# Use of Aeration to Prevent Ice Buildup at Gaging Station Controls

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ABSTRACT

The buildup of surface ice at gaging station controls distorts the stage-discharge relation and causes large uncertainties in the accuracy of stream-flow data. An effective means of reducing or eliminating ice cover at gaging station control structures would improve the reliability of winter discharge data.

The technique of bubbling air in the water beneath boats, docks, and locks to prevent ice buildup has been used successfully for many years. The U.S. Geological Survey implemented a pilot project to evaluate the effectiveness of this technique to maintain an ice-free environment at gaging station controls during the 1988-89 and 1989-90 winter seasons. Four sites having varying climatic conditions, control types, and stream widths were selected. Systems at two sites operated continuously and allowed only a minimal buildup of ice. At the other two sites, mechanical or operational problems resulted in several system failures. Experience gained during the first year improved second-year operation. Preliminary results indicate that this technique offers an effective way to prevent ice buildup at gaging station control structures.

## Introduction

Many stream-gaging stations include a low-head concrete or sheet piling weir that serves as a control structure to create a stable stage-discharge relation. When ice forms on these man-made controls or on natural channel controls, the normal stage-discharge relation is disrupted, causing uncertainties in computation of actual flow. For many years it has been common practice to periodically remove ice buildup manually with ice chisels or similar tools. Once the ice is removed and flow conditions stabilize, the normal stage-discharge relation describes actual flow until new ice formation again disrupts normal relations. Manual ice removal may be required several times a week during winter periods. This process is inefficient and costly. A method that would prevent ice formation would be the best solution to this problem. Heaters enclosed above small artificial controls have been used with some success, but energy costs are high and many operational problems occur.

The technique of bubbling air into water beneath boats and docks to prevent ice formation has been used successfully for several decades. More recently the technique has been routinely used to prevent ice buildup at navigation locks.

The U.S. Geological Survey implemented a pilot project to evaluate the effectiveness of this system to maintain an ice-free environment at gaging-station controls during the 1988-89 and 1989-90 winter seasons. Four sites, three in New York and one in North Dakota, were selected for study.

## Site Selection

The sites were selected to represent a variety of channel and control configurations as well as a range of climatic conditions. Electric power had to be available to operate the air pump.

FALL CREEK NEAR ITHACA, NY (STA. NO. 04234000)

This site is a long-term gaging station with a drainage area of 126 $mi^2$ (326 $km^2$) and winter flows in the range of 50 to 100 $ft^3/s$ (1.4 to 2.8 $m^3/s$). The streambed is ledgerock with depths of 1 to 3 ft (0.3 to 1.0 m) for the reach several miles above the gage. The channel typically is completely ice covered. The creek receives little direct sunlight during the winter months. The gage shelter is on the left bank about 50 ft (15 m) upstream from the control, which is a concrete broad-crested weir 90 ft (27 m) long with a 1 ft (0.3 m) deep, 20 ft (6.1 m) long rectangular notch near the right end. The control is located at the head of a falls, where winter temperatures and the spray of water as it bounces over the ledgerock of the falls combine to gradually form an ice tunnel below the control. This formation normally builds until it finally meets the ice cover of the pool, causing siphonic action.

LITTLE TONAWANDA CREEK AT LINDEN, NY (STA. NO. 04216500)

This site is a long-term gaging station with a drainage area of 22.1 $mi^2$ (57.3 $km^2$) and winter flows in the range of 15 to 50 $ft^3/s$ (0.4 to 1.4 $m^3/s$). The streambed is stable clay above the concrete control structure. The creek flows westerly and receives little direct sunlight during the winter months. The gage shelter is on the right bank about 10 ft (3 m) upstream from the bridge and control. The control is a partially reinforced concrete weir with a catenary-shaped crest and is located at the upstream side of the bridge. The downstream side of the control has about a 2 ft (0.6 m) vertical drop into a short sluiceway under the bridge then flows to a pool downstream. During the winter months the gage pool freezes over completely as does the pool downstream. Ice builds inward gradually until an ice tunnel is formed over the control, causing siphonic action.

