An Inexpensive, Automatic Gravity-fed Water Sampler for Investigating Water Quality in Small Streams

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Introduction

Water samples are commonly collected, either manually (grab samples) or with automated samplers, in many environmental monitoring and research programs (e.g., Toews and Gluns 2003; Winkler *et al.* 2004). Manual sampling in remote areas can be labour intensive and time consuming, whereas the price of automated samplers (around $4,000) may be prohibitive to many monitoring programs.

This article describes a low-cost (< $600 per unit), gravity-fed, automated water sampler (auto-sampler) that can collect water samples from small streams less than 5 m in bankfull width. The auto-sampler is best suited to collect samples for analyses of water quality measures in the dissolved phase, such as pH, conductivity, carbon, phosphorus, and ammonia. Sediment samples have not yet been collected with the auto-sampler, and therefore sediment sampling is not considered in this article.

Auto-Sampler Components and Design

A simple, lightweight gravity-fed auto-sampler can be constructed from commonly available irrigation supplies. The sampler consists of a water intake system, a valve manifold system, and a series of standard sample bottles (Figures 1 and 2). The water intake system (Figure 3) is constructed from a PVC pipe with a piece of screen mesh secured on the intake end to minimize large debris from clogging the lines and valves. The opposite end of the PVC intake pipe is connected to a 3–6 m length of polyethylene pipe that forms the main water supply line. The valve manifold system distributes streamwater from the intake pipe through electronically controlled valves into individual sample bottles (Figure 3). A plastic cargo box is used to contain the valves, the sample containers, and the sealed battery-operated control timer, which is programmed to control the electronic valves. Flexibility in sampling depends on the number of valves in the manifold and the features associated with the control timer. Electronic control timers typically control 4–12 valves, and can be connected in series to increase the number of samples that the auto-sampler can collect. For example, two timers controlling 12 valves each could be connected in series and programmed to collect a total of 24 samples from the same sample site.

Desirable features in a control timer include the ability to independently program each valve, a 30-day programmable clock, and a master valve option. Independent programming for each valve is essential because each valve represents one sample. A 30-day programmable clock allows for flexibility in sample scheduling (e.g., daily, weekly, or monthly). The master valve option (a valve that opens whenever a sample valve is opened) is adaptable to control small pumps where a gravity-fed approach is not feasible (e.g., lakes, ponds, large rivers). We are presently developing an automated pump sampler for this purpose.

Installation

The auto-sampler should be installed outside of bankfull width to avoid damage during high flows. The intake should be installed securely (e.g., wedged between rocks, fastened to rebar) within the streambed upslope from the auto-sampler, with enough hydraulic head (e.g., 1–2 m of vertical rise) for the gravity-fed intake system to function properly. For our applications we have chosen ¼-inch valves although ½- or ¾-inch valves can be used. Less hydraulic head is required for smaller valves compared with the larger valves, which require higher minimum operating pressures,

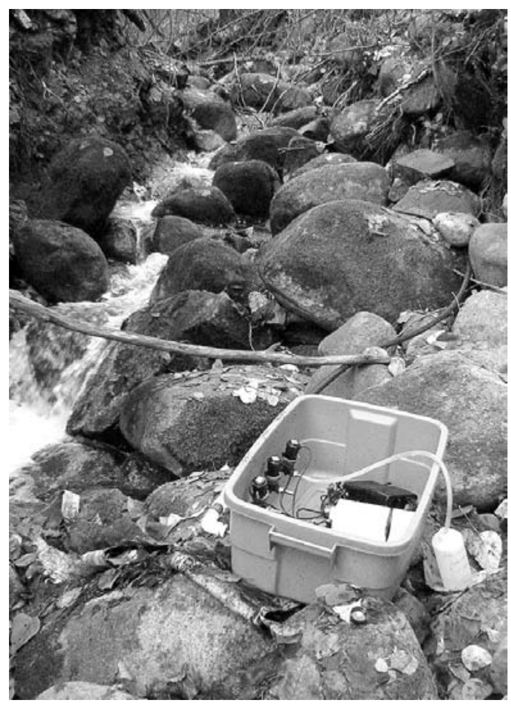

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Figure 1. Auto-sampler setup adjacent to creek.

