the readers (i.e. New York, Washington DC, Boston) as well as some smaller communities (i.e. Pixley). AMR uses radio frequencies (RF) to transmit data from the meter. AMR can allow the meter to be read either: (a) on-site, "walk-by" AMR, (b) by mobile AMR, "drive-by", or (c) by fixed network AMI (this is how PG&E smart meters work). The radio is a separate device from the meter, and would connect to the meter. The user would need the appropriate device to read the meter (the manufacturer would have software). Meters with pulse outputs can be connected to AMR radios (the three meters in this memo can have pulse outputs).

AMR capability: The Netafim Octave Ultrasonic Meter is essentially the same meter as the Master Meter Octave Ultrasonic Meter. The following table shows the installation options for that meter for a variety of AMR/AMI radios.

Manufacturer	Model	Communication Type	Octave Red Wire	Octave Green Wire	Octave Black Wire
Aclara	Star 3000 Series	Encoder	Red	White	Black
	Star 3000 Series	Pulse	Red	N/A	Black or White
Badger	Orion	Encoder	Red	Green	Black
Datamatic	Firefly	Encoder	Red	White	Black
	Mosaic	Encoder	Red	Green	Black
Elster	MTU	Encoder	White	Red	Black
	MTU	Pulse	Red	White	Green
Hersey	Hot Rod	Encoder	Red	Green or White	Black
Itron	60w	Encoder	Green	Red	Unshielded
	60wp	Pulse	Red	N/A	White
	100w	Encoder	Grey	Brown	Yellow
Kemp Meeks	Visu-Link VL-9S	Pulse		atter - Connect Red and minal, disregard green v	
	Visu-Link VL-9	Encoder	Red	Green	Black
Master Meter	Universal XTR	Encoder	Red	Green	Black
	Fast Pulse XTR	Pulse	Red	N/A	Black
	ReadPad		Red	N/A	Black
Metron Farnier (T2)	T2 M2w	Encoder	Red	Green	Black
Neptune	R900	Encoder	Black	Red	Green
Sensus	MXU Pit Unit	Encoder	Red	Green	Black
	MXU Wall Unit	Encoder	Red	Green	Black
	Touch Pad	Encoder	Red	Green	Black

Appendix A

Netafim Ultrasonic Water Meter



OCTAVE® LULTRASONIC WATER METER

INSTALLATION & USER GUIDE



TABLE OF CONTENTS

General Information	4
Warranty	4
Included Items	4
Operation	5
Specifications	5
Dimensions & Weight	5
Installation	
Handling the Water Meter	6
Installation Position & Location	6
Installation Examples	7
Installation Notes	8
Pipe Flanges	8
Start-Up	8
Display	8
Outputs	
Electrical Outputs	9
Pulse Output Module	9
Analog Output Module	10
Grounding Instructions	11
Grounding Parts	12

GENERAL INFORMATION

- Do not install, operate or maintain this flow meter without reading, understanding and following the factory-supplied instructions. Otherwise, injury or damage may result.
- Read these instructions carefully before beginning installation and save them for future reference.
- Observe all warnings and instructions marked on the product and in this guide.
- Consider handling and lifting instructions to avoid damage.
- If the product does not operate normally, refer to the service instructions or call your Netafim Representative.
- There are no operator-serviceable parts inside this product.

WARRANTY

Octave water meters are warranted to be free from original defects in materials and workmanship for a period up to five (5) years. If the meter encounters a problem, Netafim USA will choose to cover the cost of repair or replacement based on a five (5) year pro-rated schedule as follows:

Year 0 through Year 2: 100%
Year 3 through Year 4: 50%
Year 4 through Year 5: 25%

All Octave water meters must be installed with a Netafim branded Combination Air/Vacuum or Continuous Acting Air Vents to qualify for the five (5) year pro-rated product warranty.

INCLUDED ITEMS

- One Octave Ultrasonic Water Meter, size as indicated on the packaging box, pieced together into a complete compact system (flow tube plus electronics).
- One pre-installed Output Module, either Digital or Analog (if ordered).
- Documentation includes: Installation and User Manual, Report of Factory Meter Settings and Certificate of Calibration Data.
- This product has been thoroughly inspected, tested and calibrated before shipment and is ready for operation.
- After carefully unpacking the meter, inspect for shipping damage before attempting to install. If any indication of damage is found, immediately contact the responsible transportation company and Netafim USA.

OPERATION

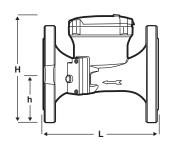
- The Octave's measurement method is based on an ultrasonic, transit-time, dual-beam sensors that determines the length of time it takes an ultrasonic wave to travel the distance between the two sensors located in the meter's body. The sensors function as both sender and receiver, each one alternating these functions so that the ultrasonic wave travels both with and against the direction of the flow. Because the ultrasonic wave travels slower against the flow than with the flow, the time difference of the two waves allows the meter to determine the flow rate.
- The Octave is a battery-powered precision water meter designed for linear, bidirectional flow measurement of water.
- · Flow measurement values can be transferred through the standard digital or analog output.
- The Octave display can be set up for a wide range of outputs.

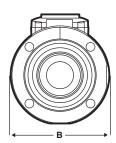
SPECIFICATIONS

- Maximum Working Pressure: 175 psi
 Liquid Temperature: 32° to 122° F
- Precision Class: ISO 4064 rev.2005, Accuracy Class 2
- Configuration: Compact display is built into the unit
- Power Source: 2 'D' size Lithium Batteries (not serviceable by user)
- Environmental Protection: IP-68, Ambient operation temperature for display: -13° to 131° F (-25° to 55° C)
- Display Units: Multi-line, programmable 9 digit LCD display
- Volume Display Options: 1. Net (Forward less Reverse), 2. Forward Only, 3. Forward and Reverse Alternating
- Outputs (optional): Programmable single/dual open collector pulse output our externally powered 4-20 mA loop
- Connections: Flanges ANSI ISO for AWWA connection standard
- Severity Levels: Environmental class C, mechanical class M1, Electromagnetic environment class E1
- Pressure Loss: ΔP 16

DIMENSIONS & WEIGHT

DIME	DIMENSIONS & WEIGHT				
SIZE	LENGTH (L)	WIDTH (B)	HEIGHT (H)	HEIGHT (h)	WEIGHT
2"	7.9"	6.5"	7.5"	1.6"	19.8 LBS.
3"	8.9"	7.9"	8.3"	3.5"	28.7 LBS.
4"	9.8"	8.7"	8.8"	4.1"	33.1 LBS.
6"	11.8"	11.2"	11.1"	5.5"	70.5 LBS.
8"	13.8"	13.4"	13.1"	6.5"	99 LBS.
10"	17.7"	15.9"	15.9"	8.0"	150 LBS.
12"	19.7"	19.2"	19.3"	9.6"	216 LBS.





INSTALLATION

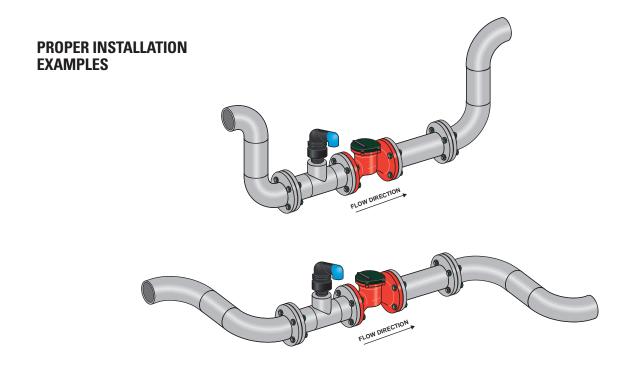
HANDLING THE WATER METER

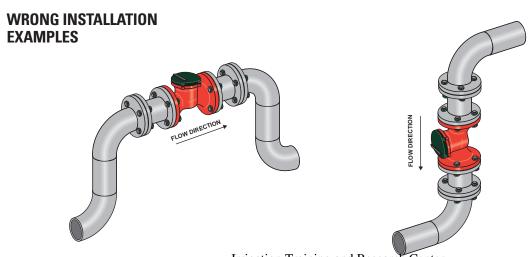
Important handling Information:

- Do not lift the Octave by the electronic housing.
- Do not carry the Octave by the lid.
- Do not place the Octave on the electronic housing.
- When handling the Octave, avoid hard blows, jolts or impacts.

INSTALLATION POSITION & LOCATION

Installation requirements for position and location are illustrated below.



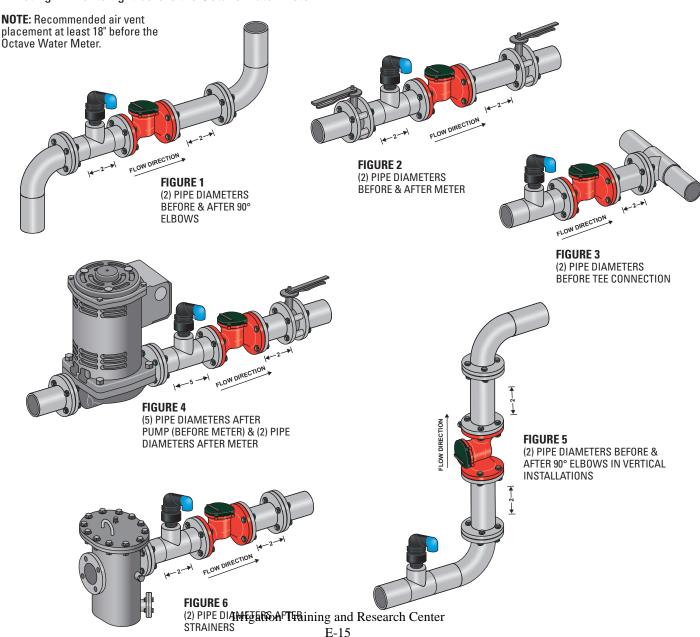


Irrigation Training and Research Center

INSTALLATION

INSTALLATION EXAMPLES FOR ACHIEVING TOP PERFORMANCE

- Two (2) diameters of straight pipe are required when installing a 90° elbow before or after the meter. (See Figure 1)
- Two (2) diameters of straight pipe are required when installing the meter upstream or downstream of a valve, tee
 connection or other source of significant turbulence. (See Figures 2 and 3)
 - NOTE: The installation of the meter upstream of a pump or large valve is not recommended due to potential cavitation issues.
- Five (5) diameters of straight pipe downstream of a pump (before the meter) and Two (2) diameters of straight pipe downstream of the meter are required. (See Figure 4)
- Meter can be installed horizontally or vertically with the water flowing up. It is not recommended for installation where the direction of flow is below the horizontal plane. (See Figure 5)
- Install a pressure breaker after the meter pipe length should be at least Two (2) diameters and the longer the better.
- To eliminate air in the pipeline and maintain accuracy, install Netafim branded Combination Air/Vacuum or Continuous Acting Air Vents right before the Octave water meter.



INSTALLATION

INSTALLATION NOTES

- For proper flow measurements, the Octave's measuring chamber should be completely full at all times. Non-wetted sensors show loss of signal. Though this will not cause damage to the meter, it will however, not measure flow and display zero.
- Flow direction: the Octave is a bidirectional water meter. Note the indicating arrow on the Octave display for forward and backward flow.
- Leave the lid closed except when reading the meter.
- Do not expose the Octave to excessive vibration. To avoid vibration, support the pipeline on both sides of the meter.
- Ambient working temperature: -13° to 131° F
- Water working temperature: 32° to 122° F
- To avoid measuring errors due to air in the flow tube, observe the following precautions:
 - Since air collects at the highest point in the system, installation of the water meter should be at the lowest point
 - Always install control valves downstream of the meter in order to avoid cavitation
 - Neve install the meter on a pump suction side in order to avoid cavitation
- It is required to install Netafim branded Combination Air/Vacuum or Continuous Acting Air Vents right before the Octave water meter.

PIPE FLANGES

- Refer to the standard dimensional drawings for flange spacing, accommodating for the thickness of gaskets.
- Install meter inline with the pipe axis. The pipe flange faces must be parallel to each other.
- Permissible length deviation: Lmax Lmin 0.5mm (0.02").

START-UP

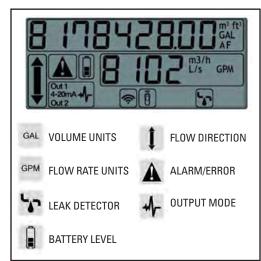
- · Check that the meter has been installed correctly.
- Check that the flow rate and volume units are correctly pre-programmed on the display.
- Check that the output module is correctly attached.

DISPLAY

Each Octave will be pre-programmed before shipment for an instantaneous flow rate in Gallons per Minute (GPM) and the specified user's requirements for:

- Volume Totalizer Units (Gallons or Acre Feet)
- Output Resolution for Optional Pulsed Output

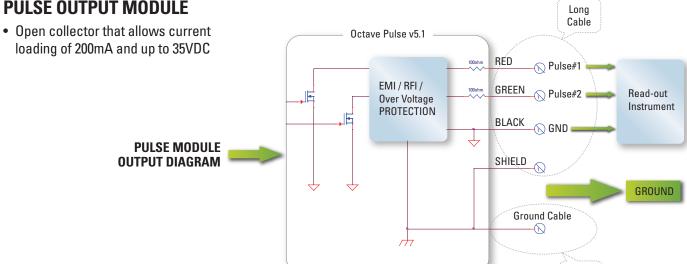
NOTE: Programming software is not available to the end user. Once the meter is programmed by the Netafim prior to shipment, it can only be reset by Netafim. When changing between totalizer options (US Gallons to Acre Feet), the totalizer memory can not be reset so vital data will not be lost.



ELECTRICAL OUTPUTS

- The Octave has several output options:
 - Dual pulse output for volumes
 - Analog output (4-20mA) for flow

PULSE OUTPUT MODULE



PULSE OUTPUT CABLES			
CABLE	WIRE	FUNCTION	
	RED	PULSE OUT #1	
LONG CABLE	GREEN	PULSE OUT #2	
	BLACK	GROUND	
	OPEN	GROUND / SHIELD	
SHORT CABLE	RING TERMINAL	GROUND	

WARNING: Signal connection polarity is mandatory.

PULSE OUTPUT CHARACTERISTICS		
OUTPUTS TYPE DRAIN		
CABLE LENGTH - SUPPLIED	5 FEET	
MAXIMUM CABLE LENGTH*	1,640 FEET	
MAXIMUM APPLIED VOLTAGE	30 VDC	

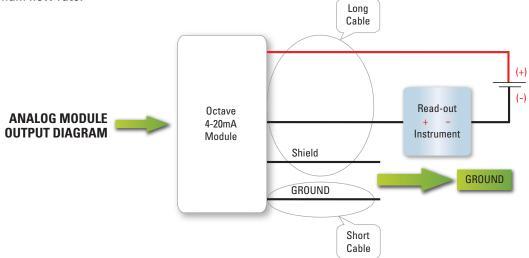
Short Cable

^{*} The Maximum cable length depends on the cable type, controller and electrical noise level

OUTPUTS

ANALOG OUTPUT MODULE (4-20mA)

- The current output is a passive 4-20mA.
- 4mA is always '0' zero flow and the 20mA is factory programmed according to customer requirements. If the customer does not specify, 20mA will be the maximum flow rate.



ANALOG MODULE OUTPUT CABLES				
CABLE WIRE FUNCTION				
LONG CABLE	RED	CURRENT LOOP +		
	BLACK	CURRENT LOOP -		
	OPEN	GROUND / SHIELD		
SHORT CABLE	RING TERMINAL	GROUND		

WARNING: Signa	I connection pola	rity is mandatory.
----------------	-------------------	--------------------

ANALOG OUTPUT CHARACTERISTICS		
OUTPUTS TYPE 4-20mA OUTPUT		
CABLE LENGTH - SUPPLIED	5 FEET	
MAXIMUM CABLE LENGTH*	1,640 FEET	
LOOP SUPPLY VOLTAGE	12 - 24 VDC	
OUTPUT IMPEDANCE	25 [M] TYP	

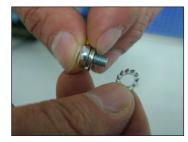
GROUNDING INSTRUCTIONS



STEP 1Insert the M5 screw through the pre-assembled Ring Terminal Lug.



STEP 2Insert the flat washer on top of the Ring Terminal Lug.



STEP 3 Insert the serrated washer on the flat washer.







STEP 4Attach to the Fork Terminal Lug and tighten (as shown in all three pictures).



STEP 5
Insert flat washer and serrated washer on bolt - use the correct washers per bolt size (M16 or M20 respectively). Insert the bolt in the hole of the pipe's flange - do not insert on meter's flange.



STEP 6Slide the Fork Terminal Lug between the flat washer and serrated washer.



STEP 7Add serrated washer to the other side of the bolt (on meter's flange side).



STEP 8Add the flat washer on top of the serrated washer.



STEP 9Add nut and tighten. Make sure the Fork Terminal Lug is in position.

GROUNDING PARTS

PARTS KIT FOR RING TERMINAL LUG



PICTURED LEFT TO RIGHT

- Fork Terminal Lug
- Flat Washer
- M5 Screw
- Serrated Washer

PARTS KIT FOR FORK TERMINAL LUG CONNECTION TO PIPE



PICTURED TOP TO BOTTOM

- M16 or M20 Bolt (not included in kit)
- Flat Washer in M16 and M20 size (2 each included in kit)
- Serrated Washer in M16 and M20 sizes (2 each included in kit)
- M16 or M20 Nut (not included in kit)



NETAFIM USA 5470 E. Home Ave. Fresno, CA 93727 CS 888 638 2346 www.netafimusa.com

Appendix B

McCrometer McMag 3000 Magnetic Meter



Battery Powered Electromagnetic Flow Meter

Quick Start Installation Guide





3255 WEST STETSON AVENUE • HEMET, CALIFORNIA 92545 USA

TEL: 951-652-6811 • 800-220-2279 • FAX: 951-652-3078 Printed In The U.S.A.

Lit. 30121-64 Rev. 1.2/04-15 www.mccrometer.com
Irrigation Training and Research Center
Copyright © 2014-2015 McCrometer, Inc. All printed material showledge to be changed or altered without permission of McCrometer. Any published technical data and instructions are subject to change without notice. Contact your McCrometer representative for current technical data and instructions. Mc Mag^{3000™} is a trademark of McCrometer, Inc. U.S. Patent 8,997,580 B2; foreign patents pending.

About This Quick Start Guide

This Quick Start Guide is a supplement to the Installation, Operation and Maintenance manual supplied with this meter. It is intended to be a quick reference for the basic installation and reading of the Mc Mag³⁰⁰⁰. For more detailed information concerning the external connections, external power, pulse output, or data logger, please refer to the meter manual (30120-85 Mc Mag³⁰⁰⁰ IOM) or the data logger manual (30121-87 McLogger IOM) downloadable from www.mccrometer.com).

WARNING!

Incorrect installation or removal of meters can result in serious injury or death. Read the instructions in this guide on the proper procedures carefully.

- Any person installing, inspecting, or maintaining a McCrometer flowmeter should have a working understanding of piping configurations and systems under pressure.
- Before adjusting or removing any meter, be certain the system has depressurized completely.
- Be careful when lifting meters. Meters can cause serious injury if lifted incorrectly or dropped.

General Installation Considerations

Proper meter installation is the first step to ensure excellent meter performance. Follow these instructions closely. Consult an authorized service representative or the Factory for any circumstances encountered which are not covered in this guide.

All McCrometer products are tested and inspected during manufacture and prior to shipping. An inspection should be performed at the time of unpacking to detect any damage that might have occurred during shipment.

- All magnetic flowmeters are calibrated for a full pipeline only; if less, the flowmeter will over register the flow.
- Although a minimum line pressure is not necessary for an accurate measurement, a full pipe is necessary.
- With the meter installed, check the rate-of-flow indicator. It should be stable to the point that it can be easily read. Some indicator movement is normal due to variations in flow. Erratic movement of the indicator is normally caused by flow variations and the system should be checked. Drastic variations in flow can decrease meter accuracy. If you suspect a problem with the meter, please contact your local McCrometer representative.

Flow Direction

It is very important to install the flow meter relative to the flow of the water. The sensor is designed at an angle to shed debris in the flow and for other performance enhancements.

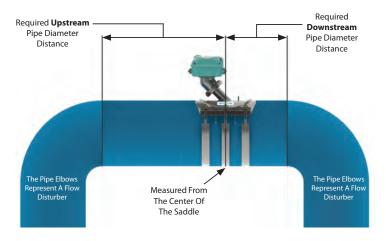


Pipe Run Requirements

Flow meters are velocity sensing devices and are vulnerable to certain upstream disturbances. Because of this, meters need certain lengths of straight pipe before and after the meter. These distances relate to the diameter of the pipe used. Obstructions can include elbows, valves, pumps, and changes in pipe diameter. The uneven flow created by these obstructions can vary with each system.

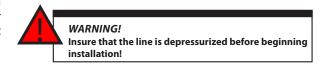
- Upstream Requirement: Mc Mag³⁰⁰⁰ meters should be installed a minimum of three diameters away from of most obstructions.
- Downstream Requirement: The downstream run should be one diameter of straight pipe length after the meter.

Both upstream and downstream distances are measured from the center of the saddle as shown below.



Flow Meter Installation

The Mc Mag³⁰⁰⁰ is a saddle type meter. It may be installed directly onto an existing pipe, or may be installed into an optional spool piece to be added to a system.



New Installations

Saddle type meters offer simplicity of installation. A minimum round hole size of $2^{3}/4^{"}$ should be cut into the top center of the pipe. The saddle meter is then installed as follows:

- 1. Loosen and remove the nuts and washers from the straps. Remove the straps from the saddle.
- 2. Cut or hole-saw the pipe and remove all burrs, slag, and rough edges from the inside and outside of the cutout section.
- 3. Place the meter assembly on the pipe with the flat gasket on the 4" models, and the "D" shaped ring gasket for larger meters in position on the bottom of the saddle. The saddle must be positioned so that the flat gasket or D-ring maintains contact with the surface of the pipe completely around the cutout



4. Insert the meter probe through the hole and slide the meter forward (downstream) until the probe contacts the front edge of the pipe wall. Then slide the back away from the pipe wall 1/8" to 1/4" leaving the probe in a free state and not in contact with the pipe wall.



IMPORTANT!

Insure that the meter probe is not in contact with the pipe wall when installed!

- 5. Install the straps from under the pipe and insert the threaded ends through the holes in the brackets on the side of the saddle.
- 6. For each strap bolt, replace the washers and nuts.
- 7. Tighten each of the U-bolt nuts evenly.



WARNING!