MANOR KILL AT WEST CONESVILLE NEAR GILBOA, NY (STA. NO. 01350080)

This site is a relatively new gaging station with a drainage area of 32.4 $mi^2$ (45.9 $km^2$) and a winter flow in the range of 20 $ft^3/s$ (0.6 $m^3/s$). The channel is shale-ledgerock and the stream flows in a westerly direction. The gage is located on the right bank about 20 ft (6 m) above a ledgerock control. The control is at the downstream end of a large natural pool with a smooth bedrock bottom. The control itself is about 15 ft (4.6 m) wide with 11 ft (3.4 m) of it forming a natural V-type notch 1 ft (0.3 m) deep at center.

HEART RIVER ABOVE LAKE TSCHIDA NEAR JUDSON, ND (STA. NO. 063445780)

This site is a new manometer-type gaging station with a sheet piling artificial control. The drainage area is 1,700 $mi^2$ (4400 $km^2$) and winter flows are in the range of 5 $ft^3/s$ (0.4 $m^3/s$). The sheet piling control is about 30 ft (9 m) wide and forms a pool about 2 ft (0.6 m) deep. The distance from the lowest point of the piling to the downstream channel is about 1.5 ft (0.5 m). Since this is a new station, little was known about the freeze-up pattern, except that complete channel ice cover could be expected.

Equipment

An aeration system consists of an electrically driven air pump, mounted in the gage house, and a diffuser system to distribute the air and create bubbles on the streambed behind a control (Figure 1). The concept is that the bubbles will cause relatively warmer water from the streambed to rise to the surface. The warmer water and bubble-caused disturbance of the water surface will inhibit ice cover formation. Theoretically, the deeper the pool, the more warm water will be available and the more effective the system will be.

