Development of Environmentally Responsible Techniques and Practices for Freshwater Aquaculture in Ontario

Part 1:

Water Monitoring

Final Report submitted to:

Ontario Sustainable Aquaculture Working Group



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Table of Contents

1. Introduction

Aquaculture in Ontario is a agricultural sector that has developed to produce over 4,000 tonnes of fish with a farm-gate value exceeding $15.5 million in 2005 (Stats Canada, 2006). Approximately 80% of the production results from open water cage culture of rainbow trout in the Georgian Bay region of the Great Lakes. The balance of the production comes from a variety of land-based facilities rearing rainbow trout, Arctic charr, tilapia and other freshwater fish. Land-based fish hatcheries are also responsible for producing the juvenile fish stock required by the cage facilities, and additionally, the Ontario Ministry of Natural Resources (OMNR) and the Community Fish Involvement Program (CFIP) have fish hatcheries involved with stocking Ontario's lakes and rivers. Land-based facilities generally access either ground water or surface water for their operation – a few facilities use municipal supplies in recirculation systems. The quantities of water taken varies considerably, ranging from less than 150 Lpm to over 20,000 Lpm at one of the OMNR hatcheries and are an important sector of the provincial water budget. However, it is important to recognize that at all these facilities, virtually all of the water taken is returned to a surface water body for subsequent reuse.

The management of surface and ground water in Ontario is legislated by the Ontario Water resources Act (OWRA) and accompanying regulations. Section 34 of the OWRA requires a Permit To Take Water (PTTW) for most facilities taking more than 50,000 litres per day. New regulations, that have been phased in between 1st January 2005 through 1st January 2007, expanded upon the monitoring and reporting of water taking for all PTTW permit holders. The Water Taking and Transfer Regulation (O.Reg 387/04) Section 9 requires all permit holders to collect and record data on the actual volume of water taken daily[1] and to report this data to the Ontario Ministry of the Environment (MOE) annually. The volume of water taken must be measured by a flow meter or calculated using a ministry approved method. Several publications are available to assist permit holders comply with these regulations (e.g. MOE 2005) and an online data reporting system has been developed. Knowledge of the actual water taking data, as opposed to the maximum permitted amount, will allow better management of Ontario's water resources through the development of water budgets and watershed based planning and development strategies (Kreutzwiser et al. 2004).

Most land-based aquaculture facilities hold a PTTW with a variety of conditions attached. This report provides a brief review of the potential methods available for water flow monitoring at land-based aquaculture farms, outlines the criteria used for selection of an appropriate measurement device , and provides a detailed evaluation on the use of electronic "Magnetic flow meters" recently installed at the Alma Aquaculture Research Station of the University of Guelph.

[1] The existing PTTW records the maximum permitted taking, not the actual water taking.

2. Methods for Monitoring Water Flow

Water sources for aquaculture can be classified as either ground water or surface water. Typical ground water sources include springs, artesian wells and pumped aquifers, while surface water sources include streams, rivers and lakes. For all sources, the type of delivery system, i.e. an enclosed and pressurized pipe or an open channel, is fundamental in the selection of a monitoring method. Selection of a suitable method depends on whether it is the actual volume delivered (e.g. litres) or the instantaneous rate of delivery (e.g. litres per minute) that is required. Extensive information on measuring water flow is given in the text book "Aquaculture Engineering" by Wheaton (1985) and the "Water Measurement Manual" produced by the U.S. Department of the Interior, Bureau of Reclamation (2001) and online at:

http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/

In the current study, several water flow monitoring methods were subjectively evaluated for accuracy of measurement, level of maintenance and cost-effectiveness.

A. Water Measurement in Enclosed Pipes

1. **Direct Volume Measurement**

The simplest method to determine flow rate is to measure the volume of water delivered over a known period of time (e.g. bucket and stopwatch) taking care that an adequate volume is collected to minimise measurement errors. From this measured rate of flow, and knowing the duration of the flow, the total volume delivered can then be calculated. While this manual method can be very accurate, it does not readily provide any measure of flow variability, without considerable effort, and is not easily carried out when large flow rates are involved.