WARNING: Customers are warned that the U-Bolt nuts are to be tightened evenly to approximately 30 foot pounds torque. This is sufficient to seal the saddle to the pipeline. Additional tightening may be required to seal the saddle on rough or irregular pipe (60 FOOT POUNDS MAXIMUM).

Installations Replacing Existing Saddle Meters

The Mc Mag³⁰⁰⁰ can be used to replace existing McCrometer saddle meters. The Mc Mag³⁰⁰⁰ can be installed with Water Specialties bolt-on saddle meter cutout templates for 6" meters and 8"-20" meters, as well as with McPropeller bolt-on saddle meter cutout templates for 12"-16" OD pipe.



NOTE:

The meter CANNOT be installed with Water Specialties bolton saddle meter cutout templates for 4" meters.

Grounding

The Mc Mag³⁰⁰⁰ is fitted with a grounding lug on the saddle for proper grounding. For typical installations the lug can be connected to an earth ground and/or the metal pipe in which it is installed. For electrically noisy installations connect the grounding lug to a dedicated, low impedance earth ground. Low impedance is 10 Ohms or less.



The Ground wire is

Converter Boot

The Mc Mag³⁰⁰⁰ comes with a boot to help protect the meter.

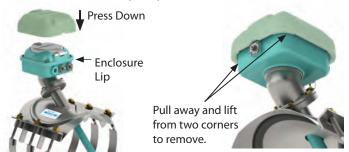


NOTE:

It is HIGHLY recommended that the boot be utilized at all times when the meter is not being read. The boot adds protection to the meter and insures proper closure of the lid, insuring the maximum battery life.

The boot simply slips over the electronics enclosure. When installing the boot insure the corners of the boot fit snugly over the lip of the

To remove the boot, grip two corners and pull them away from the lip of the enclosure and then pull upwards.



Operation

The Mc Mag³⁰⁰⁰ comes pre-configured from the Factory based on the installation parameters provided to McCrometer at the time of order. Other than activating the display, there is nothing required of the user for the basic operation of the flow meter.

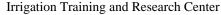
Activating The Display

For the purpose of conserving power the display remains blank until activated. To activate the screen open the lid and then close the lid for two seconds to allow the magnetic switch to activate the display. When the lid is reopened the screen display will be active. The screen will automatically deactivate after 60 seconds.





If the lid is left up, propped up or broken off, the battery life of the meter will be reduced. If the lid is broken off, contact the Factory for a lid replacement kit. In the meantime, set the lid on the meter in its proper position and use the boot to hold it in place.







Display Descriptions

Upon activating the display, the Mc Mag³⁰⁰⁰ automatically cycles through four display screens.

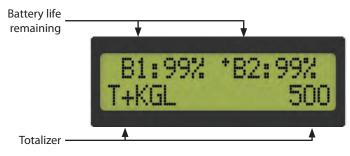
Screen 1:

The first screen display shows any active alarms. In the sample below, there is one alarm active for an empty pipe.



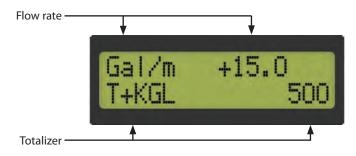
Screen 2:

The second screen display shows the battery life remaining for both battery packs and the flow totalizer. In the sample below, both battery packs are at 99% and total flow is 500 kilogallons.



Screen 3:

The third screen display shows the flow rate and the flow totalizer. In the sample below, flow rate is 15 gallons per minute and total flow is 500 kilogallons.



Screen 4:

The fourth screen display shows the flow rate and percent of full scale. In the sample below the flow rate is 15 GPM and the meter is running at 80% of full scale.



Alarm Messages

ALARM MESSAGE	POTENTIAL CAUSE / CORRECTIVE ACTION
B.TEMP.OUT R.	The measured board temperature is out of the allowed range. Ensure that the instrument is operating within the specified temperature conditions: -4° to 140°F (-20° to 60°C).
B1 LOW	The battery 'B1' powering the main board is exhausted. Replace the battery.
B2 LOW	The battery 'B2' powering the main board is exhausted. Replace the battery.
CALIBRATION ERR.	Contact Factory. This could be a damaged sensor or a noise issue. Check the ground connection.
CONFIG. ENTERED	The system detects an access to the configuration parameters. Check the data logger events log and take the appropriate action depending on your data protection policy.
EL.SIG.ERROR	The system detected an error condition on the measuring electrodes. Check the electrode surfaces, the grounding and the process condition.
EXCIT.ERROR	The system detected an error in the coil's excitation circuit. Contact Factory.
F.SENSOR ERROR	The system detected one or more errors in the flow sensor. Contact Factory.
FLOW>FS	The flow rate is higher than the set full scale value. Check the maximum full scale value and the process conditions.
MAX Q+	The positive flow rate is higher than the maximum threshold value set.
MIN Q+	The positive flow rate is lower than the minimum threshold value set.
NO ALARMS	The system is running with no problems.
P.EMPTY	The system detected an empty pipe alarm condition. Ensure pipe is full.
POWER SUPPLY OFF	The power coming from the external power supply went off. Check the power supply source and the relative cables.
PULS.1>F.MAX	The pulse frequency at Output 1 is too high. Contact Factory.
PULS.2>F.MAX	The pulse frequency at Output 2 is too high. Contact Factory.
SYSTEM RESTART	The system was restarted after a reset signal. If this message appears after an AUTO-TEST command, it is not an error indication, otherwise check all the connections, the batteries and the grounding.
SYSTEM STARTUP	The system was started.





Battery Powered Electromagnetic Flow Meter

Sensor Installation, Operation And Maintenance Manual

> 30120-85 Rev. 1.4 April, 2015





CONTENTS

1.0 Safety	
1.1 Safety Symbols And Warnings 1.2 Safety Warnings	
2.0 Introduction	2
3.0 Principle Of Operation	2
4.0 Dimensions	3
5.0 Installation	4
5.1 General Installation Considerations	4
5.2 Flow Direction	
5.3 Pipe Run Requirements	
5.4 Meter Installation	
5.5 Grounding	
5.6 Converter Boot	8
6.0 Operation	
6.1 General	
6.2 Activating The Display	
6.3 Display Descriptions	9
7.0 External Connectors -10-32 VDC Power/ 4-20mA Output And Pulse Out	put11
8.0 5-Pin DC Power And 4-20mA Cable (Optional)	
8.1 DC Power Supply Specifications (Optional)	
9.0 7-Pin Pulse Output Cable (Optional)	13
10.0 Maintenance	14
11.0 Specifications	14
12.0 Troubleshooting	15
13.0 Returning A Unit For Repair	17
14.0 Dimensions And Weights	18
Warranty Statement	
**u::u::ty Jtute:	

Copyright © 2014-2015 McCrometer, Inc. All printed material should not be changed or altered without permission of McCrometer. Any published technical data and instructions are subject to change without notice. Contact your McCrometer representative for current technical data and instructions. U.S. Patent 8,997,580 B2, foreign patents pending. Mc Mag $^{3000^{TM}}$ is a trademark of McCrometer, Inc.



3255 WEST STETSON AVENUE • HEMET, CALIFORNIA 92545 USA TEL: 951-652-6811 • 800-220-2279 • FAX: 951-652-3078 Printed In The U.S.A. Lit. 30120-85 Rev. 1.4/04-15

1.0 Safety

1.1 Safety Symbols And Warnings

Throughout this manual are safety warning and caution information boxes. Each warning and caution box will be identified by a large symbol indicating the type of information contained in the box. The symbols are explained below:



This symbol indicates important safety information. Failure to follow the instructions can result in serious injury or death.



This symbol indicates important information. Failure to follow the instructions can result in permanent damage to the meter or installation site.

1.2 Safety Warnings

When installing, operating, and maintaining McCrometer equipment where hazards may be present, you must protect yourself by wearing Personal Protective Equipment (PPE) and be trained to enter confined spaces. Examples of confined spaces are manholes, pumping stations, pipelines, pits, septic tanks, sewage digesters, vaults, degreasers, storage tanks, boilers, and furnaces.

You must follow all state and local laws, as well as Occupational Safety and Health Administration (OSHA) regulations concerning Personal Protective Equipment and confined-space entry. Specific requirements can be found in the OSHA section of the Code of Federal Regulations: 29 CFR, 1910.132 - 1910.140, Personal Protective Equipment; and CFR Title 29, Part 1910.146, Permit-Required Confined-Spaces.



WARNING!

Incorrect installation or removal of meters can result in serious injury or death. Read the instructions in this manual on the proper procedures carefully.



WARNING!

Never enter a confined space without testing the air at the top, middle, and bottom of the space. The air may be toxic, oxygen deficient, or explosive. Do not trust your senses to determine if the air is safe. You cannot see or smell many toxic gases.



WARNING!

Never enter a confined space without the proper safety equipment. You may need a respirator, gas detector, tripod, lifeline, and other safety equipment.



WARNING!

Never enter a confined space without standby/rescue personnel within earshot. Standby/rescue personnel must know what action to take in case of an emergency.



WARNING!

Cutting into a pressurized pipe may cause injury or death. Always insure the pipe is empty BEFORE cutting.



2.0 Introduction

Thank you for selecting the Mc Mag^{3000™} (Battery Powered Electromagnetic Flow Meter). This bolt-on saddle meter offers the convenience of installation and operation of a propeller meter with the accuracy and ease of use of a mag meter.

The Mc Mag³⁰⁰⁰ flow meter combines an innovative multi-point sensor with a battery powered integrated electronic converter package to provide accurate flow measurement for full-pipe flow monitoring applications.

The saddle mounted sensor (available for pipe sizes from 4 to 12 inches) uses electromagnetic technology to measure the water flow and correct for shifting velocity in the pipe by constantly obtaining a mean velocity from its multiple sensors.

The integrated converter is powered by a replaceable three cell lithium-thionyl chloride (Li-SOCI₂) battery that can provide flow measurement for a guaranteed five years. Also available is the optional DC power supply (required for 4-20mA output). The streamlined, debris-shedding sensor shape allows the Mc Mag³⁰⁰⁰ to be used under many flow conditions, including surface water applications.

The Mc Mag³⁰⁰⁰ can also be ordered with the optional McLogger data logger. Please see the McLogger manual for more information (Literature number 30121-87).

3.0 Principle Of Operation

The Mc Mag³⁰⁰⁰ uses *Faraday's Law of Electromagnetic Induction* to measure water velocity. Faraday's Law states:

A conductor, moving through a magnetic field, produces a voltage.

Charge carriers in the fluid produce a voltage when passing through a magnetic field. The magnitude of the voltage is directly proportional to the velocity at which the fluid moves through the magnetic field. Electromagnetic coils inside the sensor produce magnetic fields, and electrodes on the sensor's surface measure the voltage generated by the moving fluid.

The electrode pairs are positioned in specific configurations along the axis of the sensor. The individual velocity measurements are averaged together providing the average velocity across the pipe center line. Flow is calculated by multiplying the average velocity by the cross-sectional area of the pipe.



4.0 Dimensions



Figure 1: Enclosure Top View

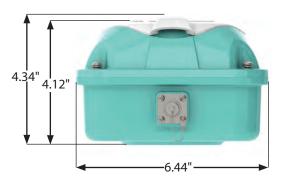


Figure 2: Enclosure Front View

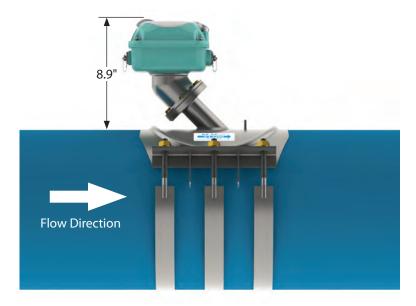


Figure 3: Enclosure Height



5.0 Installation

5.1 General Installation Considerations

Proper meter installation is the first step to ensure excellent meter performance. Follow these instructions closely. Consult an authorized service representative or the actory for any circumstances encountered which are not covered in this manual.

All McCrometer products are tested and inspected during manufacture and prior to shipping. An inspection should be performed at the time of unpacking to detect any damage that might have occurred during shipment.

WARNING!

Incorrect installation or removal of meters can result in serious injury or death. Read the instructions in this manual on the proper procedures carefully.

- Any person installing, inspecting, or maintaining a McCrometer flow meter should have a working understanding of piping configurations and systems under pressure.
- Before adjusting or removing any meter, be certain the system has depressurized completely.
- Be careful when lifting meters. Meters can cause serious injury if lifted incorrectly or dropped.
- All magnetic flow meters are calibrated for a full pipeline only; if less, the flow meter will over register the flow.
- Although a minimum line pressure is not necessary for an accurate measurement, a full pipe is necessary.
- With the meter installed, check the rate-of-flow indicator. It should be stable to the point that it can be easily
 read. Some indicator movement is normal due to variations in flow. Erratic movement of the indicator is
 normally caused by flow variations and the system should be checked. Drastic variations in flow can decrease
 meter accuracy. If you suspect a problem with the meter, please contact your local McCrometer representative.

5.2 Flow Direction

It is very important to install the flow meter relative to the flow of the water. The sensor is designed at an angle to shed debris in the flow and for other performance enhancements.

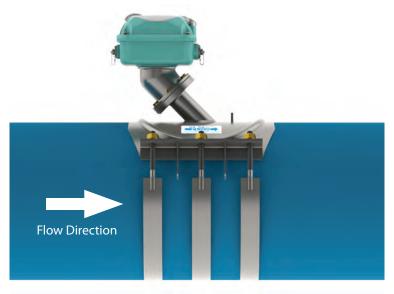


Figure 4: Proper Meter Installation For Flow Direction (6" To 12" Line Size Configuration Shown)



5.3 Straight Pipe Requirements

Flow meters are velocity sensing devices and are vulnerable to certain upstream disturbances. Because of this, meters need certain lengths of straight pipe before and after the meter. These distances relate to the diameter of the pipe used. Obstructions can include elbows, valves, pumps, and changes in pipe diameter. The uneven flow created by these obstructions can vary with each system.

Both upstream and downstream distances are measured from the center of the saddle as shown below.

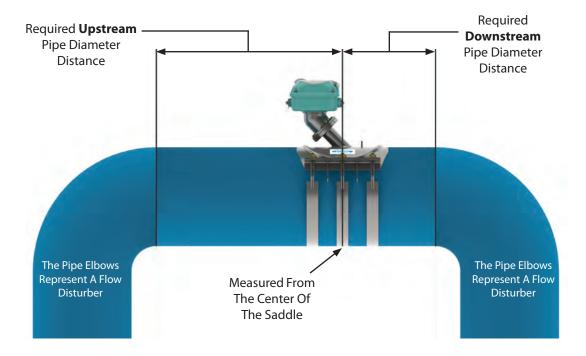


Figure 5: How To Measure Straight Pipe Requirements

In a typical installation to achieve $\pm 2\%$ accuracy the Mc Mag³⁰⁰⁰ flow meter should be installed a minimum of three diameters upstream from most flow disturbers and one diameter downstream of the meter. Accuracy of $\pm 1\%$ is available in many applications with a Factory consultation prior to ordering.



5.4 Flow Meter Installation

The Mc Mag³⁰⁰⁰ is a saddle type meter. It may be installed directly onto an existing pipe, or may be installed into an optional spool piece to be added to a system.



WARNING!

Insure that the line is depressurized before beginning installation!

5.4.1 New Installations

Saddle type meters offer simplicity of installation. A minimum round hole size of 2.75" should be cut into the top center of the pipe. The saddle meter is then installed as follows:

- 1. Loosen and remove the nuts and washers from the straps. Remove the straps from the saddle.
- 2. Cut or hole-saw the pipe and remove all burrs, slag, and rough edges from the inside and outside of the cutout section.
- 3. Place the meter assembly on the pipe with the flat gasket on the 4" models, and the "D" shaped ring gasket for larger meters in position on the bottom of the saddle. The saddle must be positioned so that the flat gasket or D-ring maintains contact with the surface of the pipe completely around the cutout opening.
- 4. Insert the meter probe through the hole and slide the meter forward (downstream) until the probe contacts the front edge of the pipe wall. Then slide the back away from the pipe wall 1/8" to 1/4" leaving the probe in a free state and not in contact with the pipe wall.



IMPORTANT!

Insure that the meter probe is not in contact with the pipe wall when installed!

- 5. Install the straps from under the pipe and insert the threaded ends through the holes in the brackets on the side of the saddle.
- 6. For each strap bolt, replace the washers and nuts.
- 7. Tighten each of the U-bolt nuts evenly.



WARNING!

WARNING: Customers are warned that the U-Bolt nuts are to be tightened evenly to approximately 30 foot pounds torque. This is sufficient to seal the saddle to the pipeline. Additional tightening may be required to seal the saddle on rough or irregular pipe (60 FOOT POUNDS MAXIMUM).

5.4.2 Installations Replacing Existing Saddle Meters

The Mc Mag³⁰⁰⁰ can be used to replace existing McCrometer saddle meters. The Mc Mag³⁰⁰⁰ can be installed with Water Specialties bolt-on saddle meter cutout templates for 6" meters and 8"-20" meters, as well as with McPropeller bolt-on saddle meter cutout templates for 12"-16" OD pipe.



NOTE:

The meter CANNOT be installed with Water Specialties bolt on saddle meter cutout templates for 4" meters.



5.5 Grounding

The Mc Mag³⁰⁰⁰ is fitted with a grounding lug on the saddle for proper grounding. For typical installations the lug can be connected to an earth ground and/or the metal pipe in which it is installed.

For electrically noisy installations connect the grounding lug to a dedicated, low impedance earth ground. Low impedance is 10 Ohms or less.





Figure 6: Mc Mag³⁰⁰⁰ Grounding Lug

Irrigation Training and Research Center
E-35



5.6 Converter Boot

The Mc Mag³⁰⁰⁰ comes with a boot to help protect the meter.



NOTE:

It is HIGHLY recommended that the boot be utilized at all times when the meter is not being read. The boot adds protection to the meter and insures proper closure of the lid, insuring the maximum battery life.

The boot simply slips over the electronics enclosure. When installing the boot, insure the corners of the boot fit snugly over the lip of the enclosure. See Figure 7.

To remove the boot, grip two corners and pull them away from the lip of the enclosure and then pull upwards. *See Figure 7*.



Figure 7: Boot Installation

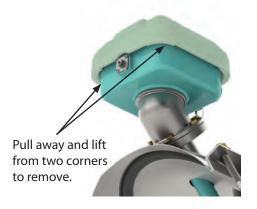


Figure 8: Boot Removal



Figure 9: Proper Boot Installation



6.0 Operation

6.1 General

The Mc Mag³⁰⁰⁰ comes pre-configured from the Factory based on the installation parameters provided to McCrometer at the time of order. Other than activating the display, there is nothing required of the user for the basic operation of the flow meter.

6.2 Activating The Display

For the purpose of conserving power the display remains blank until activated. To activate the screen open the lid and then close the lid for two seconds to allow the magnetic switch to activate the display. When the lid is reopened the screen display will be active. The screen will automatically deactivate after 60 seconds.



Figure 10: Lid Operation To Activate Display



CAUTION:

If the lid is left up, propped up or broken off, the battery life of the meter will be reduced. If the lid is broken off, contact the Factory for a lid replacement kit. In the meantime, set the lid on the meter in its proper position and use the boot to hold it in place.

6.3 Display Descriptions

Upon activating the display, the Mc Mag³⁰⁰⁰ automatically cycles through four display screens.

6.3.1

The first screen display shows any active alarms. In the sample below, there is one alarm active for an empty pipe.



Figure 11: Display Cycle One

Irrigation Training and Research Center E-37



The second screen display shows the battery life remaining for both battery packs and the flow totalizer. In the sample below, both battery packs are at 99% and total flow is 500 kilogallons.

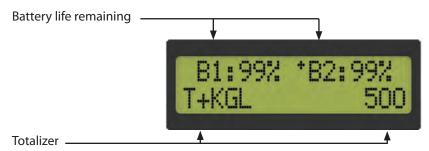


Figure 12: Display Cycle Two

6.3.3

The third screen display shows the flow rate and the flow totalizer. In the sample below, flow rate is 15 gallons per minute and total flow is 500 kilogallons.



Figure 13: Display Cycle Three

6.3.4

The fourth screen display shows the flow rate and percent of full scale. In the sample below, the flow rate is 15 gallons per minute and the meter is running at 80% of full scale.



Figure 14: Display Cycle Four



7.0 External Connectors - 10-32VDC Power/4-20mA Output And Pulse Output

The Mc Mag³⁰⁰⁰ has two external connectors on the downstream side of the electronics enclosure. The two connectors are for: 1. a 5-pin connector for an optional 10-32 VDC power and 4-20mA output; 2. a 7-pin connector for pulse output 1 and 2. *See Figure 15*. The Mc Mag³⁰⁰⁰ is configured at the Factory for the optional pulse output as requested by the customer at the time of order. The external cables attach with a screw locking type waterproof connector. *See Figure 16*.



IMPORTANT:

When not in use, always keep the attached cap firmly screwed into the connector to insure a water-tight seal. Also, keep the contacts in the cable connector clean and dry during assembly.



Figure 15: External Connectors

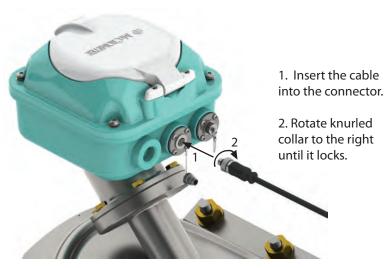


Figure 16: External Cable Connection



8.0 5-Pin DC Power And 4-20mA Output Cable (Optional)

The 5-pin cable contains wiring for both the optional 10-32VDC power to the meter, and the 4-20mA output from the meter. See *Figure 17* for the color scheme.



Figure 17: 5-Pin DC Power And 4-20mA Cable Wiring Color Scheme (Optional)

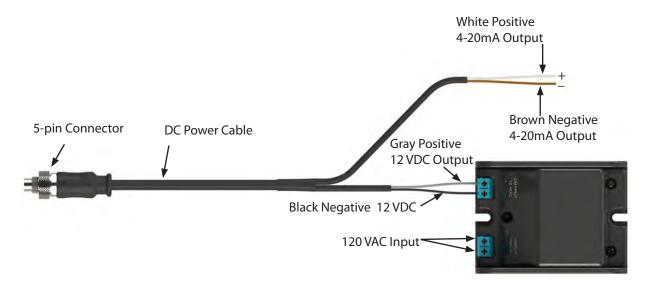


Figure 18: 5-Pin DC Power Cable And Power Supply (Optional)



8.1 DC Power Supply Specifications

Part Number: 115-12

Voltage – Input: 120 VAC \pm 5% / 60 Hz (external fuse recommended)

Voltage – Output: 12V ± 0.5 VDC @ 200mA

Current - Output (Max): 200mA

Power - 2.4W

Environment: Operating Temperature: 0 to 55°C (21 to 130°F); Maximum Humidity: 95% Relative Humidity,

Noncondensing Weight – 0.38 lb.