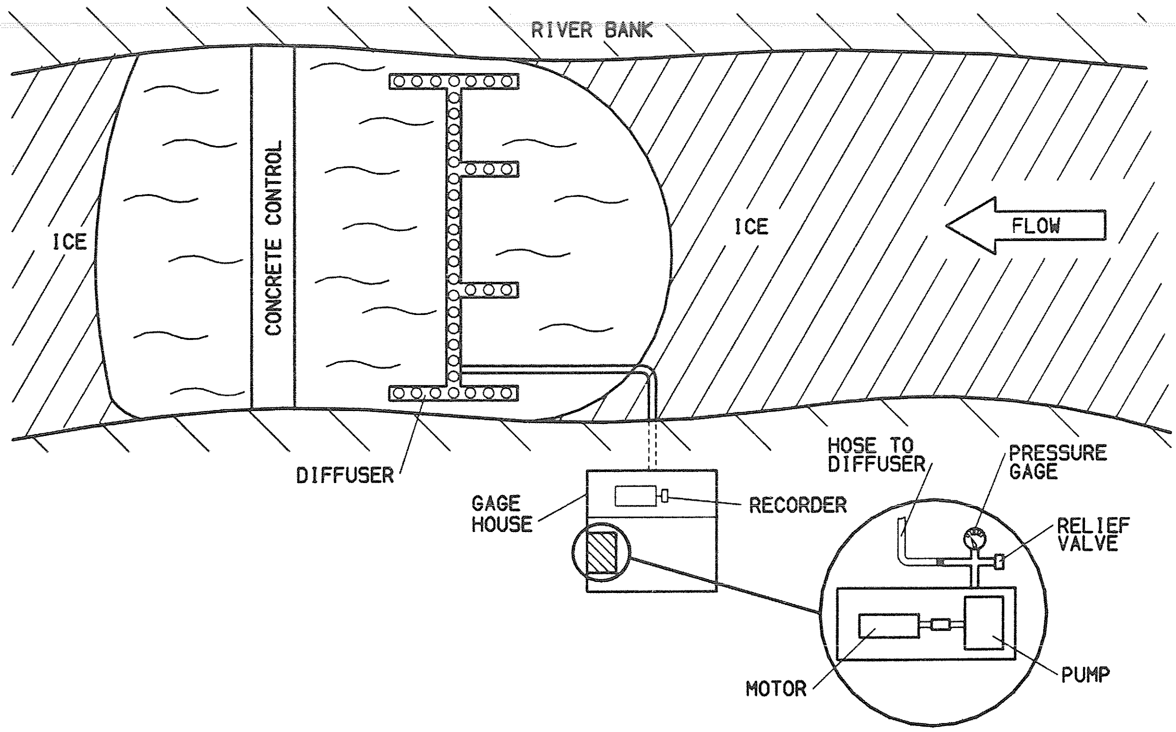


Figure 1.--Aeration System Diagram

The preferred air pump is a low pressure, high volume type with as few moving parts as possible to minimize wear during continuous operation. The pump selected was the AQUATHAW Model 500 Air Injection Pump[1] developed and sold by Hydro Aeration, Inc., of Cleveland, Ohio. This pump is powered by a 110 volt, 1/2 horsepower (370 W) electric meter. The pump, motor and controls are packaged in a weatherproof aluminum box. Diffusers were fabricated on site to fit individual channel configurations. The New York systems used 1 inch (25.4 mm) galvanized pipe with approximately thirty-five 1/16 inch (1.5 mm) holes spaced 1/2 ft (0.15 m) apart. The North Dakota system used copper pipe for the diffuser. The Fall Creek system had a single pipe installed perpendicular to the stream. The other systems had "fingers" at 90 degrees to the main pipe to distribute more air to the edges of the streams. The diffusers were held on the streambed by wedging them under large rocks or were held down with concrete-block weights. A variety of pipes and hoses were used to connect the pumps located in the gage houses to the instream diffuser. Inexpensive garden hose worked as well as anything else. Previous applications of this technology involved installations in still water, where bubbles move straight up. In the Survey's applications in moving water, a downstream velocity component requires that the diffuser systems are located upstream of the desired open-water area. Initial design of diffuser configuration and placement were engineering estimates.

Mr. Larry Frish, President of Hydro Aeration, Inc., has designed and installed many successful systems in marinas throughout the Great Lakes area. He took a very active interest in this project and provided a great deal of personal support, including several trips to New York to participate in the installation of the first site and several follow-up trips at no cost to the Survey.

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[1] Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

## Results

The four systems were carefully monitored and evaluated for performance of the system and effectiveness in preventing ice buildup. Two systems, those at Little Tonawanda Creek and Manor Kill, operated continuously through both winter periods and allowed only minimal buildup of ice. Reconfiguration of diffuser design might eliminate all ice buildup at these sites.

The Fall Creek and Heart River systems encountered several operational failures that caused the systems to shut down and thus allowed ice formation at times throughout the evaluation period. Once the air supply was cut off the systems froze and were difficult to reactivate. In one case the system wasn't activated early enough and was partially frozen, causing a pressure buildup that shut off the motor because of a thermal overload. The North Dakota site had a low-voltage power supply, which also caused thermal protection shutdown before a voltage-tolerant motor was installed. Pressure gages and pressure relief valves were determined to be essential in all future installations. Modifications to diffuser configuration and relocation in relation to the weir structure may be necessary to find the right combination at any specific site. The diffuser system at the Fall Creek site was washed away each year during spring breakup and high water. At the Heart River site, a bearing in the pump failed in the second winter.

## Conclusions

The result of this pilot project indicates that this technique offers an effective and economical way to improve the accuracy of winter discharge data at many gaging stations. These systems will work best on small streams in areas of moderate winter temperatures. Stream width, velocity, and depth of water are critical factors, although these limits have not been quantitatively defined.

The Geological Survey has improved its knowledge of system design through experience with a variety of field conditions and can now design a system with a high probability of operational success. Future studies will be conducted to define operating limits of this technique.