Several types of mechanical meter have been developed to measure water volume. Displacement meters operate by measuring either the weight (e.g. tilting trap meter) or the volume (e.g. piston meter) of water that passes through a pipe. Similarly, a nutating disk meter operates with a ball and attached plate rotating in accordance to the volume of water passing and is commonly found in domestic water meters. Each of these meters is designed to record the total volume of water that passes and not the rate of flow. Some of these meters can be fitted with a magnetic sensor assembly and timing device to allow flow rate to be calculated and recorded.

2. Differential-Pressure Flow Meters

Bernoulli's equation relates velocity increase and pressure decrease so that by measuring the pressure differential across a restriction in a pipe, the change in pressure can be related to flow rate. A variety of differential-pressure flow meters are available. Venturi meters consist of a converging section (throat) and a diverging section. Water passes through the throat at maximum velocity and minimum pressure. The difference in pressure before and at the throat is a function of velocity and related to flow rate, which can either be calculated or empirically measured to provide a calibration chart of flow rate against pressure differential. Nozzle meters are very similar in design, but the more abrupt change in pipe diameter results in a smaller meter size. Extending this contraction still further, a thin-plate orifice meter consists of a thin plate with an accurately placed centre hole; the water velocity increases as it passes through this restricting hole and the pressure difference is related to the water velocity. By knowing the cross-sectional area of the pipe and the water velocity, the flow rate can be found. The accurate range of orifice plate meters is limited, unless variable area plates are used with their corresponding increased complexity and opportunity for wear. Other differential pressure meters include centrifugal and pitot tube meters.

Differential-pressure meters can be very accurate (especially with digital pressure transducers) and their maintenance is usually low because the lack of moving parts, although wear from abrasion can be a problem. Venturi meters are larger, more expensive, but require less maintenance than nozzle and orifice plate meters and retain their calibration better.

3. Variable Area Flow Meters

A commonly used type of variable area flow meter is the rotameter which consists of a vertically mounted, tapered tube with a "float" inside. As the liquid (or gas) moves up the tube, the drag on the float causes the float to move to a position that is balanced by gravity (i.e. "floating" in the stream of fluid passing by). Highly accurate flow measurement is available, although fouling and mechanical wear require continual maintenance. No provision for data logging limits their applicability in water monitoring.

4. Turbine Meters

The rotation of a turbine or propeller is proportional to the velocity of the water over the blades and a counter is used to record the number of revolutions. By knowing the cross-sectional area and the water velocity the flow rate can be calculated. The mechanical nature of the meter and fouling of the propeller (and inlet filters if installed) requires maintenance and affects long-term accuracy. The addition of magnetic pulse readers can provide for continuous recording of total volume and/or flow rate. Hand-held turbine meters are available for field measurement of open channel flow rates

5. Magnetic Flow Meters

A conductive fluid (e.g. water) moving in a magnetic field induces an electromotive force (Faraday's Law), which is measured and directly proportional to the velocity of the fluid. Similar to turbine meters, by knowing the cross-sectional area and the water velocity, the flow rate can be calculated. The lack of any obstructions within the meter body limits pressure loss and with no moving parts, magnetic flow meters are reliable and can be very accurate over a wide range of flow rates (e.g. accuracy of ±0.25% with flow range of 1000:1). The lack of suspended material in the water does not affect the meters operation, unlike some types of ultrasonic meters. A further advantage is the option to separate the sensor assembly from the monitor using either wired or wireless transmission.

6. Ultrasonic Flow Meters

Two types of ultrasonic meter are available, using either the Doppler effect or "Transit Time". In Doppler meters, an ultrasonic energy source (100 kHz range) is transmitted into a fluid and the sensor detects the phase shift that is proportional to the fluid velocity. Doppler meters require particles or entrained bubbles in the water to reflect the sound. "Transit Time" meters measure the very small difference in travel time that occurs when an ultrasonic sound moves either with or against the flow of water and can operate in "clean water". Both types of ultrasonic meters can be attached to the outside of a pipe. Doppler based meters can be used to measure current direction and velocity in open water bodies (Acoustical Doppler Current Profiler - ADCP) and have many varied applications.