Mounting – Side or base chassis mount

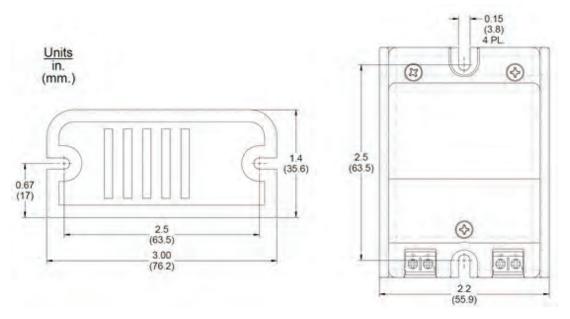


Figure 19: Power Supply Dimension (Optional)

9.0 7-Pin Pulse Output Cable (Optional)

The 7-pin cable contains wiring for both Pulse Output 1 and Pulse Output 2. See *Figure 20* for wiring color scheme.



Figure 20: 7-Pin Pulse Output Cable Wiring Color Scheme (Optional)



10.0 Maintenance

The Mc Mag³⁰⁰⁰ is essentially a maintenance free meter with no user serviceable parts. However, the metered fluid may contain solids or other contaminants which may coat the sensor electrodes. A periodic inspection may be recommended to insure the sensor electrodes are clean. To clean the unit, remove the sensor following all of the instructions and safety warnings contained in *Sections 1.0 and 5.0*. When the sensor is removed from the pipe, carefully wipe down the sensor with a soft cloth and rubbing alcohol.

11.0 Specifications

SPECIFICATIONS

MEASUREMENT:

Volumetric flow in full pipe conduits nominal line sizes from 4" (100 mm) to 12" (300 mm) utilizing insertable electromagnetic averaging sensor.

FLOW MEASUREMENT:

Method: Electromagnetic

Accuracy: ± 2% with default calibration

± 1% with custom Factory calibration **Reverse Flow**: Reverse flow indication only

POWER REQUIREMENTS:

Battery Power: Standard: three 3.6V lithium-thionyl chloride (Li-SOCl₂) D size batteries. Guaranteed 5-year battery life on the main power batteries. (Third battery serves as back-up power).

Main power batteries are field replaceable.

MATERIALS:

Sensor Body: Fusion bonded epoxy coated stainless steel (316)

Sensor Electrodes: Stainless steel (316)
Saddle Mount: Stainless steel (304)
Saddle Hardware: Stainless Steel (304)

O-Ring: SBR Rubber D-Ring Boot Cover: EPDM Rubber

OUTPUTS:

Outputs (DC powered version only): Open collector digital outputs (2) for pulse and alarm as well as 4-20mA output (not galvanically separated from supply power).

ENGINEERING UNITS:

US gallons, US gallons x1000, US gallons x1,000,000, cubic inches, cubic feet, cubic feet x1000, cubic centimeters, cubic decimeters, milliliters, liters, deciliters, hectoliters, kiloliters, megaliters, cubic meters, cubic meters x1000, acre feet, acre inches, imperial gallons, imperial gallons x1000, imperial gallons x1,000,000, standard barrels, oil barrels, and miner inch days.

Rate scales: seconds, minutes, hours, and days

CONDUCTIVITY:

Minimum conductivity of 50µS/cm, for lower conductive fluid consult Factory

CONVERTER ENCLOSURE:

Diecast aluminum enclosure, $6\frac{1}{2}$ " x $6\frac{1}{2}$ " x $4\frac{3}{8}$ " tall Tamper resistant screws

ELECTRICAL CONNECTIONS:

Optional shielded cable for 10-32VDC/4-20mA output Optional shielded cable for pulse out

RATINGS:

IP-67



ENVIRONMENTAL:

Operating Temperature: -4° to 220°F (-20° to 105°C) sensor (in process fluid), -4° to 140°F (-20° to 60°C)

converter (ambient)

Storage Temperature: -40° to 149°F (-40° to 65°C)

Operating Pressure: 150 PSI

PIPE RUN REQUIREMENTS:

3D Upstream / 1D Downstream for most installations (See Section 5.3 Straight Pipe Requirements)

INSTALLATION DIMENSIONS:

Minimum/Standard Cutout Diameter: 2.75" Maximum Cutout Diameter: Consult Factory.

Note: Meters can be installed in Water Specialties bolt saddle meter cutouts for 6" meters and 8"-12" meters as well as in McCrometer bolt on saddle meter cutouts for 12" OD pipe. **The meter CANNOT be installed in Water Specialties bolt on saddle meter cutouts for 4" meters.** If replacing an existing meter, consult Factory.

DISPLAY:

2-Line LCD display (no backlight), 16 characters per line

- Total and Partial Totalizer (to 9 digits of precision)
- Flow Rate and Velocity (to 5 digits of precision)
- Two alarms: low battery and empty pipe (optional)

To preserve battery life a magnetic switch in the housing lid activates the display

OPTIONS AND ACCESSORIES:

- Epoxy coated carbon steel flanged spool piece
- DC Power w/battery backup: (Pulse & 4 20mA Out)
- Annual Verification / Calibration
- Stainless Steel ID Tag
- McLogger Data Logger



12.0 Troubleshooting

12.1 Alarm Messages

ALARM MESSAGE	POSSIBLE CAUSE / CORRECTIVE ACTION
B.TEMP.OUT R.	The measured board temperature is out of the allowed range. Ensure that the instrument is operating within the specified temperature conditions: -4° to 140°F (-20° to 60°C).
B1 LOW	The battery 'B1' powering the main board is exhausted. Replace the battery.
B2 LOW	The battery 'B2' powering the main board is exhausted. Replace the battery.
CALIBRATION ERR.	Contact Factory. This could be a damaged sensor or a noise issue. Check the ground connection.
CONFIG.ENTERED	The system detects an access to the configuration parameters. Check the data logger and take the appropriate action depending on your data protection policy.
EL.SIG.ERROR	The system detected an error condition on the measuring electrodes. Check the electrode surfaces, the grounding and the process condition.
EXCIT.ERROR	The system detected an error in the coil's excitation circuit. Contact Factory.
F.SENSOR ERROR	The system detected one or more errors in the flow sensor. Contact Factory.
FLOW>FS	The flow rate is higher than the set full scale value. Check the maximum full scale value and the process conditions.
MAX Q+	The positive flow rate is higher than the maximum threshold value set.
MIN Q+	The positive flow rate is lower than the minimum threshold value set.
NO ALARMS	The system is running with no problems.
P.EMPTY	The system detected an empty pipe alarm condition. Ensure pipe is full.
POWER SUPPLY OFF	The power coming from the external power supply went off. Check the power supply source and the relative cables.
PULS.1>F.MAX	The pulse frequency at Output 1 is too high. Contact Factory.
PULS.2>F.MAX	The pulse frequency at Output 2 is too high. Contact Factory.
SYSTEM RESTART	The system was restarted after a reset signal. If this message appears after an AUTO-TEST command, it is not an error indication, otherwise check all the connections, the batteries and the grounding.
SYSTEM STARTUP	The system was started.



13.0 Returning A Unit For Repair

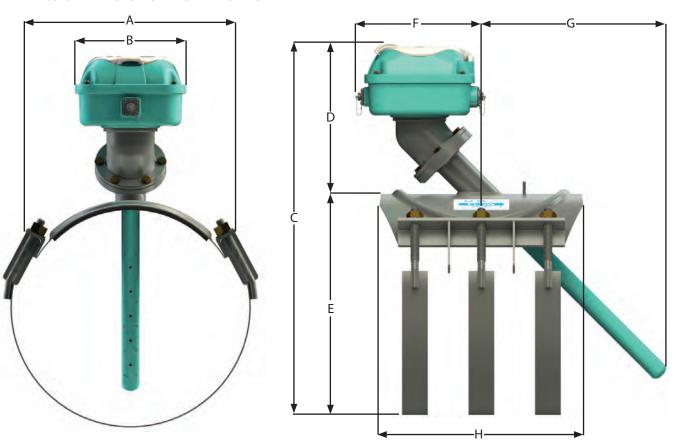
If the unit needs to be returned to the Factory for repair, please do the following:

- Prior to calling for a return authorization number, determine the model number, serial number (located inside the front panel of converter), and reason for return.
- Call the McCrometer Customer Service Department and ask for a Return Authorization (RA) number.
- Ship the meter in the original packaging, if possible. Do not ship manuals, power cords, or other parts with your unit unless required for repair.
- Please make sure the meter is clean and free from foreign debris prior to shipping.
- Write the RA number on the outside of the shipping box. All return shipments should be insured.
- Address all shipments to:

McCrometer, Inc. RMA # 3255 W. Stetson Avenue Hemet, CA 92545



14.0 DIMENSIONS AND WEIGHTS



	Nominal Pipe Size								
Max/Min Flow And Weight	4"	6"	8"	10"	12"				
Maximum Flow U.S. GPM	600	1350	2350	3700	5300				
Minimum Flow U.S. GPM	40	90	150	240	350				
Approximate Shipping Weight lbs.	23	26	29	30	32				

	Nominal Pipe Size							
Dimensions (Inches)	4"	6"	8"	10"	12"			
А	7.50	13.00	12.50	13.25	15.25			
В	6.44	6.44	6.44	6.44	6.44			
С	13.50	15.50	17.50	19.75	21.75			
D	8.90	8.90	8.90	8.90	8.90			
E	4.50	6.625	8.625	10.75	12.75			
F	7.37	7.37	7.37	7.37	7.37			
G	3.56	4.93	7.32	8.38	10.77			
Н	8.00	12.00	12.00	12.00	12.00			

All Dimensions based on ANSI B36.10 Nominal Pipe





WARRANTY STATEMENT

Manufacturer warrants all products of its manufacture to be free from defects in workmanship and material under normal use and service. The warranty for the *Mc Mag*³⁰⁰⁰ extends for a period of twenty-four (24) months after date of shipment, unless altered by mutual agreement between the purchaser and manufacturer prior to the shipment of the product. If this product is believed to be defective and is within its warranty period, purchaser shall notify the manufacturer, and will return the product to the manufacturer, postage paid, within twenty-four (24) months after date of shipment by the manufacturer. If the purchaser believes the return of the product to be impractical, manufacturer shall have the option, but will not be required, to inspect the product wherever located. In any event, if the purchaser requests the manufacturer visit their location, the purchaser agrees to pay the non-warranty expenses of travel, lodging and subsistence for the field service response. If the product is found by the manufacturer's inspection to be defective in workmanship or material, the defective part or parts will either be repaired or replaced, at manufacturer's election, free of charge, and if necessary the product will be returned to purchaser, transportation prepaid to any point in the United States. If inspection by the manufacturer of such product does not disclose any defect of workmanship or material, manufacturer's regular service repair charges will apply. Computing devices sold but not manufactured by McCrometer, Inc. are covered only by the original manufacturer's written warranty. Hence, this warranty statement does not apply.

THE FOREGOING WARRANTY IS MANUFACTURER'S SOLE WARRANTY, AND ALL OTHER WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE NEGATED AND EXCLUDED. THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, GUARANTEES, REPRESENTATIONS, OBLIGATIONS OR LIABILITIES ON THE PART OF THE MANUFACTURER.

Purchaser's sole remedy and manufacturer's sole obligation for alleged product failure, whether under warranty claim or otherwise, shall be the aforestated obligation of manufacturer to repair or replace products returned within twenty-four months after date of original shipment. The manufacturer shall not be liable for, and the purchaser assumes and agrees to indemnify and save harmless the manufacturer in respect to, any loss or damage that may arise through the use by the purchaser of any of the manufacturer's products.

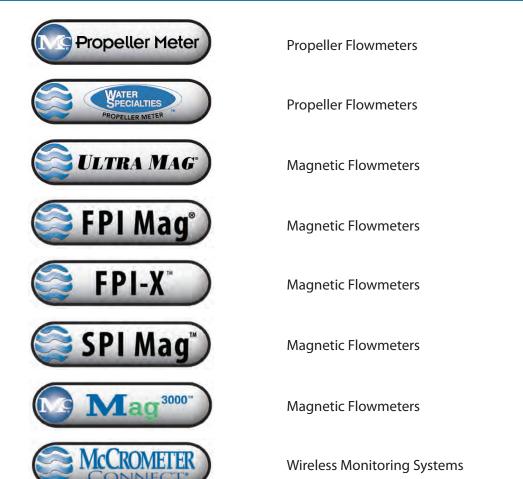
BATTERY GUARANTEE:

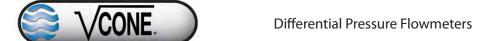
The Mc Mag³⁰⁰⁰ main power batteries will be replaced at no charge should they fail within 5 (five) years from the date of purchase with the meter. Guarantee is not valid for replacement batteries. Guarantee is limited to the a one-time replacement of the main power batteries. McCrometer is not responsible for any lost data or any other direct or indirect losses resulting therefrom. The batteries and their configuration are specific to the Mc Mag³⁰⁰⁰ flow meter and only McCrometer batteries can be used. Any use of batteries other than those supplied from McCrometer will void the above Warranty.





OTHER McCROMETER PRODUCTS INCLUDE:









Represented By:

Appendix C *McCrometer McPropeller Meter*



Mc Propeller Flowmeters

Installation, Operation And Maintenance Manual

24517-11 Rev. 4.0 November, 2013

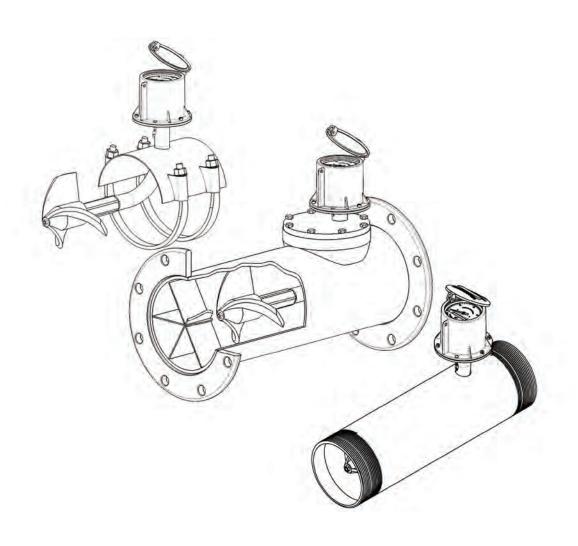




TABLE OF CONTENTS

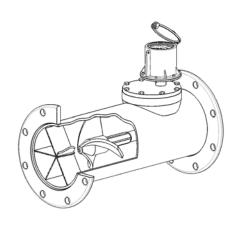
1.0) INTRODUCTION	
	1.1 MODEL TYPES	1
	1.2 TYPICAL APPLICATIONS	1
2.0	SPECIFICATIONS	2
2.0	2.1 GENERAL SPECIFICATIONS	
	2.2 HOW TO READ A TOTALIZER	
	2.3 UNDERSTANDING THE REGISTER GEAR RATIO	
	2.4 ACCURACY	
	2.5 HEADLOSS	
) INSTALLATION INSTRUCTIONS	
3.0	3.1 SAFETY	
	3.2 STRAIGHTENING VANES	
	3.3 INSTALLATION CONSIDERATIONS	
	3.4 PIPE RUN REQUIREMENTS	
	3.5 FLOW DIRECTION	
4.0	METER CONSTRUCTION	
	4.1 COMMON PARTS	
	4.2 PROPELLER	
	4.3 BEARING ASSEMBLY	
	4.4 DRIVE ASSEMBLY	
	4.5 METERHEAD4.6 REGISTER EXTENSION	
5.0	MAINTENANCE AND TROUBLESHOOTING	
	5.1 OCCASIONAL INSPECTIONS	
	5.2 TOOLS LIST	
	5.3 DISASSEMBLY AND INSPECTION PROCEDURE	
	5.4 ORDERING REPLACEMENT PARTS	
6.0	TECHNICAL SPECIFICATIONS	14
TEC	CHNICAL SUPPORT	14
ME	ETER MODEL DRAWINGS	15
	MF100, MG100, MS100. MT100 2" - 3"	
	MF100, MZ100, MZ200, MG100, MS100, MT104, MT106 4" - 24"	16
	ML100	17
	M0300	18
	M0300SW	19
	M0304	
	MW/QW500, MG900, MT900, MW900 2" - 3"	
	MW500, MW600, MG/MW900, MT904, MT906 4" - 24"	
	MZ500	23
	QW500	24
	M1104	
	M1400	
	M1708 THROUGH M1736	
	MM803 THROUGH MM816	
	MW803 THROUGH MW824	
WA	\RRANTY	30

Copyright © 1997-2013 McCrometer, Inc. All printed material should not be changed or altered without permission of McCrometer. Any published technical data and instructions are subject to change without notice. Contact your McCrometer representative for current technical data and instructions. Mc° of Mc Propeller is a registered trademark of McCrometer, Inc.

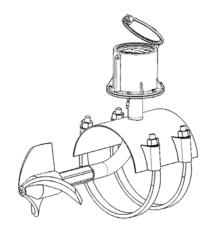
1.0 INTRODUCTION

Propeller flowmeters are widely accepted as a proven technology for measuring flow with high accuracy and excellent repeatability. McCrometer Inc. produces propeller flowmeters used around the world for agricultural, municipal, and industrial applications. Typical Mc Propeller Flowmeter configurations are shown in Figure: 1 below.

1.1 MODEL TYPES



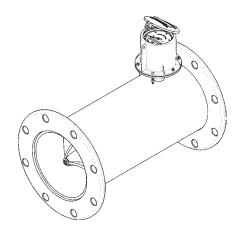
Removeable Top-Plate - MZ500 Shown



Saddle Type - M0300 Shown



Open Flow - M1700 Shown



Fixed Ell - MF100 Shown

Figure: 1 Typical Mc Propeller Flowmeter Configurations

1.2 TYPICAL APPLICATIONS

- Sprinkler irrigation systems
- Center pivot systems
- Farm turnouts from irrigation districts
- Drip irrigation systems
- Golf course and park management
- · Remote indication, totalizing, & recording
- Commercial nurseries
- Multi-stage pump actuation and control

- Raw water intake
- Water and wastewater management
- Plant effluent
- Valve actuation and control
- Return activated sludge
- Hot water & petroleum mixtures
- · Process batching & chemical feed

2.0 SPECIFICATIONS

The measuring element of a propeller flowmeter consists of a rotating device, called a rotor or propeller. Positioned in the center of the flowstream, the propeller rotates at a rate proportional to the velocity of the fluid through the flowmeter. This rotation can be transmitted mechanically to a register assembly and the fluid's volumetric flowrate and accumulated volume can then be displayed.

2.1 GENERAL SPECIFICATIONS

DESCRIPTIONS:

TURNDOWN: Propeller meters are specified to work within a certain range of flowrates. Turndown is the ratio of the maximum flowrate to the minimum flowrate of the meter. A typical turndown of an 8" meter is 15:1. (e.g., max. flow = 1500 gpm to min. flow = 100 gpm)

ACCURACY: Accuracy is the relation between the volume shown on the meter's totalizer and the actual volume of fluid which has passed through the meter. McCrometer guarantees that the meter will report within $\pm 2\%$ of the actual flow if it is normally operated between its minimum and maximum rates of flow.

2" to 96"
40 to 75,000 GPM
up to 15:1
±2%
±0.25%
150 PSI
160°F

REPEATABILITY: Flowmeter repeatability is the ability of a meter to reproduce a measurement under similar conditions. This is not by itself a measure of accuracy, but rather a component of the meter's total accuracy. McCrometer propeller meters have a repeatability of $\pm 0.25\%$.

PRESSURE: The pressure rating for standard propeller meters is 150 PSI. This pressure rating refers to the constant line pressure in the pipe. Some models can be rated up to 300 PSI. Higher pressures are available on special request.

TEMPERATURE: The temperature rating for standard propeller meters is 160° F constant temperature. This temperature rating refers to fluid temperature. Most standard models can be upgraded to 180° F constant temperature on special request.

2.2 HOW TO READ A TOTALIZER

The following guidelines should be helpful for reading totalizers on Mc Propeller flowmeters:

Most totalizers have "multipliers". Multipliers are always a multiple or fraction of ten which are used to multiply the direct reading of the totalizer. For example, an eight inch meter that totalizes in gallons will have a multiplier of times 100, see Figure 2. That means that the last digit on the right of the six digit totalizer is not gallons, but hundreds of gallons. In this example, the correct reading is 500 gallons.

The same eight inch meter totalizing in acre feet will have a multiplier of 0.001, see Figure 3. In this case, "X .001" is printed below the totalizer. The three digit counters on the right side are colored yellow to indicate a decimal point should be placed between the third and fourth digit when reading the totalizer. In this example, the correct reading is 092.545 Acre Feet. When reading a totalizer care must be taken to add the correct amount of zeroes or place the decimal point in the right place. If a mistake is made, the meter reading can be off by a factor of 10, 100, or even 1000 units.



Figure 2: Totalizer In Gallons



Figure 3: Totalizer In Acre Feet

2.3 UNDERSTANDING THE REGISTER GEAR RATIO

Each register has a gear ratio that is matched to the propeller. For instance, consider an 8" McCrometer meter totalizing in gallons. A standard 8" meter will have a gear ratio of 400:1, which means the propeller must rotate 400 times for the first odometer wheel to turn one <u>complete</u> revolution. This first odometer wheel usually symbolizes a certain multiple of the totalizing units, called a multiplier. Since the totalizer on the 8" meter has a <u>multiplier</u> of times 100 (signified by two zeros to the right of the odometer wheels), each number on the first odometer wheel represents one hundred gallons. Therefore, one <u>complete</u> rotation of the first odometer wheel is ten times one hundred gallons, or 1000 gallons. So remembering the gear ratio for this example is 400 propeller revolutions to one full turn of the odometer wheel, 400 propeller revolutions equals 1000 gallons.

Example: Standard 8" meter: 400 propeller rev. = 1 rev. of odometer wheel = 1000 gallons

NOTE Each line size has its own gear ratio. Registers from different size meters cannot be interchanged freely. Be sure you know your meter's gear ratio and multiplier for reference.