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and therefore more hydraulic head. Except for the valves and the solenoid plungers, the entire system could be made from stainless steel, polyethylene, or Teflon where these materials are recommended for use in sampling different water quality parameters.

Upon securing the intake within the stream, the following points should be considered to minimize the potential for air locks in the water supply line and clogging of the intake screen. Air locks tend to occur in high points of the main intake line, particularly in highly aerated sections of stream. Intake lines should therefore be installed with a constant slope to the valve manifold, thus avoiding loops in the line that trap air. In addition, the intake screen should be submerged in non-turbulent, uniformly flowing water to minimize air bubbles entering the system. A ball valve at the lower end of the valve manifold should also be installed so that the intake lines can be manually flushed after installation and when changing the sample bottles (Figure 3). This flush allows water to flow through the intake lines to remove air and rinse the internal plumbing of the system with sample water. As the manual flush valve is larger than the ¼-inch sample valves, the flow rate is higher and thus the intake system flushes thoroughly.

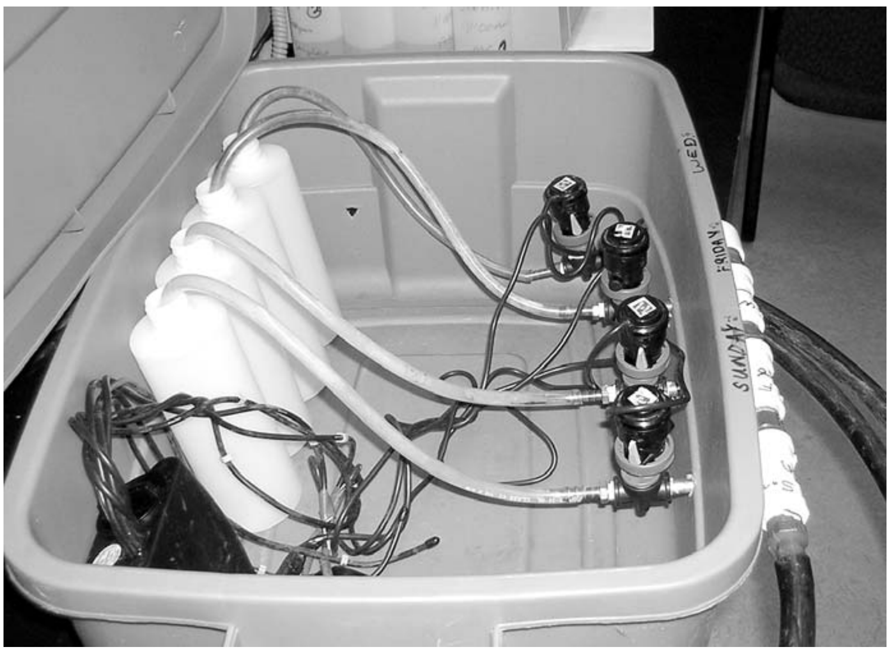

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Figure 2. Auto-sampler components and parts.

Due to the design of the sampler, clogged intake screens can significantly affect the operability of the unit. Clogged intake screens can be minimized by positioning the intake screen perpendicular to streamflow and by designating one valve to flush the system immediately before activating the sample valves. Flushing the intake system immediately before sample collection greatly reduces the risk of the intake becoming plugged or blocked with debris by comparison to a continuous flow setup. The system flush is programmed to be completed within less than 1 minute before activating the valve for sample collection.

After the unit has been installed and the control timer set, sample bottles are connected to the spouts of the valves designated for sample collection with a piece of tubing and a two-holed stopper. The time required on the control timer to fill the sample bottles will depend on the flow rate through the intake system. Similarly, the automated flush valve should be set to rinse the entire volume of the system at least 5 times immediately before sample collection. The amount of time required to flush the intake system can be calculated empirically by measuring flow rate through the system and the length of the main water supply line that is required for installation. For example, it would take 5 minutes to completely flush the volume of the intake line once given a flow rate of 1 L/min through 10 m of ½-inch intake line (volume of intake line is about 5 L; i.e., flushing time = volume of pipe/flow rate). The time required for sample collection can be calculated using the same approach (i.e., sample collection time = bottle volume/flow rate), but it is best to set the clock for more time than is required to account for decreases in flow rates. This approach ensures that sample bottles are completely filled and are flushed with sample water. Any excess water spilling from the sample bottles drains via holes in the bottom of the plastic cargo box.