B. Water Measurements in Open Channels

The accurate measurement of water flow from surface water sources, e.g. springs and streams, is generally more difficult than for that of enclosed pipes. While many of the same basic physical principles are involved, factors that include irregular channel shape and flow characteristics, low head pressure and fluctuating flow rates, all add to this difficulty. Measuring the actual volume of water discharged over a known period of time, as with enclosed pipes, is the most accurate, but is not often possible.

The velocity/area method requires calculating the average water velocity and the cross sectional area of an open channel from which the volume per unit time can be estimated. Turbine meters are often used to provide an estimate of the water velocity, although very approximate estimates can be made by timing the movement of a suitable floating object. Inaccuracies will exist because of errors in estimating the average water velocity which varies across the cross-sectional area (e.g. lower along the edge and bottom of channel because of frictional losses) and various methods are used to minimise them (Bankston and Baker 1995). In addition to turbine meters, ultrasonic Doppler meters are also used to measure velocity and water depth, which combined with their data logging capabilities provides a very powerful recording system (Hirsch and Costa 2004). The use of hydraulic structures placed in the open channel can be used to relate changes in water level (head pressure) to flow rate. The two principle structures used are weirs and flumes.

1. Weirs

A weir is an obstruction across an open channel (i.e. the water is at atmospheric pressure) that creates an increase in water level (head) that is related to the flow over this obstruction. Weirs are classified by shape, with V-notch, rectangular and trapezoidal (Cipolletti) weirs being commonly used. V-notch weirs are often used for low flow rates as the width of the weir can range from zero upwards. Generally, a head of 1-3 cm is required to ensure that water flows freely over a weir. Maintenance of weirs is generally minimal. Theoretically, a weir can have only one water level for any give flow rate and thus an equation relating head and flow can be established. Accurate water depth measurements are therefore essential for meaningful flow measurements. Mechanical “hook gauges” or electronic water depth (i.e. pressure transducers) are often used to ensure this. The availability of cost-effective electronic depth gauges and data loggers permits continuous monitoring of water flow. Furthermore, advances in telecommunications has further extended the ability to record stream flow in “real-time”.

2. Flumes

Flumes are an improvement over weirs because they have less head loss and sedimentation and debris problems are reduced. Two types are often used, Parshall and trapezoidal flumes. Parshall flumes constrict the cross-sectional area of an open channel and convert some of the static head pressure into a velocity head. The head of water is measured in the converging section and the corresponding flow rate is determined. Trapezoidal flumes have a flat bottom and a trapezoidal cross section allowing greater variation in flow rate and simpler construction compared to Parshall flumes. Flumes are usually custom designed and constructed on site, although pre-fabricated flumes are available.

3. Water Monitoring Using a Magnetic Flow Meter – A Case Study

The Alma Aquaculture Research Station of the University of Guelph is a land-based fish culture facility using ground water source. The facility's PTTW allows the taking of 7,045 Lpm (1,550 Igpm) from six wells, all accessing the same aquifer. Initially, the three main pumping wells were fitted with "differential pressure" flow meters which were calibrated for peak accuracy at the original sustainable yield of each well. Over time, reductions in well yield reduced pump flows below the initial meter calibration range, compromising metering accuracy. Recalibration and maintenance of the meters over a 15 year period was becoming costly and time consuming. Furthermore, the original meters were not capable of continuous data logging, a important consideration for complying with new MOE PTTW regulations.