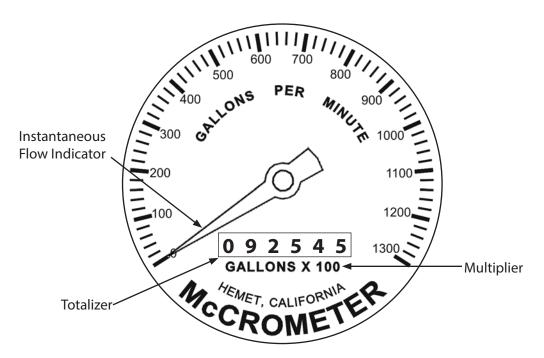
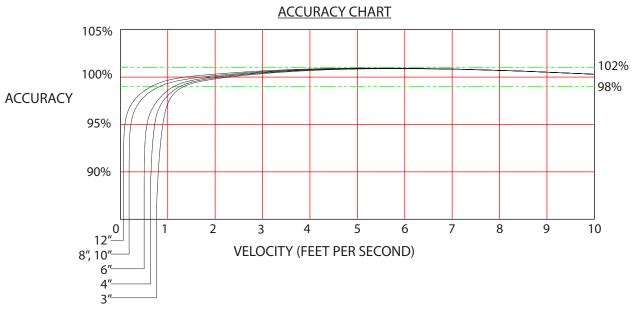


Figure: 4 Typical Dial Face

2.4 ACCURACY

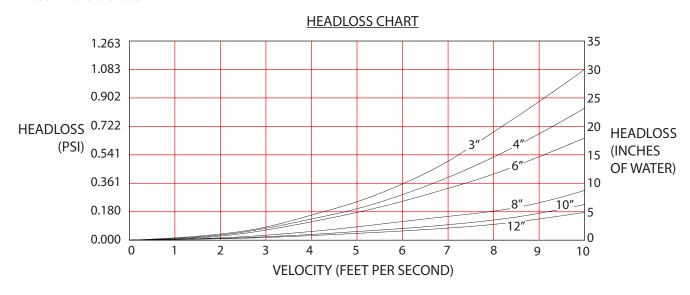


Standard flowrates for McCrometer propeller meters are shown below. Readings are guaranteed accurate within $\pm 2\%$ in these flowrates. Please note that over 80 percent of the meter's flow range, the accuracy is better than $\pm 1\%$.

Nominal Meter Size	2"	2.5"	3"	4"	6"	8"	10"	12"	14"	16"	18″	20"	24"
Minimum Flow(U.S.GPM)	40	40	40	50	90	100	125	150	250	275	400	475	700
Maximum Flow(U.S.GPM)	250	250	250	600	1200	1500	1800	2500	3000	4000	5000	6000	8500
Dial Face Range	250	250	250	800	1300	2500	3000	4000	6000	8000	10000	10000	15000

2.5 HEADLOSS

Headloss refers to the fluid pressure lost due to the meter. Propeller meters have very low permanent headloss as seen in the chart below.



Nominal Meter Size	3″	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"
Max. Headloss (in. H ₂ 0 column)	30	23	17	7	4	3	2	2	2	1	1

3.0 INSTALLATION INSTRUCTIONS

Proper meter installation is the first step to ensure excellent meter performance. Follow these instructions closely. Consult an authorized service representative or the factory for any circumstances encountered which are not covered in this manual.

All McCrometer products are tested and inspected during manufacture and prior to shipping. An inspection should be performed at the time of unpacking to detect any damage that might have occurred during shipment.

3.1 SAFETY

- Any person installing, inspecting, or maintaining a McCrometer flowmeter should have a working understanding of piping configurations and systems under pressure.
- Before adjusting or removing any meter, be certain the system has depressurized completely.

NEVER ATTEMPT TO REMOVE A METER WHILE THE LINE IS UNDER PRESSURE!

- · Be careful when lifting meters. Meters can cause serious injury if lifted incorrectly or dropped.
- Only necessary and appropriate tools should be used when working on a meter. For tools list see page 11.
- Before starting a system, make sure all connections are properly secured. Keep a safe and prudent distance away from the meter during system start-up.

3.2 STRAIGHTENING VANES

Special attention should be given to systems using two elbows "out of plane" or devices such as a centrifugal sand separator. These cause swirling flow in the line that affect propeller meters. Well developed swirls can travel up to 100 diameters downstream if unobstructed. Since most installations have less than 100 diameters to work with, straightening vanes become necessary to alleviate the problem. Straightening vanes will break up most swirls and ensure more accurate measurement. McCrometer's mainline meters like the MW500 series have vanes included as a standard feature. If your model does not have straightening vanes (e.g., M0300 Bolt-On Saddle series), McCrometer actively encourages installing vanes just ahead of the meter. Straightening vanes are available in weld-in, bolt-in, and the FS100 Flow Straightener. For more information on vane installation, please visit www.mccrometer. com and download the following McCrometer documents:

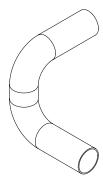


Figure: 6 Elbows Out Of Plane

- 24510-72 Installation Instructions For Bolt-In Vanes
- 24517-03 FS100 Flow Straightener Installation Instructions

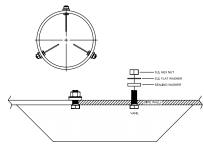


Figure: 7 Bolt In Straightening Vanes

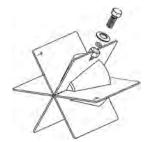


Figure: 8 FS100 Flow Straightener

3.3 OTHER INSTALLATION CONSIDERATIONS

- All propeller flowmeters are calibrated for a full pipeline only; if less, the flowmeter will over register the flow. Although a minimum line pressure is not necessary for an accurate measurement, a full pipe is necessary.
- Mc Propeller flowmeters can be mounted either horizontally or vertically. Mc Propeller flowmeters are
 calibrated for horizontal installation. Vertical mounting can offer some slight advantages due to gravity having
 a more pronounced flow conditioning effect in vertical lines. If the meter is to be mounted vertically, please
 notify the factory at time of order as the mechanical indicator needs to be calibrated for vertical installations.
- With the meter installed, check the rate-of-flow indicator. It should be stable to the point that it can be easily read. Some indicator movement is normal due to variations in flow. Erratic movement of the indicator is normally caused by flow variations and the system should be checked. Drastic variations in flow can decrease meter accuracy. If you suspect a problem with the meter, please contact your local McCrometer representative.

3.4 PIPE RUN REOUIREMENTS

Flowmeters are velocity sensing devices and are vulnerable to certain upstream disturbances. Because of this, meters need certain lengths of straight pipe runs before and after the meter. These distances usually relate to the diameter of the pipe used. Obstructions can include elbows, valves, pumps, and changes in pipe diameter. The uneven flow created by these obstructions can vary with each system. If your application provides for more than five diameters of upstream run, use the available distance.

- Upstream Requirement: Mc Propeller meters should be installed a minimum of five to ten diameters upstream of any obstructions. See the tables below. The exact upstream piping requirements are specific to the meter model number.
- Downstream Requirement: The downstream run should be one to two diameters of straight pipe length after the meter.

For upstream and downstream piping requirements relating to your specific meter, contact your local McCrometer representative. (Please be prepared to provide the serial number of your meter.)

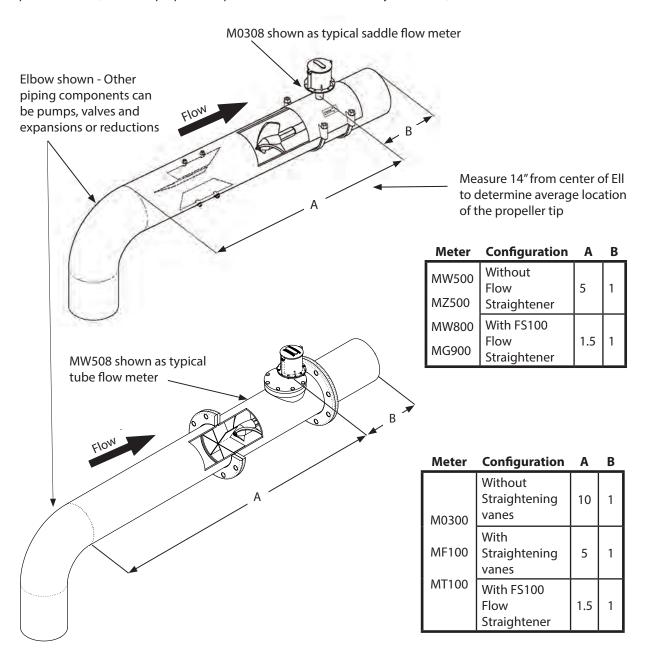


Figure: 5 Pipe Rum Requirementing and the And Tehre Style Flow Meters

3.5 FLOW DIRECTION

All McPropeller meters have a Flow Arrow displayed on the meter in an obvious location to indicate the direction of the fluid flow. This is to insure that a meter is not installed backwards.

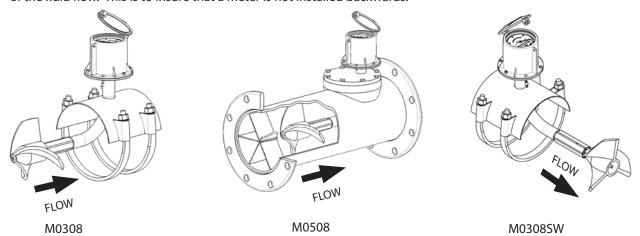


Figure: 9 McPropeller Meters With Indication Of Flow Direction

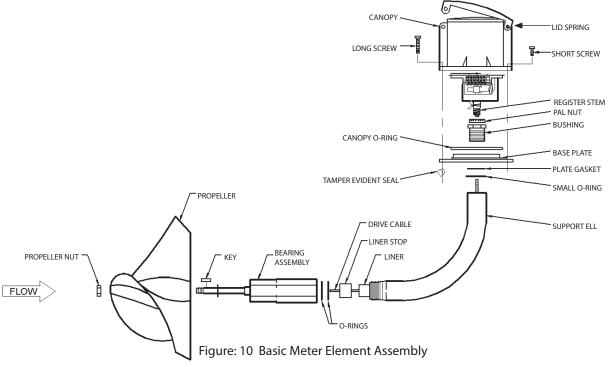
Special attention should be given to the installation direction of the Surface Water (SW) models of Mc Propeller meters, i.e. M0308SW. The M0300SW model meter is designed with the meter body turned 180 degrees from normal, a propeller installed nose-first on the bearing shaft, and a reverse flow style bearing assembly. This configuration allows the ell to curve with the flow, allowing grass or other debris to shed off with ease. Therefore, the proper installation of the M0300SW model meter appears "backwards".

4.0 METER CONSTRUCTION

Every Mc Propeller Meter is constructed and assembled at the McCrometer factory. The Mc Propeller Meter design been refined and improved over past thirty years. Quality assurance at each step of the production process ensures every meter to be accurate and reliable for years of service.

4.1 COMMON PARTS

Mc Propeller Meters have a simple design with a limited number of moving parts. Figure 10 shows labeled parts that are commonly shared among models. These components are described in detail on the following pages.



Irrigation Training and Research Center

4.2 PROPELLER

The propeller is, of course, a very important part of any propeller meter. Mc Propeller flowmeter propellers have the following characteristics that ensure accurate readings:

- Each propeller is wet calibrated in a NIST (National Institute of Standards and Technology) traceable laboratory and trimmed so that a standard ratio is achieved. This allows for easy parts replacement in the field without recalibration.
- Propellers have a curved shape called the helical lead. The helical lead governs the rotational speed for a given flow velocity.
- Propellers are as light as possible so that the momentum of the fluid is large in relation to the mass of the propeller. As a result, lower flows can be measured and changes in velocity can be detected more rapidly.
- The propeller is sufficiently rigid to retain its shape during high flow conditions throughout the life of the meter.
- Propellers are large in relationship to the line size. This is necessary to affect the whole flow, which both averages the velocity profile and reduces inaccuracy.
- The propeller covers and protects the bearings to reduce debris and other fluid particles from entering the bearing assembly.

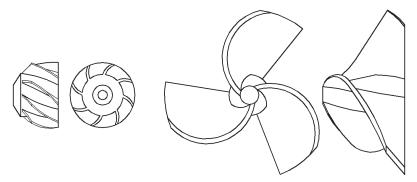
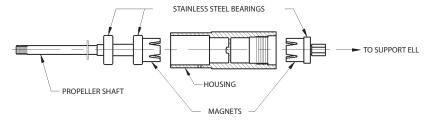


Figure: 11 Eight And Three Blade Propellers

4.3 BEARING ASSEMBLY

Two shielded stainless steel bearings support the propeller shaft and allow it to rotate freely. The propeller covers the bearings to help prevent loss of lubrication and entry of foreign particles found in the fluid. For higher than normal flows, a third over-run bearing can be added to the propeller shaft to increase the life of the meter.



Note: The bearing assembly should not be disassembled.

Figure: 12 Bearing Assembly

The bearing assembly housing prevents the process fluid from entering the drive assembly. The housing is manufactured with an integral diaphragm separating the fore and aft sections. Two permanent magnets on either side of the diaphragm transmit the rotation of the propeller through the diaphragm, while preventing fluid from entering the aft chamber. This magnetic drive makes an excellent and frictionless seal. This connection also allows the magnets to slip if a sudden surge hits the propeller. This slippage protects the meterhead from excess torque. The bearing assembly threads onto the drive assembly support and seals with two O-rings. The bearing is designed with the UltraShield which prevents debirs from entering the bearing assembly.

4.4 DRIVE ASSEMBLY

The drive assembly supports the bearing assembly and propeller and transmits propeller revolutions to the meterhead. A heavy walled stainless steel pipe cold formed into an ell (90 degree) shape supports both the bearing assembly and the propeller. This ell holds a steel cable encased in a protective vinyl liner. The cable extends outside the liner to attach to the aft of the bearing assembly and the bottom of the meterhead to transmit the revolutions of the propeller to the register.

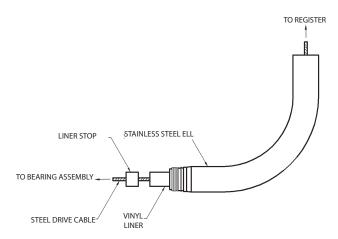


Figure: 13 Drive Assembly

4.5 METERHEAD

The meterhead consists of a register, canopy, and a base plate. The register transforms the speed of the propeller into both a totalizer and an instantaneous flow indicator. McCrometer's totalizers are six-digit, straight-reading type. Units of totalization include many standard units such as gallons, cubic feet, acre feet, and cubic meters.

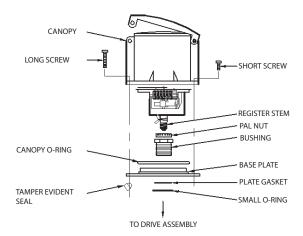


Figure: 14 Meterhead

The instantaneous flow indicator is of the mechanical magnetic cup design. Indicator units include gallons per minute, cubic feet per second, and liters per second, as well as many others. McCrometer offers this instantaneous flow indicator standard.

The entire register threads into a bushing which holds a die cast aluminum base plate to the ell where it connects with the drive cable. The base plate seals to the ell with an O-ring and gasket. A die cast aluminum canopy covers the register and attaches to the base plate with six screws. A stamped tamper evident seal attached to one of these screws ensures that the instrumentation of the register remains unaltered.

4.6 REGISTER EXTENSION

The L0780 Register Extension provides a means for relocating a McCrometer Propeller Flow Meter register to a height that improves access and protection of the register.

The L0780 Register Extension extends the register up from the top of the flow meter to a maximum height of 120′. The extension pipe material is 1″ Schedule 80, 304 stainless steel. The extension is provided as a kit, including drive cable and sealing hardware. All Mc Propeller flow meters can utilize the extension. The existing meter base plate, register and register canopy are reused.

Meter performance is typically unaffected by the addition of a register extension. Long extensions on small flow meters may require a higher minimum flow rate to operate properly. Maximum flow rates are unaffected. All other aspects of meter performance are unchanged by the extension. The stainless steel construction provides corrosion resistance and requires little maintenance once installed. The meter environmental protection rating of NEMA 4X is retained when the installation is properly installed and maintained.

Applications that would benefit from the installation of the L0780 Register Extension are:

- Flow meter locations subjected to temporary local flooding or washdown.
- Pits and other meter locations considered enclosed spaces.
- Meters installed below walkway level.
- Meters configured for higher than normal fluid temperatures.
- Electronic meters with digital registers or pulse transmitters can also use the extension for meter mounted or remote models.

The L0780 Register Extension is always mounted vertically on horizontally installed flow meters (see figure below). Meters subjected to pipe vibration should include appropriate anchoring of longer extensions. In areas with limited clearance over the meter, the overall height, including an open canopy lid, should be considered. Orientation of the register for easy viewing is accomplished when installing the register base plate after the extension is secured in place.

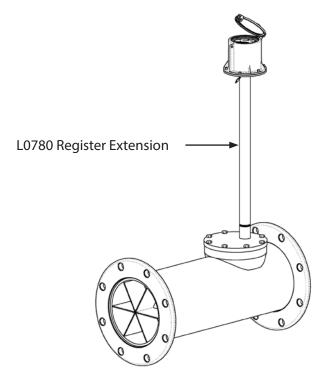


Figure: 15 L0780 Register Extension

5.0 MAINTENANCE AND TROUBLESHOOTING

McCrometer Inc. manufactures propeller meters to be as trouble free as possible. The first criterion in a successful meter application is that the meter is installed correctly. Please refer to the earlier Installation Instructions or call an authorized service representative or the factory to answer any questions.

5.1 OCCASIONAL INSPECTIONS

Mc Propeller Meters commonly operate for years with little or no routine maintenance. Occasional inspections should be conducted to listen and look for signs of mechanical wear and breakage, such as:

- Mc Propeller flowmeters operate very quietly. Any grinding or growling noises that can be detected are the first signs that mechanical failure is near.
- Visual cues are also valuable indicators. A once steady rate-of-flow indicator that has become erratic is usually indicative of something beginning to fail. Fogging visible through the lens would suggest a leak, either from the bearing assembly, or from an external seal.
- If there is doubt whether your rate of flow indicator is properly functioning, perform this simple test. Bring the flow through the meter to a relatively high, steady rate. Time a specific increment of the totalizer wheel. Each meter will require different but simple calculations to determine if your rate of flow indicator agrees with your totalizer. For assistance with this test, contact your local McCrometer representative or the factory.

5.2 TOOLS LIST

The following list includes tools needed to service and maintain Mc Propeller meters:

• Open or box end wrenches for top plate bolts (these vary with line size):

1/2" for 2", 2 1/2", and 3" line sizes 9/16" for 4", 6", and 8" line sizes 3/4" for 10" and 12" line sizes

Open or box end wrenches in the following sizes:

9/16" for propeller nut 1 3/8" for bearing assembly 15/16" for register pal nut

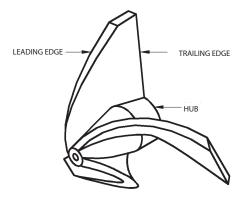
- 1 3/8" Deep Socket
- Standard, flat screwdriver with 6" reach for canopy screws
- Wire cutters for removing tamper evident seal
- Hammer
- Small wire brush for cleaning threads
- Clean cloth
- Loctite (Arontite Stock CE-805-Color Blue is suggested)
- Light machine oil

5.3 DISASSEMBLY AND INSPECTION PROCEDURE

1. REMOVE THE METER OR ELEMENT. Depending on the model, remove the entire meter or the metering element (propeller, bearing and drive assemblies, and meterhead) to access the propeller and bearing assembly.

WARNING: Do not remove the meter or top plate while the line is under pressure!

2. CHECK THE PROPELLER. Check the propeller for broken or damaged blades or foreign material hanging from it. Careful examination should be made of the propeller's trailing edge for damage. Some small nicks and abrasions to the leading edge of the blades are common and will not affect the accuracy of the meter. Mc Propeller's propeller blades are thick, resulting in a strong, stiff blade that does not change shape under normal operations.



The leading edge of the propeller can have small nicks and abbrasions without sacrificing accuracy. The trailing edge must be clean.

Figure: 16 Propeller Elements

- 3. CHECK THE BEARINGS. Check the condition of the bearings by grasping the propeller and trying to move it up and down and sideways. If the propeller has any amount of "play," then the bearing assembly should be replaced.
- 4. REMOVE THE PROPELLER. Remove the propeller by unscrewing the nut on the end of the propeller with a 9/16" wrench. Pull the propeller off the end of the bearing assembly shaft. Watch for the key, it may remain on the shaft, on the propeller, or fall free. If the propeller will not come off by hand, lightly tap the hub of the propeller with a hammer. Tap only the hub, since striking the trailing edge of the propeller blade may change the calibration of the meter. One or more stainless steel washers may be on the shaft. Leave these in place.
- 5. REMOVE THE BEARING ASSEMBLY. Remove the bearing assembly by unscrewing it with a 1 3/8" wrench. The drive cable may come out at this time. Set it aside for now. A deep 1-3/8" socket will be required for meters with fixed ells. After removing the bearing assembly, hold the shaft and spin the bearing housing. It should spin freely and smoothly. If it does not, it should be replaced.
- 6. CHECK. Check for damaged threads and clean the O-ring grooves.
- 7. REMOVE THE DRIVE CABLE. Now pull the drive cable out of the ell and inspect it for moisture, rust, wear, cracks, or breaks. If a cable appears worn, this is usually a symptom of another problem, such as moisture.
- 8. REMOVE THE REGISTER CANOPY. Remove the register canopy by unscrewing the five short screws and the one long screw with the tamper evident seal from around the base. Inspect the canopy and the base plate for signs of leaks.

IMPORTANT: Removing the tamper evident seal from a meter that is still under warranty could void the factory warranty.

- 9. REMOVE THE REGISTER HEAD. Remove the register head by loosening the pal nut on the stem of the register with a 15/16" wrench. Unscrew the whole register unit. Inspect the register for moisture. Look for a white chalky substance on the frame of the register that shows the register was wet. Turn the very bottom of the register stem several times. The register movement should turn freely. The first odometer wheel also should turn. If not, the register should be returned for repair or exchange. The purpose of the silica gel dry pack is to absorb moisture trapped during assembly. Replace the silica pack.
- 10. REMOVE THE CABLE LINER. If moisture exists inside the drive assembly, the liner should be taken out to dry. To remove the liner, use an item such as a large bolt to tap the liner down from the top. Tap enough to push the liner stop out from the bottom to allow the liner to be pulled free.

5.4 ORDERING REPLACEMENT PARTS

When ordering replacement parts, the meter's serial number is needed to ensure correct replacements. The serial number can be found on the register canopy lid. The number sequence should look similar to: 94-789-8. The first two digits are the year of manufacture, the second set of digits is the number of the meter, and the last set of digits is nominal line size. For meters manufactured before 1994, the last sets of digits are reversed. For specific meter part numbers, see the drawings of each meter type at the back of this Manual.