Sample Collection Protocol

We designed and deployed the auto-sampler to collect specific water quality parameters. Therefore, this article will not detail sampling protocol, which varies with water quality parameter of interest. For further information regarding the design of reliable monitoring programs using automated samplers, refer to the *Automated Water Quality Monitoring Field Manual* (Resource Inventory Committee 1999).

Unit Performance

We used two quality control (QC) measures to evaluate the precision and performance of the auto-sampler. The first QC measure included the direct collection of water samples (i.e., grab samples) at the auto-sampler intake in conjunction with samples being collected with the auto-sampler. The second QC measure was used to evaluate whether leaching from and adsorption to the water intake system was contaminating water quality samples. We checked this by flushing deionized water through the auto-sampler at the end of the sample season. We then compared these samples with control samples of deionized water. Analyses of pH, conductivity, dissolved organic carbon, and dissolved nutrients (PO_4 and NH_4) indicate no significant difference between the grab samples, the deionized water, and samples from the auto-sampler ($p < 0.05$).

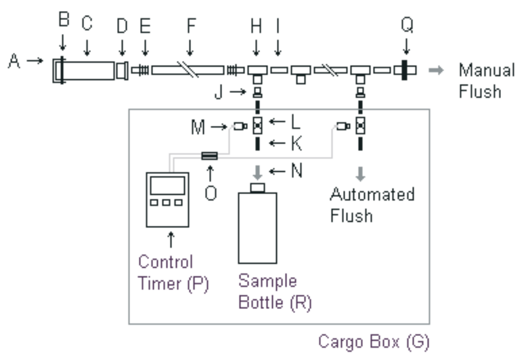

Figure 3. Schematic view of the auto-sampler. The labelled parts are listed in Table 1.

Table 1.
Equipment list for a five-bottle auto-sampler

	Water intake system	
	Item	Quantity
A	Screen mesh (10 x 10 cm)	1
B	2″ gear clamp	1
C	2″ PVC pipe	~30 cm
D	2″ x 1/2″ reducer bushing	1
E	1/2″ threaded x 1.5 cm (1/2″) barbed coupler	1
F	1/2″ polyethylene pipe	3–6 m

	Valve manifold system	
	Item	Quantity
G	Plastic cargo container with lid	1
H	1/2″ PVC threaded tee	6
I	1/2″ x 2″ threaded coupler	6
J	1/2″ x 1/8″ reducer bushing	6
K	1/8″ x 2″ brass nipple	12
L	1/4″ valve	6
M	Solenoid	6
N	1/4″ vinyl tubing	100–150 cm
O	1/4″ thick-walled heat shrink	25–30 cm
P	Battery-operated control timer	1
Q	1/2″ threaded PVC manual ball valve	1
R	500-mL polyethylene sample bottle	1–6

Applications and Constraints of the Auto-Sampler

In our study, we deployed and tested three auto-samplers for seven months (April to October 2004) in the Southern Interior of British Columbia. Units were installed in boulder–cobble streams with bankfull widths ranging between 1 and 4 m and gradients between 5 and 15%. Samples were collected from the units at a rate of 2–3 samples per week and during our field trials we found that required maintenance to the auto-samplers was minimal. Only one repair was required to a broken fitting, which caused the loss of one sample. On average, the two 9V batteries in each control timer were depleted by only 20% throughout the entire operation. All three auto-samplers were removed in late October due to freezing of the valves and intake lines.

The auto-sampler unit is aptly suited for our monitoring purposes (i.e., chemical water quality parameters, low summer flows, ice free conditions). However, the auto-sampler has not been tested or used under the following conditions that would warrant further investigation and possibly design modifications: (1) high flows and freshet, (2) sediment sampling, (3) freezing conditions, and (4) streams greater than 5 m bankfull width.

In summary, the auto-sampler has allowed us to collect water samples at a higher frequency relative to manual sampling and at a reduced cost compared with commercially available auto-sampler units. Our auto-sampler performed very well during low summer flows and allowed us to collect and analyze water samples for several dissolved water quality parameters. The auto-sampler was reliable, cost effective, and easy to maintain. Future testing and improvements to the design of the auto-sampler will likely increase its suitability to more diverse sampling environments and a greater variety of water quality parameters.

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