After consultation with several water metering companies, "magnetic" flow meters were selected as being the best solution for the stations requirements. Subjective evaluation was based upon accuracy, cost and maintenance. Initially, one 3-inch ABB AquaMaster S flow meter was installed and its operation evaluated. The meter was installed on the 6-inch discharge line of a 15 HP submersible pump, with a maximum pumping rate of 1,400 Lpm (308 Igpm). The purchase and installation costs are outlined in Table 1. The delivery time was approximately 4 weeks as the units are imported from Europe. The unit was ordered with the integrated data logging option and requires a 110 VAC power supply. Site specific plumbing included the reduction of iron pipe work from 6-inch to 3-inch and MOE required installation of a secondary discharge port onto which a calibration meter can be attached (Figure 1 and Figure 2). Installation and the calibration check took approximately 4 hours. The initial onsite calibration check recorded a 99.6% accuracy. Annual confirmation of the meter calibration is recommended. A second identical meter has subsequently been installed at the AARS and the intention is to install meters on the remaining four well supplies. While the MOE may accept a single daily total volume from multiple sources from the same hydrogologic unit, there are operational benefits to be gained from independent monitoring of each source, e.g. well screen plugging and pump wear .

Table 1. Cost breakdown for purchase and installation of one 3-inch magnetic flow meter at the Alma Aquaculture Research Station.

Description	**$ Cost (excluding taxes)**
"AquaMaster S" (80 mm, 3 inch with data logging module)	4,120
Site specific plumbing (iron pipe, 6 inch reduced to 3 inch)	820
MOE required plumbing for calibration check	350
Electrical parts and communication cable (15 feet)	135
Labour for installation and calibration check (4 hours)	440
Travel (2 hours)	200
TOTAL	**6,065**

The “AquaMaster S” meter records the current flow rate and the total flow (since initializing the recording unit) in two separate loggers, providing up to three months of data collection. The stored data can be accessed via a serial port (RS-232) and personal computer using the “LogMaster” software (Windows version only)[2]. The data is saved as a comma-separated variable (CSV) file and can be imported into an electronic spreadsheet or database (e.g. MS-Excel) for review etc. An example of the data files produced is given in Tables 2 and 3 and a representative MS-Excel chart from this information is shown in Figure 3.

The reporting of water taking to the MOE can be simplified by using MOE’s internet based data reporting system. This system requires the creation of standardised XML files which are then uploaded to the MOE database. Once set-up, the electronic capture and reporting of water taking data should provide a valuable management tool. The initial attempt to use this system for the AARS was eventually successful, thanks to the guidance from MOE staff. However, the software requirement for preparing the correct XML file are potentially expensive and further efforts are needed to overcome this constraint.

Concluding remarks:

Accurate monitoring of water taking is required for regulatory compliance but can also provide valuable operational information on the status of the wells and water delivery system. Electronic metering is seen as a cost effective solution, of which magnetic flow meters are ideally suited.

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[2] The requirement for a serial (RS-232 port) can be converted to a USB connection using an adapter cable with Windows 98, Windows XP **and** Vista.

Figure 1. "AquaMaster S" meter installed on 3-inch well at the Alma Aquaculture Research Station, showing secondary discharge port used for calibration purposes.