5.5 REASSEMBLY PROCEDURE

With the problem found and the correct replacement parts collected, the meter must be correctly reassembled to ensure trouble-free service in the future.

- 1. CLEAN ALL PARTS. As with any mechanical device, all of the parts that are going to be reused must be clean and free of dust and dirt. Take some time and make sure these parts are ready to be used.
- 2. REPLACE THE CABLE LINER. If the cable liner was removed, replace it now. Push the cable liner into the ell from the bottom up to the base plate. Replace the liner stop.
- 3. CLEAN THE LINER. Blow out any dirt that may be trapped inside the liner.
- 4. REPLACE THE BEARING ASSEMBLY. With a drop of light machine oil on your finger, lubricate the small o-rings on the end of the threaded ell. (Do not get oil on the threads of ell.) Place two drops of Loctite on the threads of the ell. Thread the bearing assembly on the ell and tighten with a wrench or a special bearing tool. Be careful not to cross thread the assembly and only snug the bearing assembly with the wrench. Extra care should be exercised in assuring that the parts are clean and the o-rings have a good sealing area.
- 5. REPLACE THE PROPELLER. Make sure the washers on the propeller shaft are in place. Slide the propeller over the shaft. Align the shaft and propeller keyways and insert the key. You may need to use a screw driver to push the key to the fully engaged position. Apply a small amount of Loctite to the threads of the nut and tighten to a good snug fit, but not as tight as possible.

IMPORTANT: Use only two drops of Loctite. Too much Loctite can cause the aft bearing to seize.

- 6. REPLACE THE DRIVE CABLE. With a clean cloth, wipe off any dirt or dust from the drive cable. Apply a small amount of light machine oil to the cable and insert it all the way into the ell. To engage the cable, slowly turn the propeller as you gently push on the cable. After you are satisfied that the cable is in the bearing assembly as far as possible, check the height of the cable in relationship to the top of the mounting plate bushing. The cable should be within 1/4 of an inch (plus or minus) from the top of the bushing. If not, it is the wrong cable or the cable is not fully seated into the bearing assembly.
- 7. REPLACE THE REGISTER HEAD. Thread the pal nut, with the open face up, onto the stem on the bottom of the register. The nut should be at least halfway up the threads. Place the register stem on the drive cable and screw it into the mounting plate bushing. The register should be screwed down far enough that the cable is well into the register stem, but not far enough to bind the cable. Face the register the desired direction and tighten the pal nut to lock the register into position.
- 8. CHECK. Spin the propeller to check that the rate of flow indicator and totalizer are engaged. Listen for any clicking or grinding noises. The meter should turn quietly.

- 9. REPLACE THE REGISTER CANOPY. Install the large o-ring and flat gasket onto the base plate. Use a small amount of light oil to lubricate the o-ring and place the register canopy down over it. Push down until the o-ring bottoms out against the base plate. Replace the six screws and lightly snug them.
- 10. RE-INSTALL THE FLOWMETER. Re-install the flowmeter. Before pressurizing the system, make sure all connections are properly secured. As an obvious general safety consideration, maintain a safe and prudent distance from the meter when the system is to be started. After the system restarts, the indicator should be smooth and the meter quiet.

6.0 TECHNICAL SPECIFICATIONS

ACCURACY/REPEATABILITY: ±2% of reading guaranteed throughout full range; ±1% over reduced range;

Repeatability 0.25% or better

MAXIMUM TEMPERATURE: (Standard Construction) 160°F constant

PRESSURE RATING: 150 psi

MATERIALS:

BEARING ASSEMBLY:

Impeller shaft is 316 stainless steel.
Ball bearings are 440C stainless steel.
MAGNETS: (Permanent type) Alnico

BEARING HOUSING: Brass; Stainless Steel optional

SADDLE: 304 stainless steel construction

REGISTER: An instantaneous flowrate indicator and six-digit straight-reading totalizer are standard. The register is hermetically sealed within a die cast aluminum case. This protective housing includes a domed acrylic lens and hinged lens cover with locking hasp.

IMPELLER: Impellers are manufactured of high-impact plastic, retaining their shape and accuracy over the life

of the meter. High temperature impeller is optional.

OPTIONS

- Saddle can be constructed to fit any outside diameter pipe dimensions, including metric sizes
- Can be used on a variety of pipe materials such as steel, plastic, cast iron, cement or asbestos cement
- Register extension
- All stainless steel bearing assembly
- High temperature construction
- Marathon bearing assembly for higher than normal flowrates
- FlowCom Electronic Register
- A complete line of flow recording / control instrumentation including transmitters and flow computers
- Blank repair saddle
- Vanes
- Flow straighteners
- Canopy Boot
- Lid spri

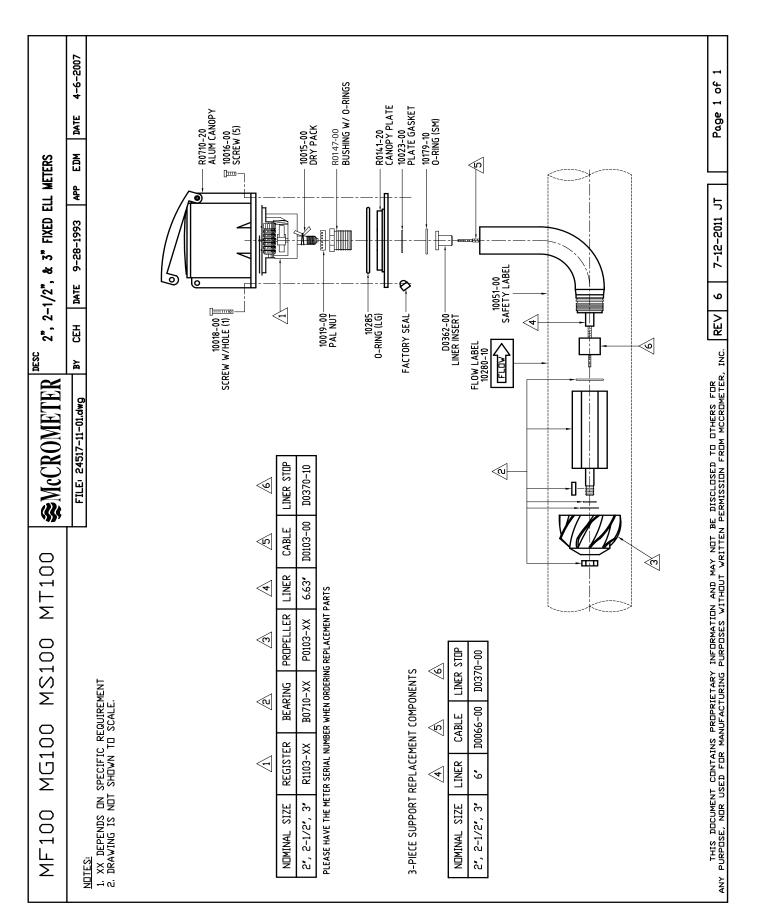
TECHNICAL SUPPORT

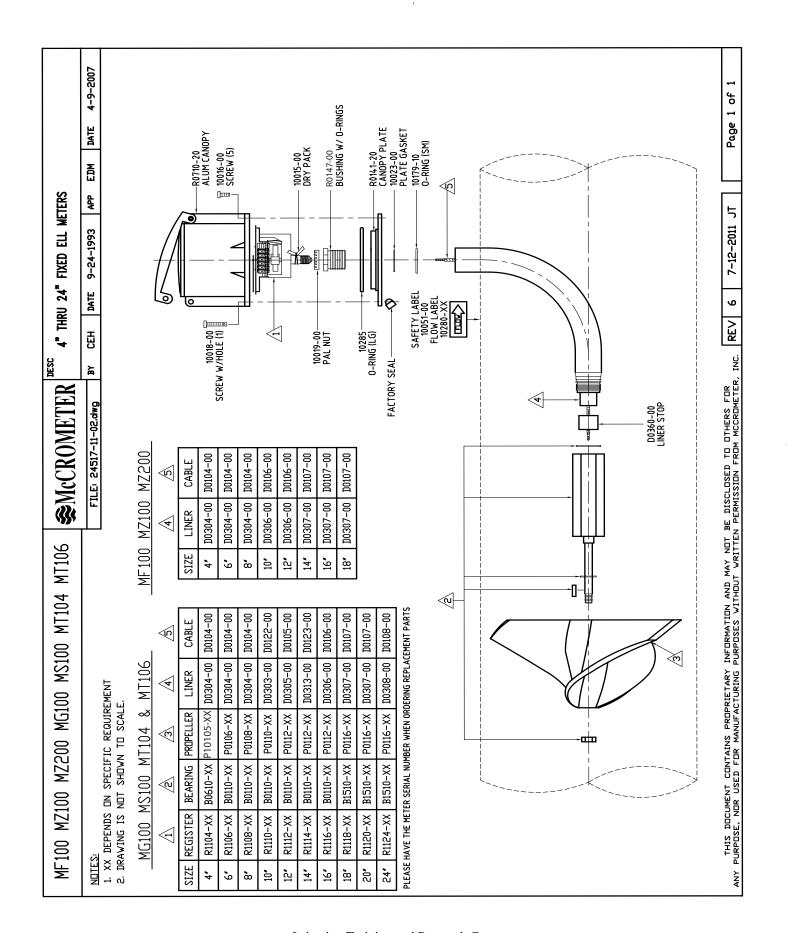
For technical assistance, please contact your authorized service representative or the factory at:

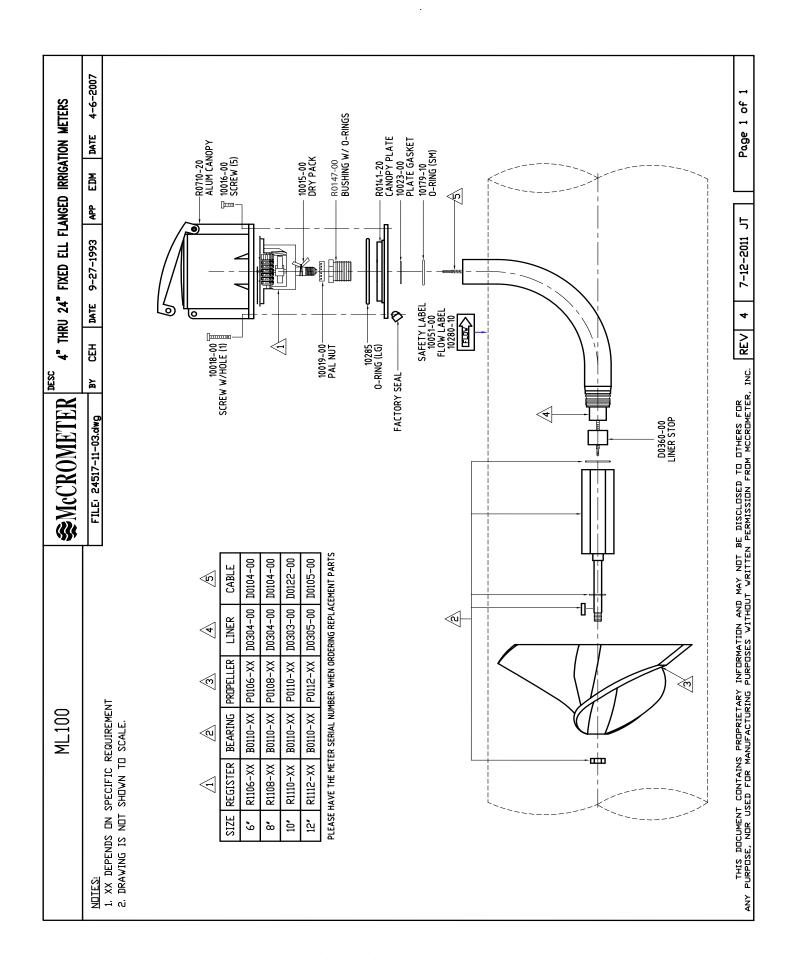
McCrometer Inc. 3255 W. Stetson Avenue Hemet, CA 92545

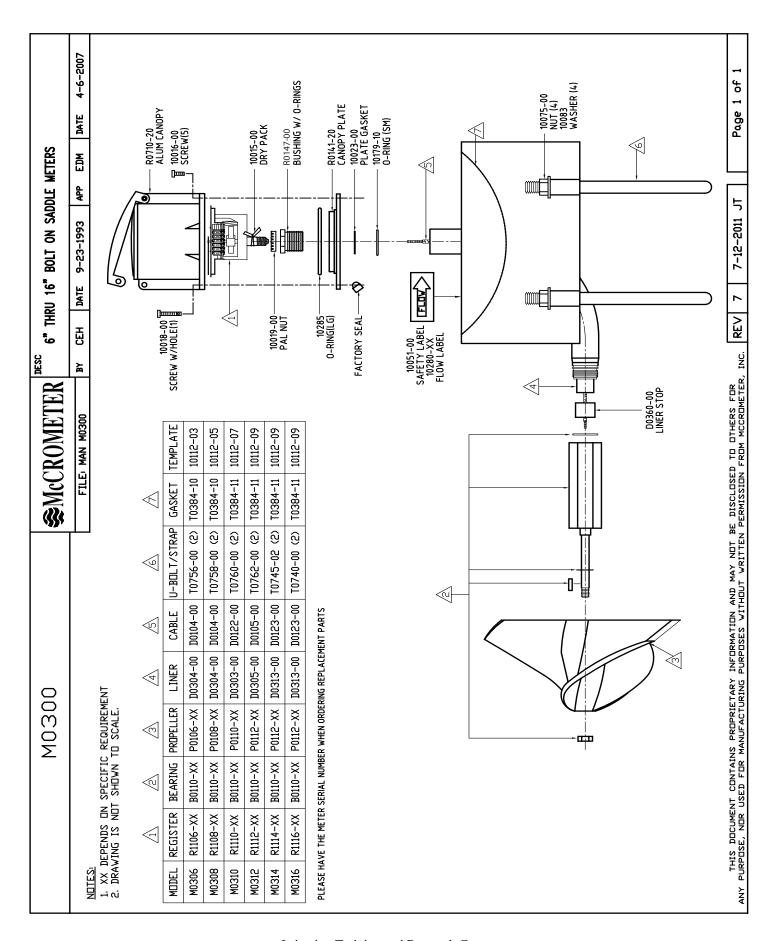
PHONE: (951) 652-6811 FAX: (951) 652-3078

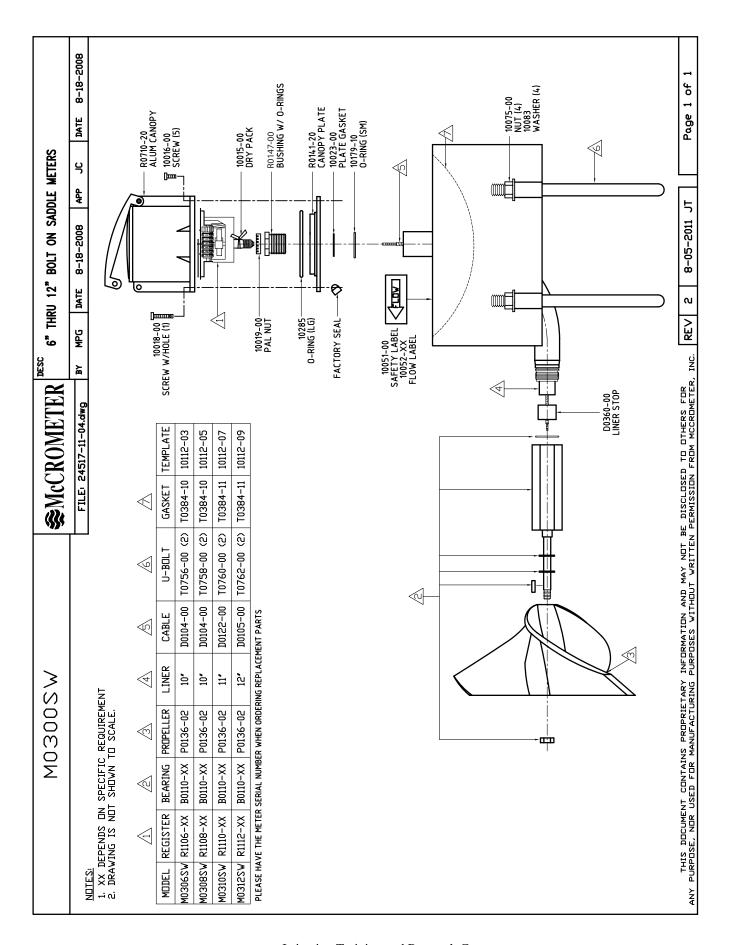
Hours: 8 a.m. - 4 p.m. PT, Mon-Fri

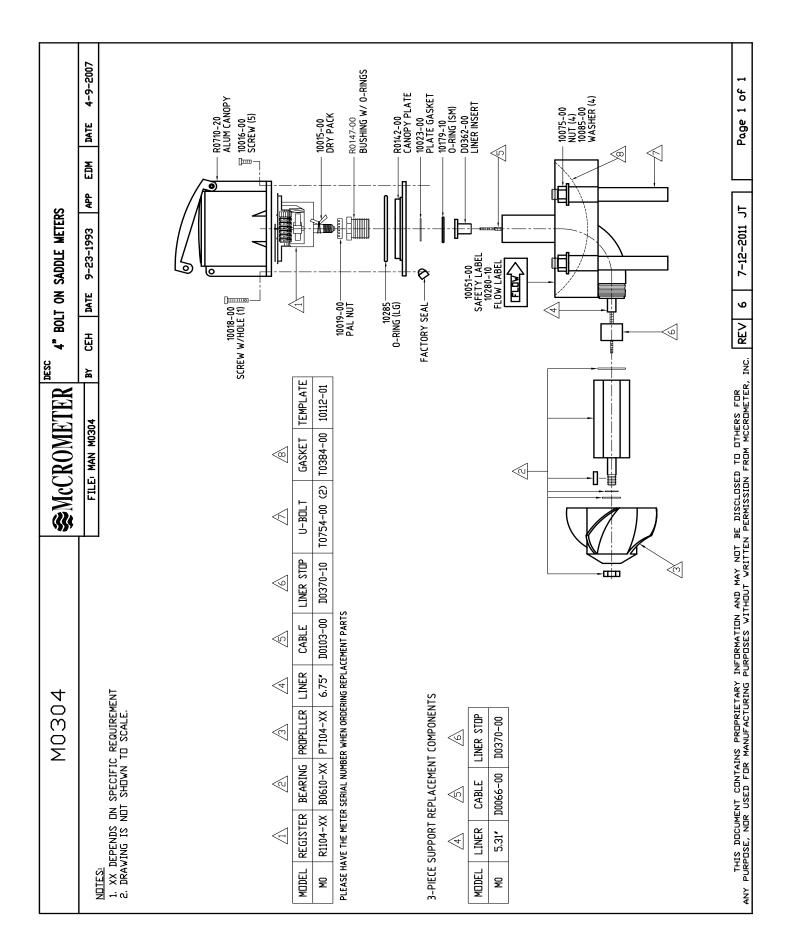


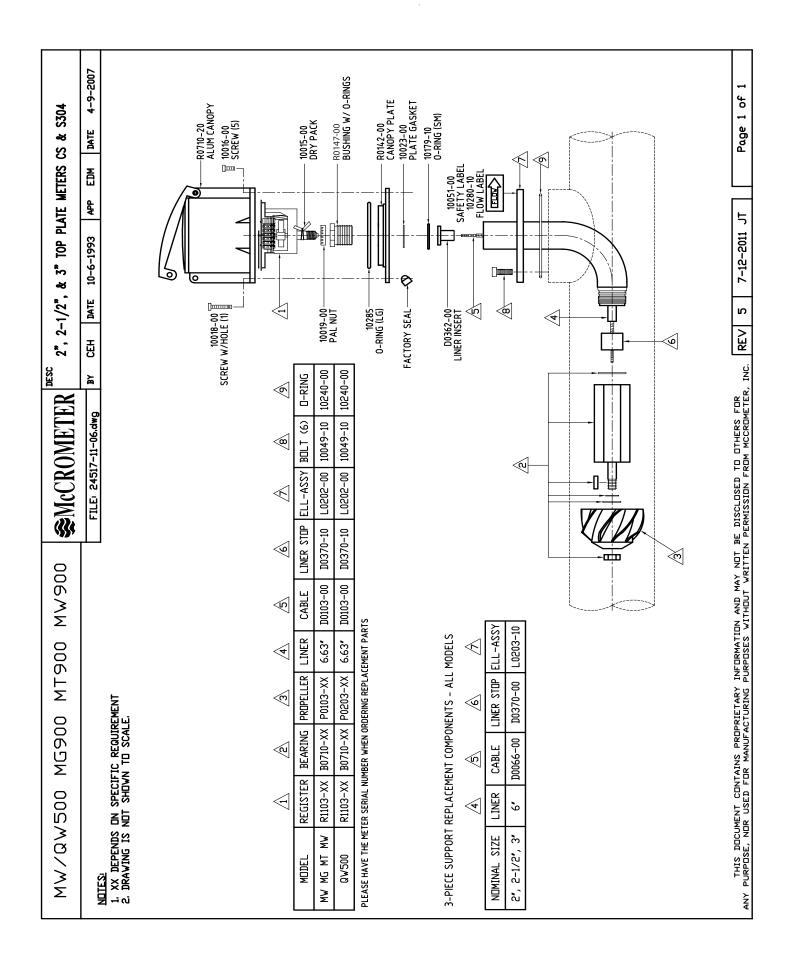


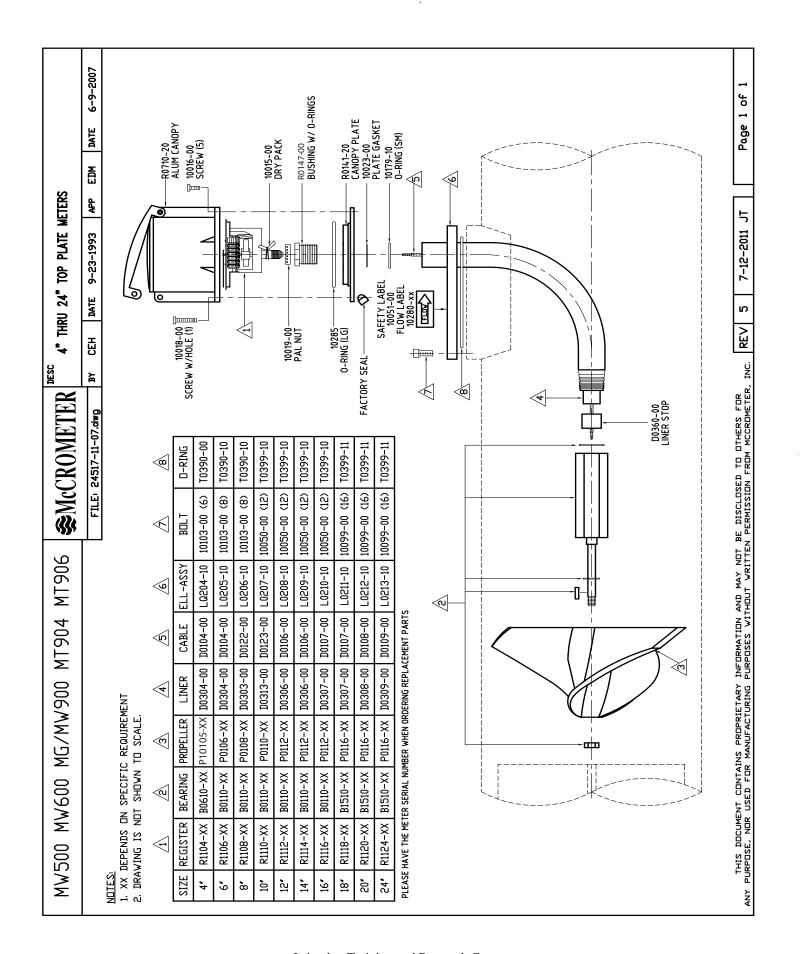


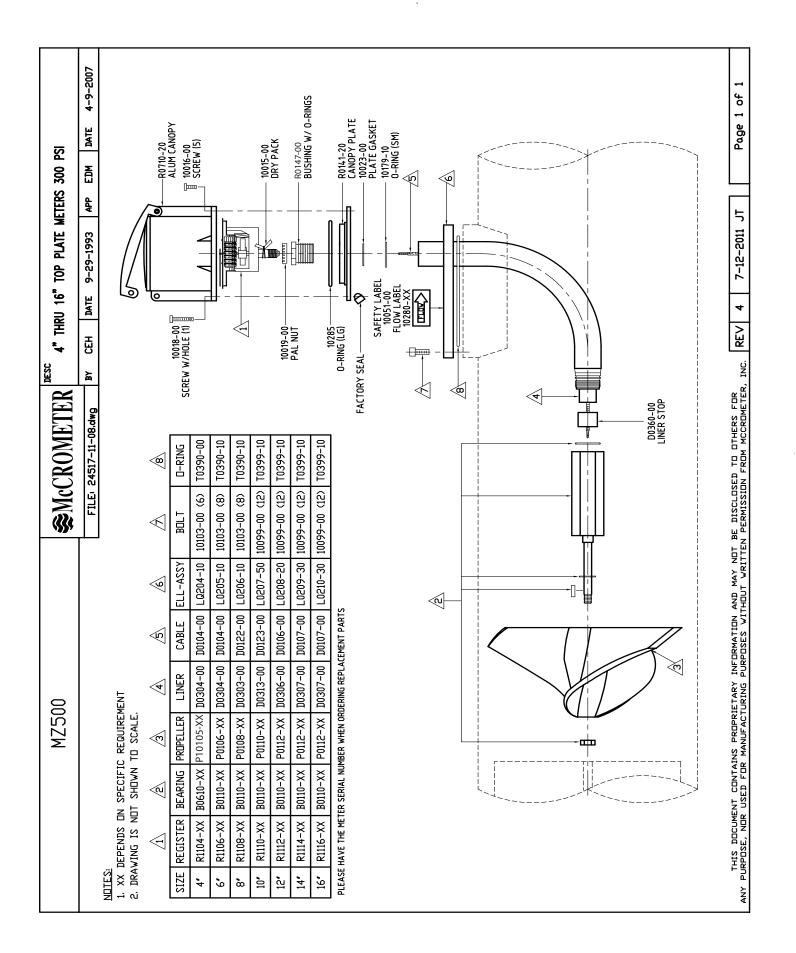


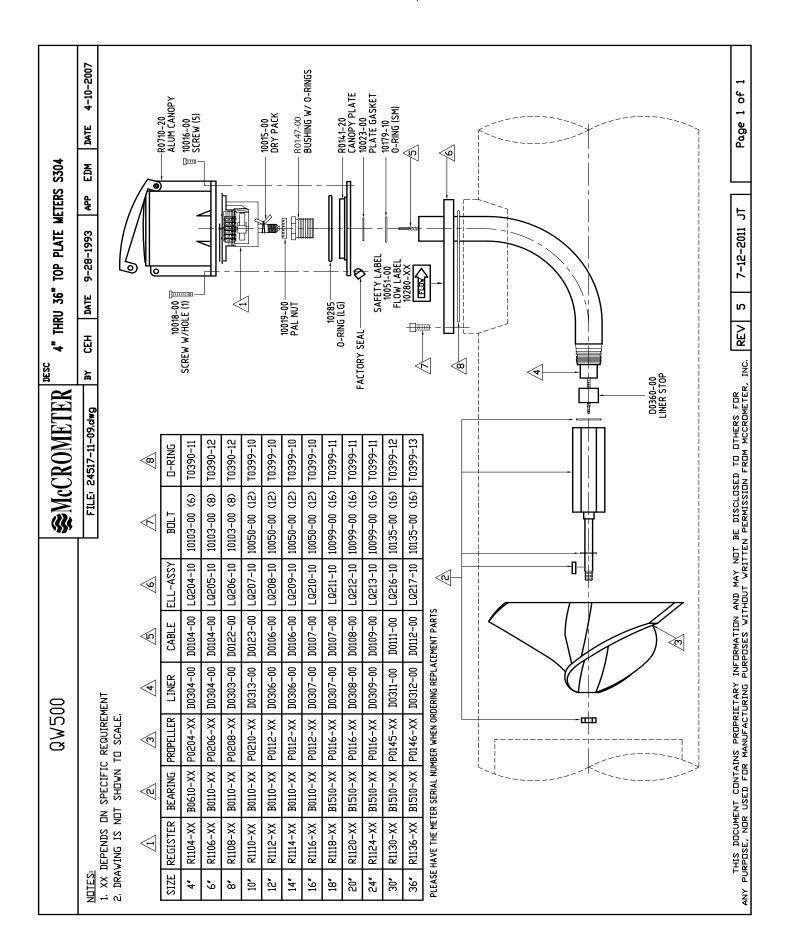


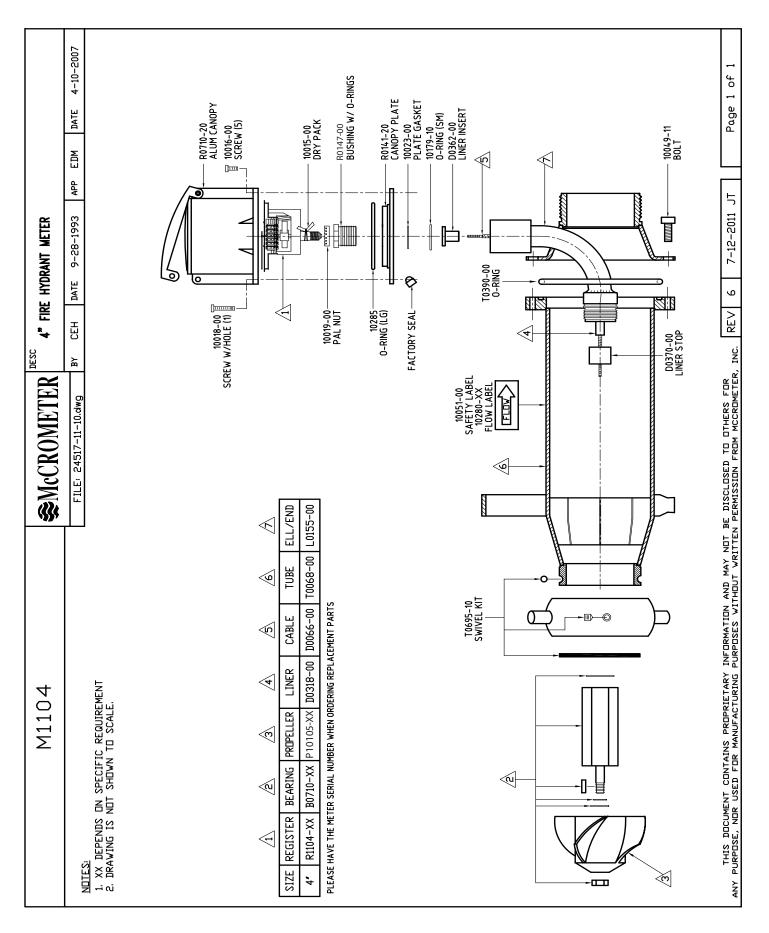


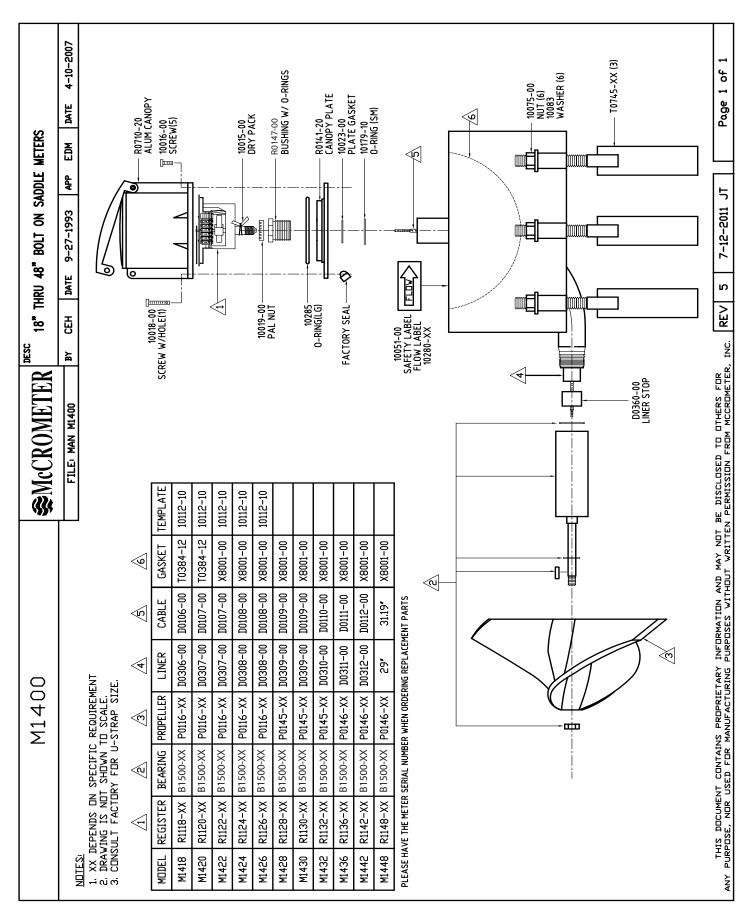


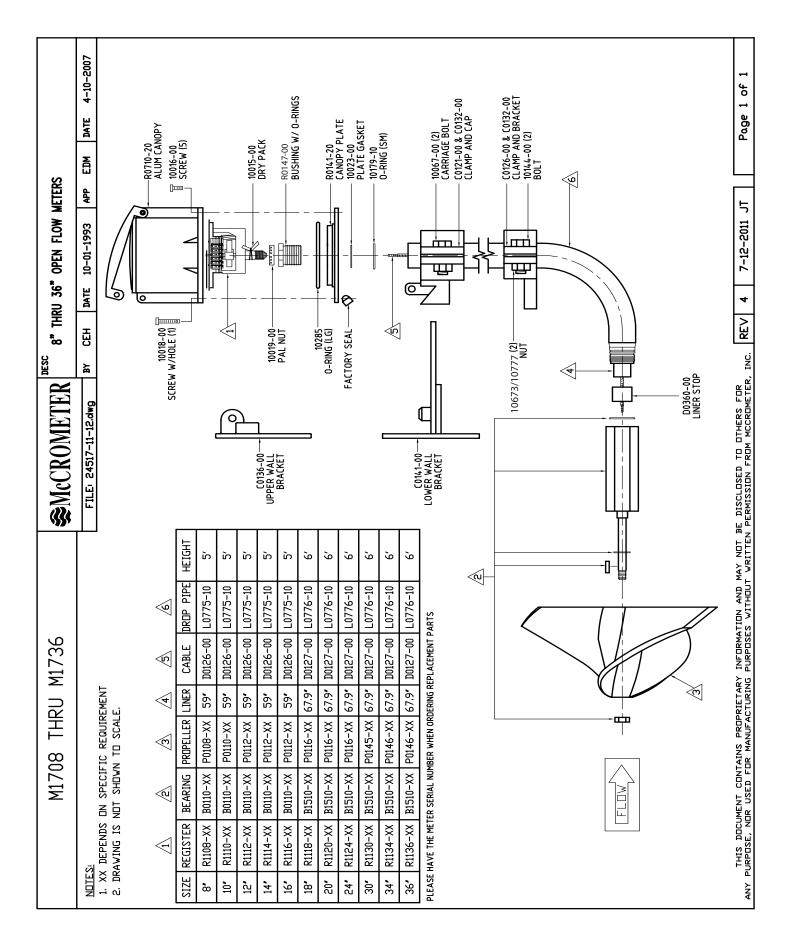


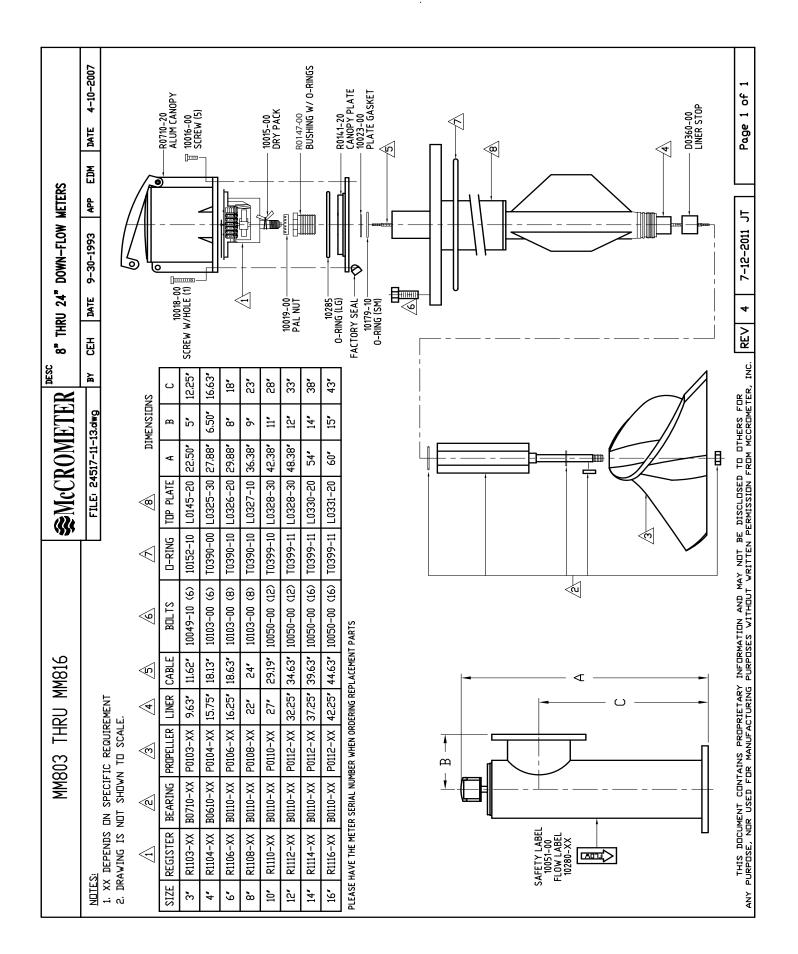


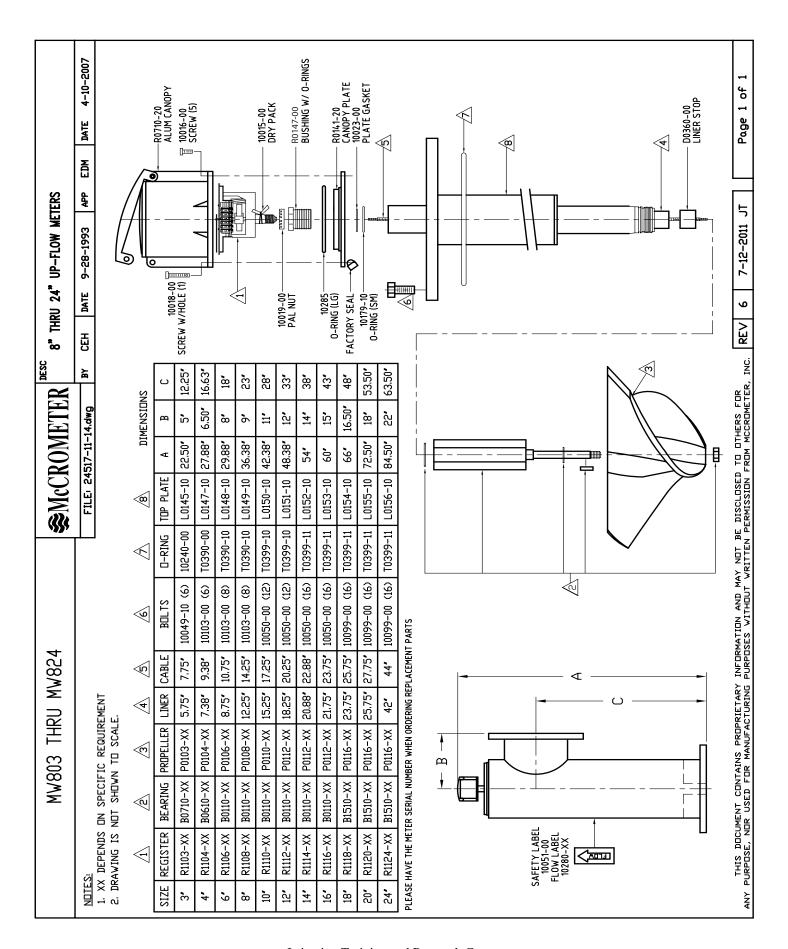












WARRANTY

This Warranty shall apply to and be limited to the original purchaser consumer of any McCrometer product. Meters or instruments defective because of faulty material or workmanship will be repaired or replaced, at the option of McCrometer Inc., free of charge, FOB the factory in Hemet, California, within a period of one (1) year from the date of delivery.

Repairs or modifications by others than McCrometer Inc. or their authorized representatives shall render this Warranty null and void in the event that factory examination reveals that such repair or modification was detrimental to the meter or instrument. Any deviations from the factory calibration require notification in writing to McCrometer Inc. of such recalibrations or this Warranty shall be voided.

In case of a claim under this Warranty, the claimant is instructed to contact McCrometer Inc., 3255 W. Stetson Ave., Hemet, California 92545, and to provide an identification or description of the meter or instrument, the date of delivery, and the nature of the problem.

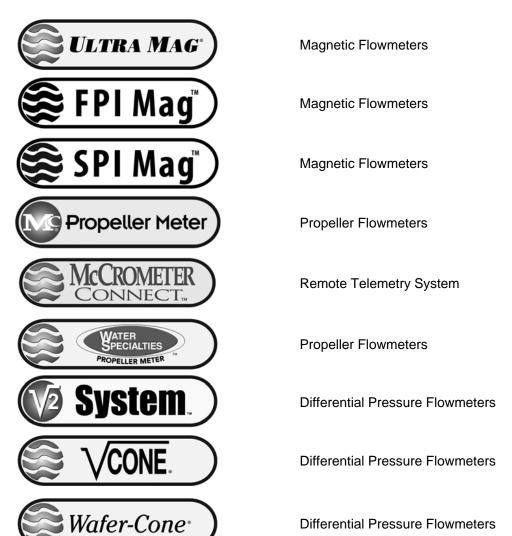
The Warranty provided above is the only Warranty made by McCrometer Inc. with respect to its products or any parts thereof and is made expressly in lieu of any other warranties, by course of dealing, usages of trade or otherwise, expressed or implied, including but not limited to any implied warranties of fitness for any particular purpose or of merchantability under the uniform commercial code. It is agreed this Warranty is in lieu of and buyer hereby waives all other warranties, guarantees or liabilities arising by law or otherwise. Seller shall not incur any other obligations or liabilities or be liable to buyer, or any customer of buyer for any anticipated or lost profits, incidental or consequential damages, or any other losses or expenses incurred by reason of the purchase, installation, repair, use or misuse by buyer or third parties of its products (including any parts repaired or replaced); and seller does not authorize any person to assume for seller any other liability in connection with the products or parts thereof. This Warranty cannot be extended, altered or varied except by a written instrument signed by seller and buyer.

This Warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

McCrometer Inc. reserves the right to make improvements and repairs on product components which are beyond the Warranty period at the manufacturer's option and expense, without obligation to renew the expired Warranty on the components or on the entire unit. Due to the rapid advancement of meter design technology, McCrometer Inc. reserves the right to make improvements in design and material without prior notice to the trade.

All sales and all agreement in relation to sales shall be deemed made at the manufacturer's place of business in Hemet, California and any dispute arising from any sale or agreement shall be interpreted under the laws of the State of California

OTHER McCROMETER PRODUCTS INCLUDE:



Copyright © 1997-2013 McCrometer, Inc. All printed material should not be changed or altered without permission of McCrometer. Any published technical data and instructions are subject to change without notice. Contact your McCrometer representative for current technical data and instructions. Mc° of Mc Propeller is a registered trademark of McCrometer, Inc.





CONFIGURATION SHEET

M0300F FLOW METER FS100 INSERTION FLOW STRAIGHTENER

DESCRIPTION:

The Mc SpaceSaver System combines our breakthrough flow straightening technology with a self-cleaning Mc Propeller meter design that virtually eliminates the upstream/downstream straight pipe runs. This advanced design delivers highly accurate liquid flow measurement in a rugged space-saving design that reduces installation costs, offers long-life and requires minimal maintenance.

SPECIFICATIONS:

Min. Up Stream

Straight Run: 1.5 pipe diameters minimum (measured from propeller)

Acceptable

Installation Effects: Chemigation Valves

In plane elbows
Out of plane elbows

Fully Open Butterfly and Gate Valves

Sizes: 6" & 8" Nominal and OD pipe.

Customer Pipe wall: Metal ≥0.08, <0.5

Plastic ≥0.25, <0.5

For M0300F

Installation: Inserted into pipeline through rectangular hole and locked in place by a single $\frac{1}{2}$ or $\frac{5}{8}$ inch

bolt. The M0300F flowmeter is designed to cover the rectangular hole used to install the flow

straightener.