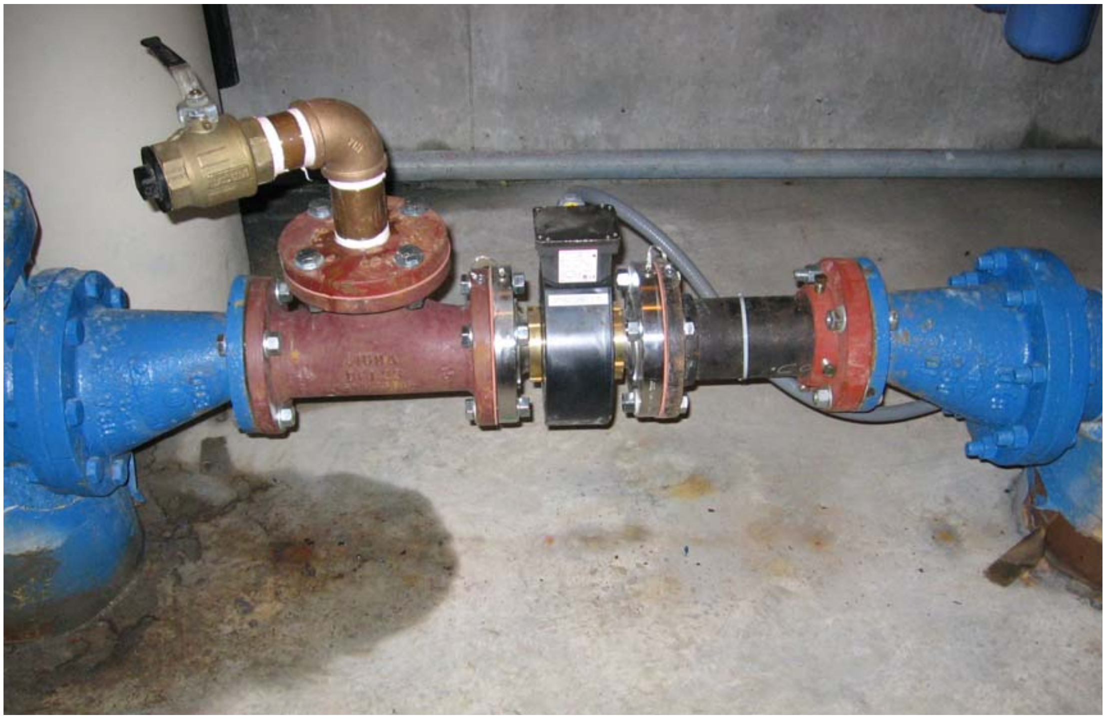

Figure 2. "AquaMaster S" data logger installed at the Alma Aquaculture Research Station. Total accumulated flow and instantaneous flow rate are displayed.

Table 2. "AquaMaster" data file showing daily accumulated total flow over a sample time period[3].

Meter ID (Flow Tag)	Alma Aquaculture							
RSN	Timestamp	Fwd	Rev	Net	Units	Tariff A	Tariff B	Units
60	12/02/07	11465577	0	11465577	Imp.gallon	0	0	Imp.gallon
61	13/02/07	11825379	0	11825379	Imp.gallon	0	0	Imp.gallon
62	14/02/07	12184774	0	12184774	Imp.gallon	0	0	Imp.gallon
63	15/02/07	12544066	0	12544066	Imp.gallon	0	0	Imp.gallon
64	16/02/07	12902960	0	12902960	Imp.gallon	0	0	Imp.gallon
65	17/02/07	13261547	0	13261547	Imp.gallon	0	0	Imp.gallon
66	18/02/07	13619903	0	13619903	Imp.gallon	0	0	Imp.gallon
67	19/02/07	13977899	0	13977899	Imp.gallon	0	0	Imp.gallon
68	20/02/07	14335367	0	14335367	Imp.gallon	0	0	Imp.gallon
69	21/02/07	14692640	0	14692640	Imp.gallon	0	0	Imp.gallon
70	22/02/07	15049773	0	15049773	Imp.gallon	0	0	Imp.gallon
71	23/02/07	15410594	0	15410594	Imp.gallon	0	0	Imp.gallon
72	24/02/07	15781778	0	15781778	Imp.gallon	0	0	Imp.gallon
73	25/02/07	16153737	0	16153737	Imp.gallon	0	0	Imp.gallon
74	26/02/07	16525569	0	16525569	Imp.gallon	0	0	Imp.gallon
75	27/02/07	16897012	0	16897012	Imp.gallon	0	0	Imp.gallon
76	28/02/07	17268265	0	17268265	Imp.gallon	0	0	Imp.gallon
77	01/03/07	17639173	0	17639173	Imp.gallon	0	0	Imp.gallon
78	02/03/07	18009622	0	18009622	Imp.gallon	0	0	Imp.gallon
79	03/03/07	18379865	0	18379865	Imp.gallon	0	0	Imp.gallon
80	04/03/07	18750022	0	18750022	Imp.gallon	0	0	Imp.gallon
81	05/03/07	19119282	0	19119282	Imp.gallon	0	0	Imp.gallon
82	06/03/07	19488089	0	19488089	Imp.gallon	0	0	Imp.gallon
83	07/03/07	19856515	0	19856515	Imp.gallon	0	0	Imp.gallon
84	08/03/07	20224152	0	20224152	Imp.gallon	0	0	Imp.gallon
85	09/03/07	20591478	0	20591478	Imp.gallon	0	0	Imp.gallon
86	10/03/07	20958176	0	20958176	Imp.gallon	0	0	Imp.gallon
87	11/03/07	21324563	0	21324563	Imp.gallon	0	0	Imp.gallon
88	12/03/07	21690713	0	21690713	Imp.gallon	0	0	Imp.gallon
89	13/03/07	22056466	0	22056466	Imp.gallon	0	0	Imp.gallon
90	14/03/07	22422207	0	22422207	Imp.gallon	0	0	Imp.gallon