For M0300

Inserted into pipeline through open end of pipeline and locked in place by a single \(^{1}/_{2}\) or \(^{5}/_{8}\) inch

bolt.

Installation Bolt: Stainless steel bolt with dual seal.

Body M0300F: Fabricated 304 stainless steel saddle with stainless steel drop pipe is supplied with: brass

bearing housing, stainless steel bearings, polypropylene impeller, magnetic drive,

instantaneous flow indicator, straight-reading six-digit totalizer, and flat neoprene gasket.

Body FS100: 304 Stainless Steel.

Exterior: Glass bead blasted.

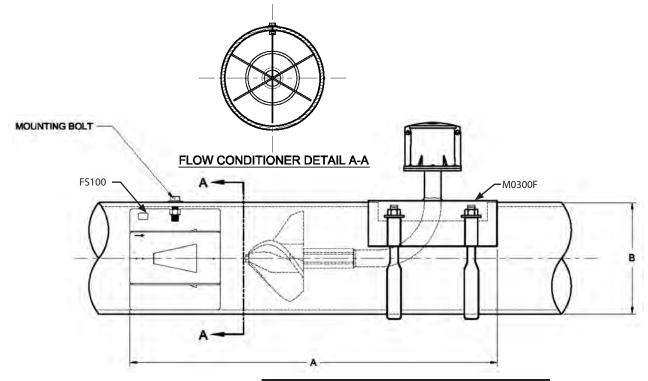
Pressure Rating: 150 psi max.





CONFIGURATION SHEET

M0300F FLOW METER FS100 INSERTION FLOW STRAIGHTENER



	MO300F FLOW METER MODELS							
M0300F Model	M0306F	M0306F	M0306F	M0306F	M0308F	M0308F	M0308F	M0308F
	FS100 FLOW STRAIGHTENER MODELS							
FS100 Model	FS106-1	FS106-2	FS106-3	FS106-4	FS108-1	FS108-2	FS108-3	FS108-4
Pipe OD (B)	6.625	6.625	6.0	6.0	8.625	8.625	8.0	8.0
Wall Thickness Range	0.080 to 0.199	0.200 to 0.320	0.080 to 0.156	0.157 to 0.260	0.080 to 0.209	0.210 to 0.340	0.080 to 0.161	0.162 to 0.260
'A' with M03xxF Flowmeter	22	22	22	22	28-5/8	28-5/8	28-5/8	28-5/8
'A' with M03xx Flowmeter	26-1/4	26-1/4	26-1/4	26-1/4	31-1/8	31-1/8	31-1/8	31-1/8
FS100 Shipping Wt. (lbs)	3.3	3.2	3	2.9	5.9	5.7	5.5	5.3
M0300F Shipping Wt. (lbs)	22	22	22	22	26	26	26	26

Notes:

- 1. Legal Protection Pending.
- 2. M0300F flowmeter, shown in diagram above, provided separately.
- 3. Upon request: special pipe diameter and special wall thickness.
- 4. Select the appropriate M0300 Flow Meter and FS100 Flow Straightener for a complete Mc SpaceSaver system.





The tight spot solution that saves money



McSpaceSaver: The tig

Conserve water and **save** money with the **high accuracy** flow meter that fits almost anywhere

Developed with a breakthrough design that combines advanced flow conditioning and propeller meter technologies, the Mc SpaceSaver™ Flow Meter from McCrometer delivers superior accuracy, lower installation costs and long-life with low maintenance. It's the ideal money-saving flow measurement solution to help farmers, water district engineers and irrigation dealers cope with the latest water metering programs.

For more than 50-years, McCrometer has been the leader in developing innovative flow measurement solutions designed specifically for rugged agricultural and turf irrigation operations. The first McCrometer flow meters were designed for farmers by farmers who knew first-hand the challenge of bringing water reliably and efficiently to crops without wasting a drop or a nickel.

How flow conditioning works

The Mc SpaceSaver Flow Meter operates over a wide 15:1 flow range and supports the most popular 6 and

8-inch irrigation line sizes. It is designed

with a built-in flow straightener assembly that greatly enhances measurement performance. As the upstream flow in an irrigation line approaches the Mc SpaceSaver, its built-in straightener mixes and shapes the liquid flow into a smooth

stream before it reaches the impeller to optimize

measurement performance.

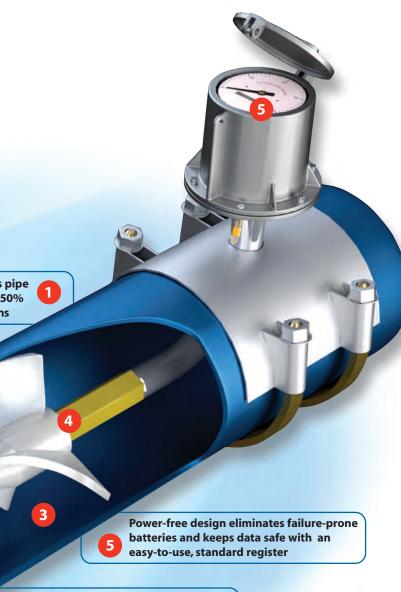
for a tight fit in crowded installation **Built-in flow conditioning and proven** propeller meter technology deliver high accuracy of $\pm 2\%$ with ± 0.25 repeatability Customer supplied pipe, tube shown for illustration Reduced straight-run eliminate piping mate labor to cut total inst

Unique space-saving design shrinks

straight-run requirements by up to

Irrigation Training and Research Center E-88

ght spot meter



Advanced propeller meter prevents solids build-up for trouble-free performance in rugged agricultural and turf operations

requirements erial and extra allation costs

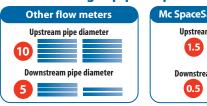
The result is greater flow measurement accuracy, in real world installations of up to ± 2 percent, with ± 0.25 percent repeatability. The Mc SpaceSaver's built-in flow straightener allows it to be installed in close proximity to chemigation, butterfly and gate valves, or out-of-plane elbows, and reducers with excellent measurement stability -- compared to mag and other flow meters, which specify accuracy based on ideal laboratory flow conditions.

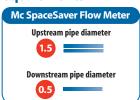
The Mc SpaceSaver is designed with heavy-duty propeller meter technology for rugged agricultural service. Featuring a self-cleaning propeller design, the Mc SpaceSaver prevents the build-up of solids. Its unique magnetic coupling system keeps the register drive isolated from the flow while permitting unrestricted movement of the impeller. Free rotation of the impeller also is assured by factory-lubricated stainless steel bearings.

The straight story on straight runs

The advanced Mc SpaceSaver from McCrometer is a total system solution, featuring a built-in flow straightener to condition water flow, which virtually eliminates the upstream/downstream straight pipe runs typically required in existing or new flow meter applications.

Straight pipe requirements





Requiring only a minimum of 1.5 straight pipe diameters upstream and 0.5 downstream, the Mc SpaceSaver reduces typical installation piping and labor costs by more than 50 percent, which makes it the right Irrigation Training and Research Center fit for both retrofit and in brand new installations.

Flow rate indicator and totalized flow output

The Mc SpaceSaver Flow Meter comes with a standard instantaneous flow rate indicator and a straight-reading totalizer. Unlike mag and other types of flow meters, the Mc SpaceSaver

requires no electric power to operate. With no Lithium batteries to fail in extreme heat or cold or humidity, your valuable flow data is continuously available and safe via the Mc SpaceSaver's standard register.







The versatile water measurement solution

- Agriculture irrigation
- Turf irrigation
- Drip and sprinkler systems
- Greenhouse growers
- Pumping stations
- Canal laterals
- Golf course
- Park management
- Center pivot systems

Mc SpaceSaver Specifications

Mc SpaceSaver consists of: MO300F Flow Meter and FS100 Flow Straightener

Minimum Upstream Straight Run: 1.5 pipe diameter minimum (measured from propeller)

Acceptable Installation Effects: Chemigation Valves, in plane elbows, out of plane elbows, fully open butterfly and gate valves

Sizes: 6" and 8" nominal and OD pipe

Customer Pipe Wall: Metal: ≥0.08, <0.5 **Plastic:** ≥0.25, <0.5

For M0300F Installation: Inserted into pipeline through rectangular hole and locked in place by a single 1/2 or 5/8 inch bolt. The M0300F Flow Meter is designed to cover the rectangular hole used to install the flow straightener.

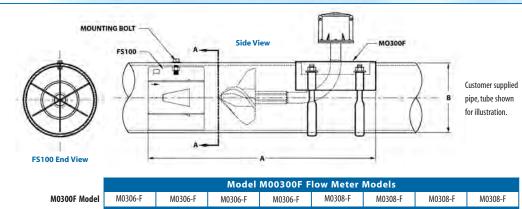
For Existing M0300 Installation: Inserted into pipeline through open end of pipeline and locked in place by a single 1/2 or 5/8 inch bolt.

Installation Bolt: Stainless steel with dual seal.

Body M0300F: Fabrication 304 stainless steel saddle with stainless steel drop pipe is supplied with: brass bearing housing, stainless steel bearings, polypropylene impeller, magnetic drive, instantaneous flow indicator, straight-reading six-digit totalizer, and flat neoprene gasket.

Body FS100: 304 stainless steel **Exterior:** Glass bead blasted

Pressure Rating: 150 psi maximum



M0300F Model	M0306-F	M0306-F	M0306-F	M0306-F	M0308-F	M0308-F	M0308-F	M0308-F
	FS100 Flow Straightener Models							
FS100 Model	FS106-1	FS106-2	FS106-3	FS106-4	FS108-1	FS108-2	FS108-3	FS108-4
Pipe OD (B)	6.625	6.625	6.0	6.0	8.625	8.625	8.0	8.0
Wall Thickness Range	0.08-0.199	0.2-0.32	0.8-0.156	0.157-0.260	0.08-0.209	0.21-0.34	0.08-0.161	0.162-0.260
'A' with M030xF Flow Meter	22	22	22	22	28 5/8	28 5/8	28 5/8	28 5/8
'A' with M030x Flow Meter	26 1/4	26 1/4	26 1/4	26 1/4	31 1/8	31 1/8	31 1/8	31 1/8
FS100 Shipping Wt. (lbs.)		3.2	3.0	2.9	5.9	5.7	5.5	5.3
M0300F Shipping Wt. (lbs.)	22	22	22	22	26	26	26	26

Notes: 1. Legal protection pending; 2. M0300F Flow Meter, shown in diagram above, provided separately; 3. Upon request: special pipe diameter and special wall thickness; 4. Select the appropriate M0300F and F5100 for a complete Mc SpaceSaver system; 5. Refer to 24510-68 McSpaceSaver configuration sheet for additional sizes.



mccrometer.com

3255 West Stetson Avenue, Hemet, California 92545 USA
Specialists for 50 lears Training and Research Center 951-652-3078
E-90

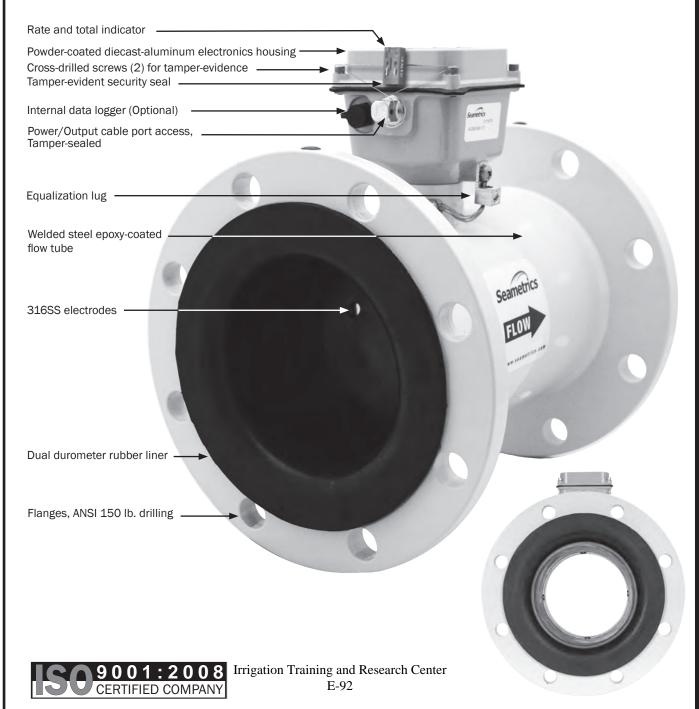
Appendix DSeametrics Ag2000 Meter

AG2000



IRRIGATION MAGMETER INSTRUCTIONS

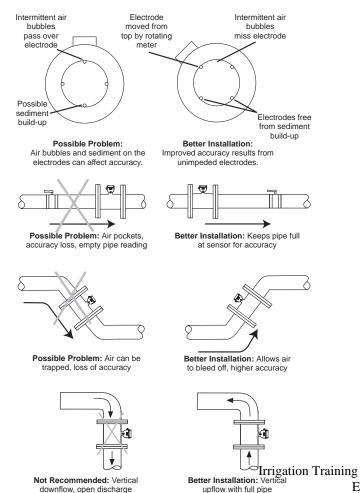
FEATURES



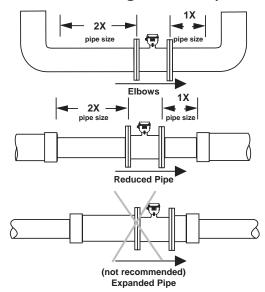
Tamper-Evident Seal. The battery-powered AG2000 has a seal wire to protect against unauthorized access. The seal can be broken to change units of measure, replace the battery pack, or to field-install a power/output cable (see page 4). **CAUTION**: If water usage regulation is in effect, only a person authorized by your regulatory agency should break the seal wire, and replace it when finished.

Positioning the Meter. These meters can be installed horizontally, vertically, and in any radial position. If sludge accumulation is possible, vertical or horizontal placement with the register at a 45° angle is recommended. Using a check valve on the upstream side of the meter, and/or an air vent (vacuum relief valve) in the same, unobstructed run of pipe as the meter, is required in any installation where the meter may be exposed to suction when the system is not in normal operation. Suction can cause damage to the liner. Liner damage caused by suction, without the use of a check valve and/or air vent, may void the warranty.

Full Pipe Recommendations. All magmeters require a method for determining that the pipe is empty, to prevent false reading. This meter is designed to go to zero reading if one or more electrodes is exposed. For highest accuracy, install the meter so that the pipe will be full when there is flow. If air bubbles may be present in the pipe, rotate the meter by one flange hole to position the control housing at a 45° angle. See mounting diagrams below.



Straight Pipe Recommendations. See the diagrams below for manufacturers' recommendations. Local regulations may vary, confirm before installing to assure compliance.



Note: See Technical Bulletin 'Piping Configurations for AG2000 Magmeters' at www.seametrics.com for additional configuration information.

Chemigation Applications. Magmeters in chemigation applications must be placed either upstream of the chemical injection line, or far enough downstream for complete mixing to occur before the solution reaches the meter. Proper placement prevents spikes and drops in readings that result when fluids of different conductivity pass through the meter. (For more information, refer to the technical bulletin on the Seametrics website Downloads page.)

Fittings and Flanges. The AG2000 flanges have standard ANSI 150 lb. drilling, and should match up with any other ANSI 150 lb. flange. **IMPORTANT:** Piping protruding beyond welded-on flange faces may damage meter sealing surfaces.

Temperature. These flow sensors are recommended for operating temperatures of 10° to 130° F (-12° to 54° C) and non-operating temperatures of -40° to 158° F (-40° to 70° C).

Calibration. The AG2000 is factory calibrated and cannot be recalibrated in the field.

Protecting the Meter. A weather guard is recommended (Seametrics part #31388) for environmental protection.

Conductivity. The AG2000 requires media with >20 microSiemens/cm of conductivity.

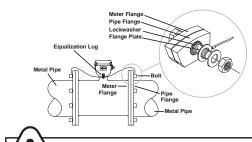
FLOW RANGE

	Minimum	Maximum
4"	12 gal/min (.75 liter/sec)	1,000 gal/min (63 liter/sec)
6"	32 gal/min (2 liter/sec)	2,400 gal/min (151 liter/sec)
8"	60 gal/min (4 liter/sec)	4,400 gal/min (278 liter/sec)
and Re sea -93	irch Center 95 gal/min (6 liter/sec)	7,000 gal/min (442 liter/sec)

EQUALIZATION and GROUNDING

Metal Pipe Installations. To equalize the electric potential of the fluid, the meter, and the surrounding pipe, secure the flange plates, factory-installed on equalization lug, to both pipe flanges at one of the bolt holes. Be sure the lockwasher provided fits between the pipe flange and the flange plate.

> **CAUTION:** Grounding rings are recommended for installations that could damage the flange



Equalization Diagram

Run wire from equalization lug to both pipe flanges; secure flange plates under bolt heads as shown.



Grounding Ring Part Numbers (Does not apply to 3" meter)

> = 100876 = 100877

= 10087810" = 100879

12" = 103288

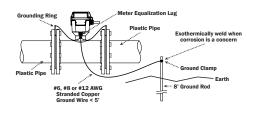


WARNING: ELECTRICAL SHOCK HAZARD

When the AG2000 is installed in a plastic piping system, or when externally powered, it is very important to ground the meter to avoid electrical shock hazard. Failure to do so can result in

electrocution.

Plastic Pipe Installations. When the AG2000 is installed in a plastic piping system, grounding rings may be required, especially in the presence of electrical interference sources such as VFD pump drives. As shown in the diagram below, the equalization wires should then be connected to the grounding ring tabs instead of the flange bolts as in metal piping installations. Where lightning is a threat, or in severe electrical environments, an optional connection to a nearby equipment ground or ground rod may be advisable.



Battery Power (standard). The AG2000 is powered by a nonrechargeable battery pack with standard battery life of 2.5 years; 5 years with extended battery life (EBL) option. Actual lifespan will vary from application to application, depending on the duty cycle (the High Frequency option, if selected, will shorten battery life).

"Low Batt" will display when it is time to replace the battery (see illustration at right). Replacement instructions come with the custom battery pack available from your dealer or Seametrics.

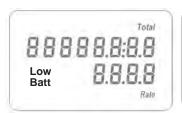
NOTE: Memory will not be lost during a battery change.

External Power (optional). Where power is available, the life of the battery pack can be indefinitely extended by the addition of an external power input cable. When external power is used, the batteries serve as backup in case of power failure, keeping the meter reading out during an outage. The display reads "P" to indicate that external power is in use (see illustration at right).

When the display is reading numbers/letters but neither the "Low Batt" or "P" symbol is displayed, the meter is functioning normally under battery power (see illustration at right). When the display is completely blank, the meter is not powered.

Solar Power (optional). In most areas of the US, a 12volt, 5 watt solar power unit (panel, charge controller and battery) should suffice to operate the meter. In this case, the internal batteries will serve as backup and battery life will be $_{\rm 24}^{\rm Research}$ conserved.

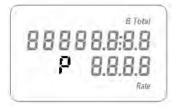
Display Reading. There are two lines to the display, the bottom line for flow rate and the top line for accumulated total. Measurement units are pre-ordered and factory-set and can be changed in the field only by an authorized individual.





Low Battery Indicator

No Power





External Power Indicator

Empty Pipe





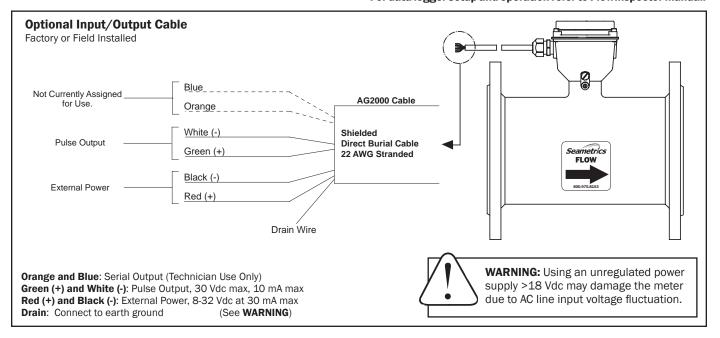
Meter Installed Backwards

Optional Input and Outputs. An optional cable, factory-installed or field-installed by an authorized individual, provides power input, pulse output* for remote reading (4-20 mA conversion, telemetry and data logging functions). See diagram below. Detailed wiring diagrams provided with cable.

IMPORTANT: When field installing the input/output cable, be sure to snugly tighten the cable strain relief to prevent water ingress.

*See High Frequency Output Technical Bulletin for available pulse rates.

For data logger setup and operation refer to FlowInspector manual.



TROUBLESHOOTING

Problem	Probable Cause	Try		
Blank display	Dead battery	Replace battery pack		
Flow rate steadily reads zero when there is flow	Flow is below cutoff (very low)	Reading will resume when flow increases		
Zero when there is now	There is air in the meter	Reposition meter for full pipe		
Display reads [-]	Meter is installed backward	Note flow direction arrow, reverse meter		
Flow rate intermittently drops when there is flow	There is air in the meter	Reposition meter for full pipe or rotate to avoid bubbles		
Jumpy reading	Improperly equalized	Check for proper equalization		
	Pulsing flow	Use external power source (allows more flow averaging)		
	Rapidly changing conductivity (chemigation applications)	Install chemigation line downstream of meter (or enough upstream for thorough mixing of fluids before meter)		



Seametrics Incorporated • 19026 72nd Avenue South • Kent, Washington 98032 • USA (P) 253.872.0284 • (F) 253.872.0285 • 1.800.975.8153 • www.Seametrics.com



AG2000 Irrigation Magmeter



APPLICATIONS

- Irrigation
- Chemigation
- · Agricultural automation
- · Well usage monitoring
- Dairy Lagoons

FEATURES

- Simple as a mechanical meter
- No moving parts
- Minimal straight pipe required
- Battery power standard; External power optional
- Solar compatible
- Built-in rate & total indicator





Seametrics' series of standard and IP68 (submersible) flanged magmeters.

Available in sizes from 3" up to 12".

Unobstructed Flow Irrigation Training and Research Center E-96



AG2000 Irrigation Magmeter

GENERAL INFORMATION

The AG2000 is a spool-type electromagnetic flowmeter for use in irrigation applications in 3" to 12" pipe. With no moving parts, these meters provide unobstructed flow and are resistant to wear from debris found in ground or surface water. Little maintenance is required because there are no bearings to wear out or propellers to stop turning. Minimal straight pipe requirements allow AG2000 meters to be used in piping configurations where there is little space between the meter and an elbow.

The standard AG2000 is battery powered. Where an external power source is available, the AG2000 can be optionally converted to 8-32 Vdc, with the batteries then serving as backup to maintain continuous operation in case of power failure. This configuration will prolong battery life indefinitely.