[3] For each Record Serial Number (RSN), the meter records forward (Fwd) , reverse (Rev) and Net flow. Two tariffs can be set for billing purposes. Units are user selected.

Table 3. "AquaMaster" data file showing flow rate at 15 minute intervals for a sample time period[4].

Meter ID (Flow Tag)	Alma Aquaculture		
RSN	Timestamp	Flow (Gal/m)	Pressure (Bar G)
4875	12/02/2007 0:00	250.239	-1.014
4876	12/02/2007 0:15	250.173	-1.014
4877	12/02/2007 0:30	250.106	-1.014
4878	12/02/2007 0:45	250.173	-1.014
4879	12/02/2007 1:00	250.106	-1.014
4880	12/02/2007 1:15	250.173	-1.014
4881	12/02/2007 1:30	249.974	-1.014
4882	12/02/2007 1:45	250.106	-1.014
4883	12/02/2007 2:00	250.04	-1.014
4884	12/02/2007 2:15	249.974	-1.014
4885	12/02/2007 2:30	249.974	-1.014
4886	12/02/2007 2:45	250.04	-1.014
4887	12/02/2007 3:00	249.974	-1.014
4888	12/02/2007 3:15	249.907	-1.014
4889	12/02/2007 3:30	249.974	-1.014
4890	12/02/2007 3:45	249.841	-1.014
4891	12/02/2007 4:00	249.841	-1.014
4892	12/02/2007 4:15	249.907	-1.014
4893	12/02/2007 4:30	249.907	-1.014
4894	12/02/2007 4:45	249.841	-1.014
4895	12/02/2007 5:00	249.841	-1.014
4896	12/02/2007 5:15	249.841	-1.014
4897	12/02/2007 5:30	249.974	-1.014
4898	12/02/2007 5:45	249.774	-1.014
4899	12/02/2007 6:00	250.04	-1.014
4900	12/02/2007 6:15	249.642	-1.014
4901	12/02/2007 6:30	249.708	-1.014
4902	12/02/2007 6:45	249.642	-1.014
4903	12/02/2007 7:00	249.575	-1.014
4904	12/02/2007 7:15	249.708	-1.014
4905	12/02/2007 7:30	249.708	-1.014
4906	12/02/2007 7:45	249.642	-1.014
4907	12/02/2007 8:00	249.575	-1.014

[4] For each Record Serial Number (RSN), the meter records instantaneous flow at user selected intervals (Timestamp). An optional pressure transducer is available.

Figure 3. Average daily pumping rate of well OW3 at the Alma Aquaculture Research Station in 2007. Decline in pumping rate was the result of perforations in the riser pipe, which was replaced in December re-establishing the normal pumping rate.