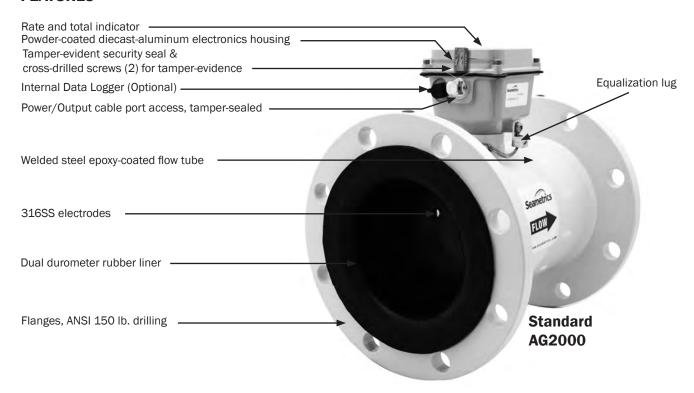
An IP68 version (-168 option) is available for burial or applications where the meter may be under water up to a depth of 3 meters for prolonged periods of time.

The meter comes with built-in pulse output (requires optional cable) for data logging or telemetry. Several pulse rates are available. An internal data logger is also available for secure flow logging (-127 option). A Seametrics FT415W or FT420W display can be added if remote rate/total reading is desired, or an A055W if a (4-20 mA) analog signal is required. (High-frequency pulse rate is required for use with most Seametrics controllers.)

The AG2000 is secured with a seal wire to protect against unauthorized access. The seal can be broken by an authorized agent, to change units of measure, replace the battery pack, or to field-install an optional power/output cable. The cable can be factory or field-installed where external power is available and/or pulse output is needed. An accessory weather guard is available for additional protection in outdoor applications.

For chemigation applications, the chemical injection point must be placed downstream of the meter **OR** far enough upstream for **complete mixing** to occur before the flow reaches the meter. (See tech bulletin on Seametrics' website, www.seametrics. com).

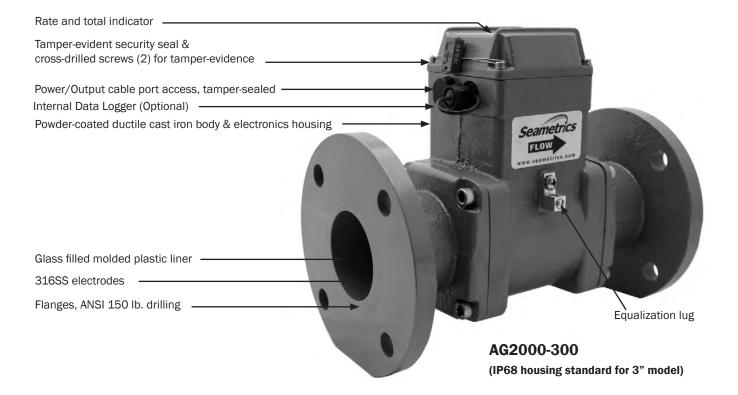
FEATURES

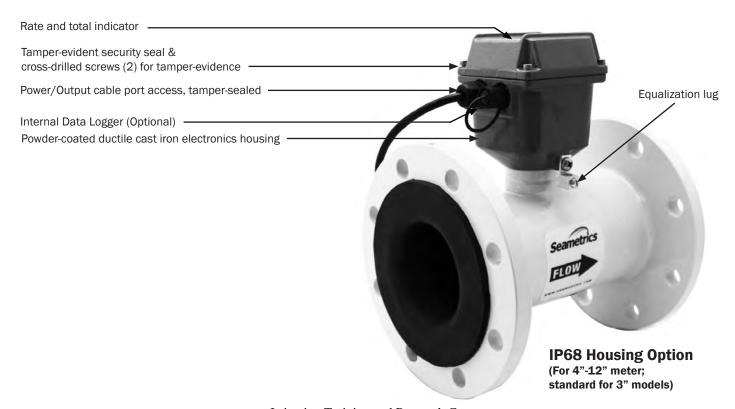




AG2000 Irrigation Magmeter

FEATURES Continued





Irrigation Training and Research Center



AG2000 Irrigation Magmeter

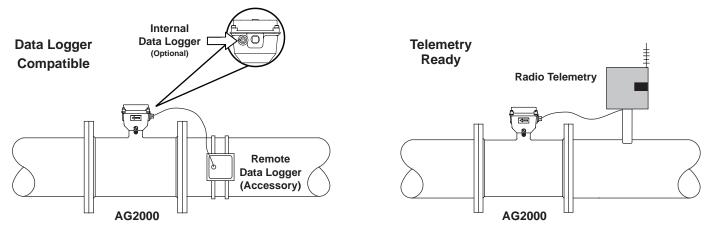
SPECIFICATIONS*

Pipe Sizes		3", 4", 6", 8",	10", 12"						
Fittings		ANSI 150 lb.	drilling						
Pressure		150 psi (10.3	bar) working	pressure					
Temperature	Operating	10° to 130°	F (-12° to 54	° C)					
	Non-Operating	-40° to 158°	F (-40° to 70	° C)					
Accuracy		+/- 1% of reac	ling for flow be	tween 10% to	100% of ma	ax flow			
		+/- 2% of reac	ling for flow fro	m cutoff to 10	% of max flo)W			
Materials	Body (3" Only)	Ductile cast in	on, powder co	pated w/NSF6	1 listed epo	oxy powder			
	Body (4"-12")	Welded steel,	epoxy-coated	I					
	Liner (3" Only)	Noryl®							
	Liner (4"-12")	Santoprene/F	Polypropylene						
	Electronics Housing	Diecast alumi	num, powder	-coated (non-l	P68)	Ductile Cast Ir	ron (IP68)		
	Electrodes	316 stainless	steel						
	O-ring (3" Only)	EPDM							
Display		Rate				Total			
., .,	Digits	5				8			
	Units	Gallon/Minute, Liter/Minute, Cubic Feet/Minute, Cubic Meter/Hour, Gallons/Sec, Liter/Second Cubic Feet/ Sec, Miner's Inch, Cubic Meter/Min Gallon, Gallon x 1000, Liter, Liter x 1000, Mega L Cubic Meters, Cubic Meter x 1000, Million Gallon, Miner's Inch D					Cubic Meter x 1000, Acre Feet, Cubic Feet,		
Power		1 battery pack that contains 2 Lithium 3.6V "D" batteries, replaceable. Standard battery life 2.5 years 5 years with extended battery life (EBL) option							
		With external power option (uses 8-32 Vdc, 30 mA), Lithium batteries serve as backup in power failure (10 year life)							
Pulse Output	(with optional cable)	The state of the s							
	Signal		Current sinking pulse, opto-isolated, 30 Vdc at 10 mA max						
	Pulse Rates	High Frequency; 10 units/pulse; 100 units/pulse; 1000 units/pulse							
High Frequency (pulse/gal)		3"	4"	6"	8"	10"	12"		
		25.228	16.362	6.307	3.344	2.15	1.530		
Conductivity		>20 microSiemens/cm							
Empty Pipe Do	etection	Hardware/software, conductivity-based							
		NEMA 4X Standard (IP68 Option)							

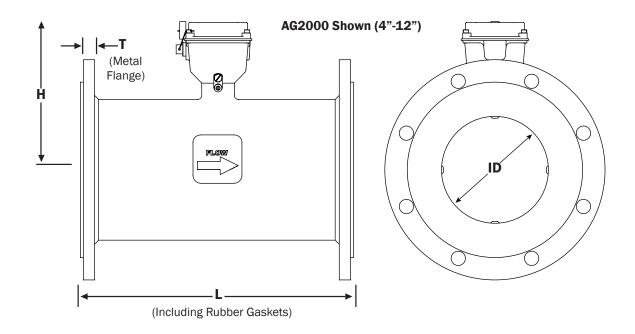
^{*}Specifications subject to change. Please consult our website for the most current data (www.seametrics.com).
**Extended battery life option is standard on all IP68 meters.



OUTPUT CAPABILITIES



DIMENSIONS

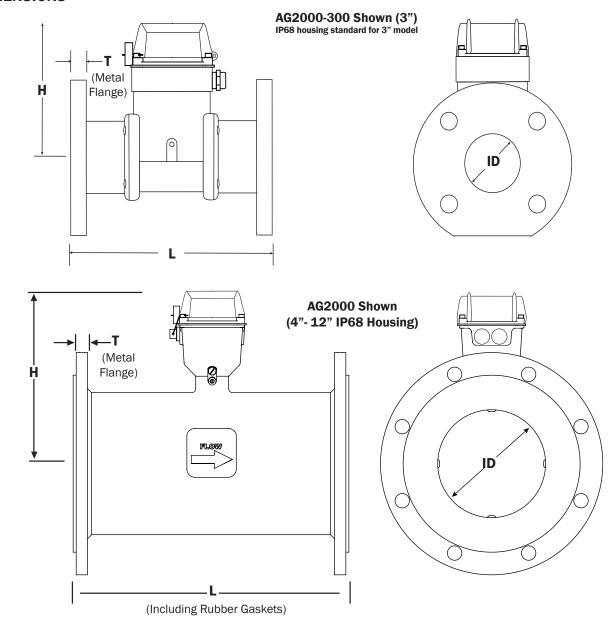


AG2000 (Standard Housing)

Standard AG2000	L		Н		т		ID		Shipping Weight Standard	
Meter Size	inch	mm	inch	mm	inch	mm	inch	mm	pounds	Kg
4"	10.24	260	7.0	178	.62	20.9	3.12	79.25	32	15
6"	12.27	312	8.1	206	.69	23.3	5.05	128.27	47	21
8"	14.24	362	9.1	231	.69	23.3	6.44	163.58	69	31
10"	18.18	462	10.1	257	.69	23.3	8.61	218.69	125	57
12"	19.68	500	11.1	Irrigation	Training	and Rese	arch 55nt	267.97	145	66
Flanges			Sta	andard Al					Cable (AG2	2000) 1 lb.



DIMENSIONS



AG2000 with IP68 Housing (-168 option)

IP68 AG2000	L		Н		Т		ID		Shipping Weight IP68 Version	
Meter Size	inch	mm	inch	mm	inch	mm	inch	mm	pounds	Kg
3"	12.0	305	6.80	173	.68	17.3	2.60	66.04	41	19
4"	10.24	260	8.12	206	.62	20.9	3.12	79.25	35	16
6"	12.27	312	9.22	234	.69	23.3	5.05	128.27	50	23
8"	14.24	362	10.22	260	.69	23.3	6.44	163.58	72	33
10"	18.18	462	11.22	285	.69	23.3	8.61	218.69	128	58
12"	19.68	500	12.28	312	.81	20.6	10.55	267.97	148	67
Flanges	Standa	Standard ANSI 150 lb. driffing ation Training and Research Center Cable (AG2000) 1 lb.								

E-101

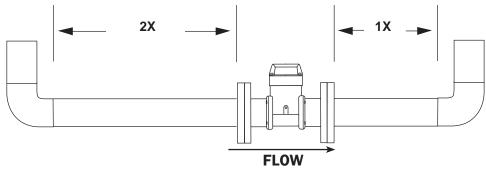


AG2000 Irrigation Magmeter

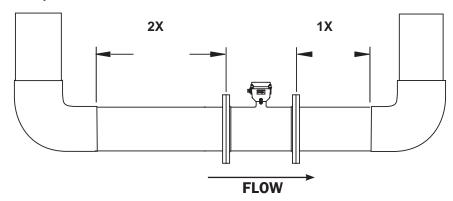
STRAIGHT PIPE RECOMMENDATIONS

(X = pipe diameter)

Minimal straight pipe required between elbows. For other piping configurations, consult factory.



(X = pipe diameter)



FLOW RANGE (3" - 12")

Meter	(3"		4"	6	3"	:	8"	1	0"	1	.2"
Size	Gal/Min	Liter/Sec										
Minimum	7.5	.47	12	.75	32	2	60	3.8	95	6	130	8.2
Maximum	700	44.2	1,000	63	2,400	151.4	4,400	277.6	7,000	441.6	10,000	630.9



AG2000 Irrigation Magmeter

HOW TO ORDER

MODEL	SIZE	OPTIONS	PULSE RATE (With Option -11)	UNITS
AG2000	3" = -300* 4" = -400 6" = -600 8" = -800 10" = -1000 12" = -1200	Factory Installed Power/ Output Cable: 6m (20 ft) = -11/6 15m (50 ft) = -11/15 30m (100 ft) = -11/30 Factory Installed IP68 Power/Output Cable: 6m (20 ft) = -11/6S 15m (50 ft) = -11/15S 30m (100 ft) = -11/30S Internal Data Logger = -127 Serial Output = -131 IP68 Submersible = -168 Extend. Battery Life¹ = -178	10 Units*/Pulse = -PxX 100 Units*/Pulse = -PxH 1000 Units*/Pulse = -PxK High Frequency**= -HF	Gal/Min = GPM Liter/Min = LPM Cu Ft/Min = CFM Cu Meter/Hr = CMH Gal/Sec = GPS Liters/Sec = LPS Cu Ft/Sec = CFS Miner's In** = MI Cu Met/Min = CMM Gal = G Gal x 1000 = GT Liter x 1000 = LT Mega Liters = ML Cubic Meters = CM Cu Met x 1000 = CMT Acre Feet = AF Cubic Feet x 1000 = CFT Million Gal = MG Miner's Inch Day = MID Acre Inch = AI
	*-300 available in IP68 only	¹ Extended battery life is standard on all IP68 meters	*Units = Gal or Liter depending on Rate/Total unit selection	Consult factory for additional units Any rate selection can be combined with any total selection

ACCESSORIES

Remote 4-20 mA (analog) signal = AO55W

Remote Rate and Total Indicator (Battery) = FT415W*

Remote Rate and Total Indicator (Powered) = FT420W*

Remote Data Logger = DL76W

Dual Power Supply, 115 Vac, 12/24 Vdc = PC42

(Use with High Frequency pulse rate)

Replacement Battery Pack = 100889

Weather Guard = 100961

Post-Factory 20-ft. Power/Output Cable (Standard Housing Only) = **DC30**

**High Frequency pulse rate will shorten battery life

Post-Factory 50-ft. Power/Output Cable (Standard Housing Only) = DC35

Post-Factory 20-ft. Power/Output Cable (IP68 Housing Only) = DC30S

Post-Factory 50-ft. Power/Output Cable (IP68 Housing Only) = DC35S

Grounding Rings

(not needed for most applications): 3" = **102157**

4" = 100876 6" = 100877 8" = 100878 10" = 100879 12" = 103288

** 1 Miner's Inch = 1.2 CFM

*Consult customer service to determine the appropriate indicator based on the distance it will be installed from the meter.

CONTACT YOUR SUPPLIER



Technical Bulletin Flow Meter Installation: Straight Run

Description

Nearly all flow meters must be installed so that there is a significant run of straight pipe before and after the location of the flow meter. This is intended to allow the straight pipe run to "smooth out" any turbulence produced by the presence of valves, thermowells, chemical injectors and diffusers, and changes in pipe direction. This type of turbulence produces error in the the reading of most flow meters.

How Much Can The Error Be?

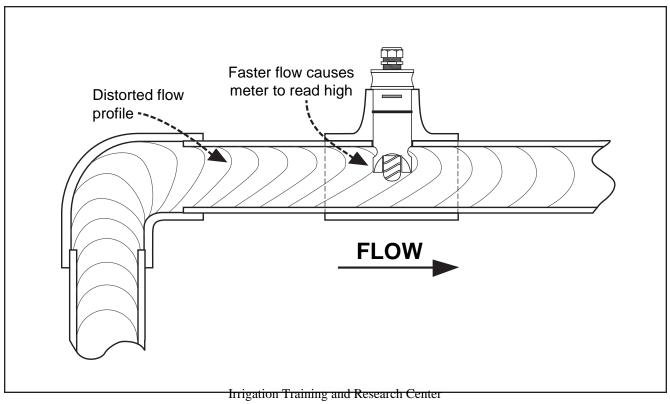
The error can be quite large. The error produced by a thermowell installed immediately upstream of a flow meter can be in the range of 5-10%. That of a gate valve or a butterfly valve can be as much as 50-60%! The error produced from a partially closed ball valve can be as much a 50%, too. Chemical injectors can produce significant error also. For example, a chlorine injector-diffuser may produce enough entrained undissolved chlorine bubbles to produce an error in the 10-20% range.

Good Installations

Seametrics suggests at least 10 diameters of straight pipe run upstream and 5 diameters of straight pipe run downstream of the flow meter installation in order to achieve proper accuracy. These are minimum values. As the diagrams on the the next page will show, you may need much more straight run under specific circumstances.

Preventing Cavitation

Cavitation can be caused by entrained air, and it can seriously damage the rotor on a turbine or paddlewheel flow meter. An amount higher than about 100 mg/l of entrained air or gas can produce error. In addition, cavitation can be caused by too little backpressure on the flow meter. For turbines and other rotary impeller flow meters, you should provide a backpressure (downstream pressure) of at least 1.25 times the vapor pressure, plus 2 times the pressure drop through the meter. This can usually be accomplished by providing the minimum downstream straight run prior to discharge.



When In Doubt, Straighten The Flow

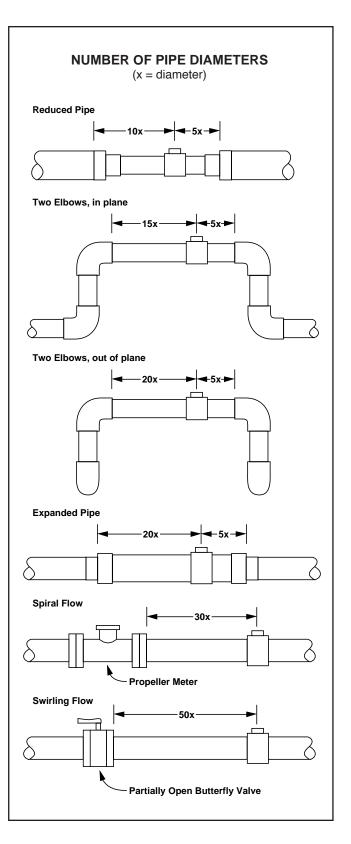
There are a number of ways to straighten the flow. Flow straighteners are included in Seametrics carbon steel and stainless steel WT series turbine flow meters and in our WP meters also. If you need the highest possible accuracy from your flow meter installation, you should install a separate flow-straightening device upstream of the flow meter. Seametrics recommends Vortab® flow straightening devices because of their accuracy and low pressure-drop. Any flow straightener requires additional diameters of straight run. Usually the mimimum requirement is 7 diameters before the flow straightener and 5 diameters between the straightener and the flow meter itself. Using a flow straightener is not a substitute for correct amount of straight pipe run!

What If You Can't Provide Adequate Straight Run?

If you can't provide enough run to smooth out the turbulence caused by valves, fittings, and changes in direction, you will have to live with the inaccurate effects this turbulence will create. This does not mean that the flow meter's reading is meaningless, however. In the majority of applications, it may be enough to provide a repeatable reading, if not an accurate one. In applications where the flow meter is a control device, operating a valve or controlling chemical addition, repeatability of reading is more critical than absolute accuracy. You may find that you can get excellent results without excellent accuracy.

Some Rules of Thumb

To the right are several diagrams with some recomendations to assist you in properly locating your Seametrics flow meter. Remember these are only Rules-of-Thumb. If you **do** experience error in spite of observing these recommendations, you may be able to perform an "on site" calibration to attempt to minimize the error. Consult with Seametrics prior to doing this, so we can advise you on appropriate methods, and potential results.





Attachment F Overview of Portable Pipe Flow Meter Option



moving water in new directions

IRRIGATION TRAINING & RESEARCH CENTER

California Polytechnic State University San Luis Obispo, CA 93407-0730

Phone: (805) 756-2434 FAX: (805) 756-2433 www.itrc.org

TECHNICAL MEMORANDUM

Date: August 24, 2015

To: Dan Vink, LTRID, dvink@ltrid.org

Eric Limas, LTRID, <u>elimas@ltrid.org</u> Kenny Phelps, LTRID <u>kphelps@ltrid.org</u>

From: Stuart Styles, ITRC, <u>sstyles@calpoly.edu</u>

Sierra Layous, ITRC slayous@calpoly.edu

Subject: Overview of a Portable Pipe Flow Meter Option for Pipelines

During a site visit to Lower Tule River Irrigation District (LTRID), the district asked ITRC about options for portable flow measurement devices for measuring flow on turnouts with low-lift pumps. Currently, the district measures flow rates about once a year using a pitot tube and manometer. There are several units on the market. The PT878 is by far the most common used by irrigation districts and pump testers.

Panametrics TransPort PT 878



The Panametrics TransPort PT 878 Portable Clamp-On Ultrasonic Flow Meter is a portable, non-intrusive flow measurement device. The device clamps on a pipe and is connected to a wired, handheld unit for programming and flow measurement.

One of the key features of the unit is that it will still give a number even if there is turbulence. This allows the user to determine if the unit is accurate rather than just getting a "fault" message. The accuracy can be checked by looking at the signal strength and the value calculated for the speed of sound in water.

Panametrics TransPort PT 878 - Specs

Batteries	9-11 hours; rechargeable
Accuracy	$\pm 1\%$ to 2% of reading typical for > 6";
	$\pm 2\%$ to 5% of reading typical for ≤ 6 "
Pipe size	0.5 to 300 inches
Wall thickness	Up to 3"
	Wall thickness can be measured by PT878
Flow Operation Range	± 0.1 to ± 40 ft/sec
Configuration	10D upstream and 5D downstream
Interface	Handheld wired unit
Recall Option	Recall parameters based on site file
	(need to give each site a file name)

Seametrics jWAVE



The Seametrics jWAVE Portable Clamp-On Ultrasonic Flow Meter is a portable, non-intrusive flow measurement device. The device clamps on a pipe and connects to a smartphone or tablet via Bluetooth for programming and flow measurement. The manufacturer's literature appears to state that the smartphone or tablet can recall previous settings based on location (i.e. each time you come back to a site, your phone or tablet will automatically recall the pipe type, wall thickness, etc).

Seametrics jWAVE Portable Clamp-On Ultrasonic Flow Meter - Specs

Batteries	8+ hours; rechargeable
Accuracy	±1% to 2% of reading
Pipe size	3 to 20 inches
Wall thickness	
Flow Operation Range	±30 ft/sec
Configuration	10D upstream and 5D downstream
Interface	Bluetooth, tablet/smartphone app
Recall Option	Recall parameters based on location
	(GPS on phone or tablet)