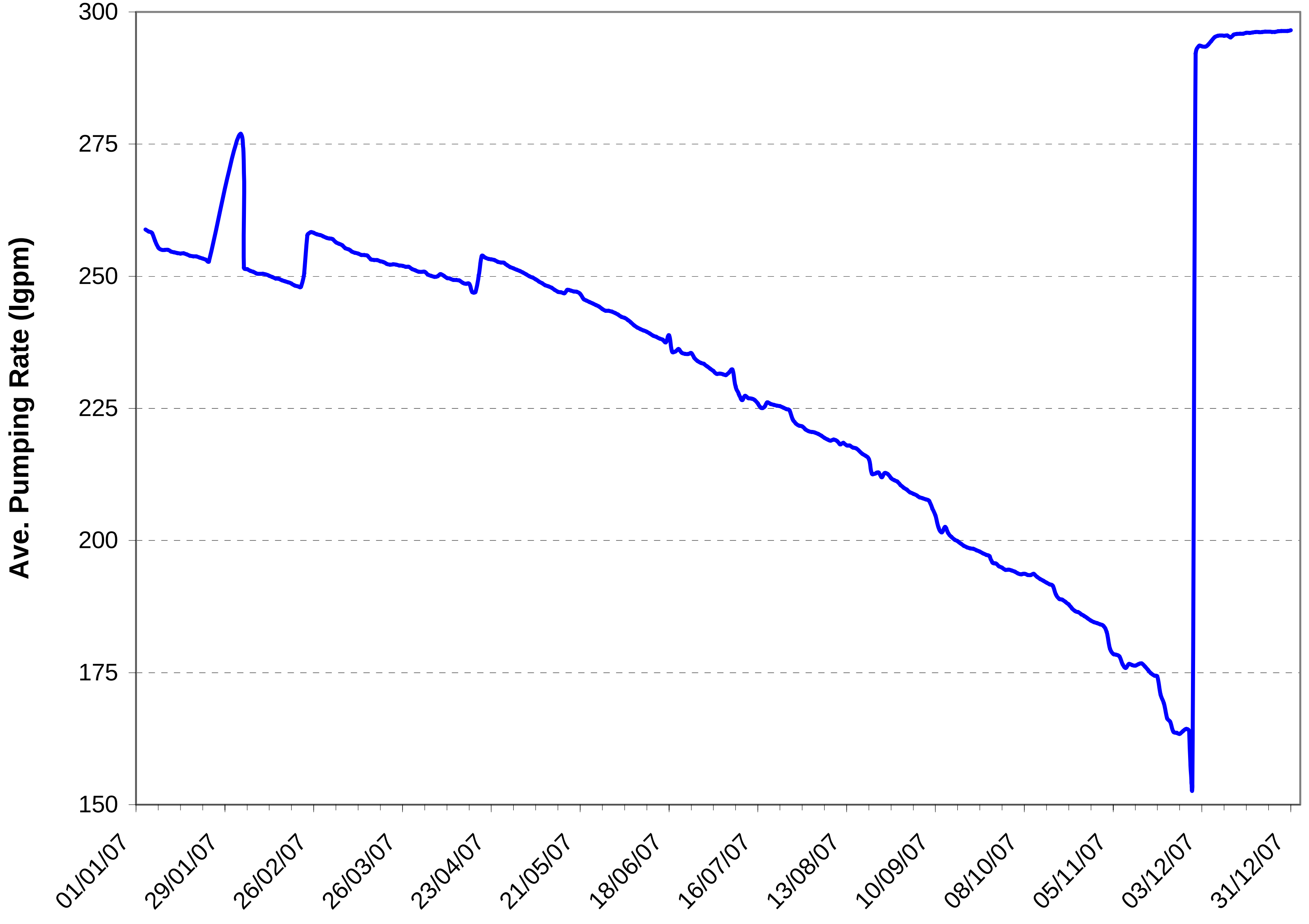

Table 4. XML information collected for online submission of water taking to Ontario Ministry of Environment.

sourceType	sourcePurpose	zone	easting	northing	year	month	takingDate	takingAmount	methodOfDetermination
	Aquaculture	17	537491	4837967	2006	1	1	681900	Metered
	Aquaculture	17	537491	4837967	2006	1	2	600072	Metered
	Aquaculture	17	537491	4837967	2006	1	3	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	4	681900	Metered
	Aquaculture	17	537491	4837967	2006	1	5	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	6	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	7	681900	Metered
	Aquaculture	17	537491	4837967	2006	1	8	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	9	600072	Metered
	Aquaculture	17	537491	4837967	2006	1	10	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	11	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	12	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	13	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	14	709176	Metered
	Aquaculture	17	537491	4837967	2006	1	15	600072	Metered
	Aquaculture	17	537491	4837967	2006	1	16	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	17	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	18	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	19	709176	Metered
	Aquaculture	17	537491	4837967	2006	1	20	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	21	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	22	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	23	600072	Metered
	Aquaculture	17	537491	4837967	2006	1	24	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	25	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	26	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	27	654624	Metered
	Aquaculture	17	537491	4837967	2006	1	28	681900	Metered
	Aquaculture	17	537491	4837967	2006	1	29	681900	Metered
	Aquaculture	17	537491	4837967	2006	1	30	600072	Metered
	Aquaculture	17	537491	4837967	2006	1	31	654624	Metered
	Aquaculture	17	537491	4837967	2006	2	1	654624	Metered
	Aquaculture	17	537491	4837967	2006	2	2	654624	Metered
	Aquaculture	17	537491	4837967	2006	2	3	654624	Metered
	Aquaculture	17	537491	4837967	2006	2	4	709176	Metered
	Aquaculture	17	537491	4837967	2006	2	5	681900	Metered

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5. Appendix I

Price quotations for alternative water metering options[5]

1. Turbine water meter, 3 inch class II with electronic data logging – Coulter Services Inc.

Item	$ Cost (excluding taxes)
Sensus W-350 Turbo (3 inch)	1,171
Adder for HSPU Register	360
Act-Pak Model 104A Pulse to analog converter	473
Adder for scaleable pulse to Act-Pak Model 104A	255
Paperless data logger to record flow & daily consumption	2,382
TOTAL, excluding taxes	**4,640**

2. Ultra-sonic Doppler current meter with electronic data logging – Hoskin Scientific Ltd.

Item	$ Cost (excluding taxes)
Argonaut-SW, 3.0MHz, 2-D up-looking real-time acoustic Doppler current Meter with programmable range selection (including Dynamic boundary adjustment), vertical acoustic beam for Water level measurement, Multi Cell (10) current profiling, Integrated temperature sensor, and 4MB data storage in a Low profile (6.5cm) polycarbonate pressure case (25m Maximum depth) with mounting plate. Includes RS232/SDI-12 interface and internal flow calculations. Software bundle includes ViewArgonaut (Windows 9x/2k/NT/XP) software for data acquisition, Analysis, and flow calculation, as well as SonUtils Pocket PC/Windows CE utility Software for PDA's. System includes 10m power and serial communications Cable, tool kit, power supply and manual (PDF) on CD.	8,128
Argonaut flow display	897
TOTAL, excluding taxes	**9,025**

[5] Note that reference to specific product or supplier is for general information only and does not suggest endorsement of product or supplier.

3. Ultra-sonic flow meter with electronic data logging – Can-Am Instruments Ltd.

Item	$ Cost (excluding taxes)
Sigma – Hach Area Velocity Flow Meter, Model 920 including: Two submerged depth/velocity sensors and "InSight Data Analysis" software	Approx. 9,000 – 10,000
TOTAL, excluding taxes	**Approx. 9,000 – 10,000**

Item	$ Cost (excluding taxes)
Greyline Portable Non-contacting Doppler Flow Meter, Model DFM 4.0	Approx. 4,000
TOTAL, excluding taxes	**Approx. 4,000**

Item	$ Cost (excluding taxes)
Greyline Portable Non-contacting Transit Time Flow Meter, Model Portaflow SE	Approx. 7,500
TOTAL, excluding taxes	**Approx. 7,500**

Appendix II

Potential suppliers and contact persons for water metering options[6]

1. Coulter Water Meter Service Inc.
   180 Whiting Street, Unit B
   Ingersoll
   Ontario N5C 3B5
   Tel: 888-304-5558
   Attn. Rick McDuffe
   coulter@coultermeterservices.com
   www.coulterservices.ca

2. Hoskin Scientific Ltd.
   4210 Morris Drive
   Burlington,
   Ontario L7L 5L6
   Tel: 905-333-5510
   Attn. Derek McKeowen
   dmckeown@hoskin.ca
   www.hoskin.ca

3. Can-Am Instruments Ltd.
   2851 Brighton Road
   Oakville
   Ontario L6H 6C9
   Tel: 905-829-0030
   Attn. Ken MacDonald
   kenmacd@cogeco.ca
   www.can-am.net

[6] Note that reference to specific supplier is for general information only and does not suggest endorsement of supplier.