DIVERSION WELLS - A LOW-COST APPROACH TO TREATMENT OF ACID MINE DRAINAGE

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ABSTRACT

The diversion well is a simple device initially developed for treatment of stream acidity caused by acid rain in Norway and Sweden. A typical diversion well consists of a cylinder of metal or concrete, 5-6 ft (1.5-1.8 m) in diameter and 6-7 ft (2.1-2.4 m) deep. This "well" may be erected in or beside a stream or may be sunken into the ground by a stream. A large pipe, 8-10 in (20-30 cm) in diameter, enters vertically down the center of the well and ends shortly above the bottom, which is usually of metal or metal-shielded concrete. Water is fed to the pipe from an upstream dam and intake, sufficient to keep the pipe full and provide a hydraulic head of at least 8 ft (2.4 m). The water flows up through the well and out an outlet notch in the top edge, from which it is conveyed back to the stream. The well is about half full of limestone gravel of a size determined by local conditions but usually about 3/4 " (2 cm) in nominal diameter. The flowing water fluidizes this limestone bed, the acid in the water reacts with the limestone and is neutralized, and the churning action grinds the limestone to fine powder which in part reacts further with the acid and in part is carried into the stream to achieve further neutralization. Both the excess fine powder and any chemically-formed precipitate can be recovered through use of a downstream settling basin, but this is usually not necessary. In some cases, the top of the well is flared out to cause reduced water velocity and allow undissolved particles to sink back into the fluidized bed.

We have constructed three diversion wells in Pennsylvania, all of which are presently treating primarily mine drainage in addition to some acidity from precipitation. One, on RauschCreek

(trib. Stony Creek) in Dauphin County, was constructed in 1986, while the other two were constructed in fall 1990 and operate as a pair to treat mine drainage in Lick Creek (trib.Babb Creek), Tioga County. During much of the operational period of these wells, I have been testing different sizes and grades of stone. This has led to erratic results, but I can say with some confidence that a diversion well of the size described above is capable of raising pH of a stream by one unit or more, provided the flow is within an acceptable range. I plan further experiments to more closely determine this range, but a good average is approximately 5 cfs (1.5 m3/sec)I have detected no adverse effects of diversion well operation on fish or aquatic macroinvertebrates. There is some evidence of colonization by macroinvertebrates and fish below our longest-operating diversion well, compared to pre-treatment conditions.

Diversion wells have proven successful for treatment of precipitation-acidified streams of moderate flow. They hold considerable promise for treatment of acid mine drainage in similar streams.

INTRODUCTION

Unlike the United States, the Scandinavian countries do not have the luxury of a choice of strategies for combating acidification of natural waters due to acid precipitation. The great bulk of precursor substances that form acid rain and snow in Sweden originate far outside its borders, in areas where the Swedes and their neighbors have little political or economic influence. At the same time, their streams and lakes are highly vulnerable to acidification and have been receiving high levels of acid precipitation (Oden, 1976). Thus, the early development of effective treatment methods was, for them, the highest priority once the problem was defined.

Faced with this need, the Swedes (and also the Norwegians) made a very large commitment of public money and scientific effort to simultaneously increase understanding of acid precipitation and its effects, and develop effective methods to mitigate those effects. Attainment of the first goal is demonstrated by the large number of high-quality scientific publications on these problems that have been published by Norwegian and Swedish workers (for summaries see Braekke 1976, Drablos and Tollan 1980, Tollan 1981, and Cowling 1982). The second goal has resulted in the development of several types of mechanical "dosers", i.e. machines which mechanically add powdered limestone or other basic substances to water at a rate somewhat proportional to flow and acid load. Some examples of this include the slurry dose feeder, the dry feeder, the Hellefors limer, and the Boxholm doser (Cementa Movab 1983, Hasselrot and Hultberg 1984, Rosseland and Skogheim 1984). In a separate project on mitigation of acid precipitation effects, now being completed, my research group evaluated three such devices -one Boxholm doser imported from Sweden and two American prototype designs. We compared these to the diversion well and to the gravity-feed hopper used by many miners for mine drainage treatment with soda ash briquettes. The diversion well was the most cost-effective within its appropriate flow range, and by far the most trouble-free. Earlier, we compared the gravity-feed hopper and two other simple approaches; none of them were fully successful (Arnold, Skinner, and Spotts, 1989).

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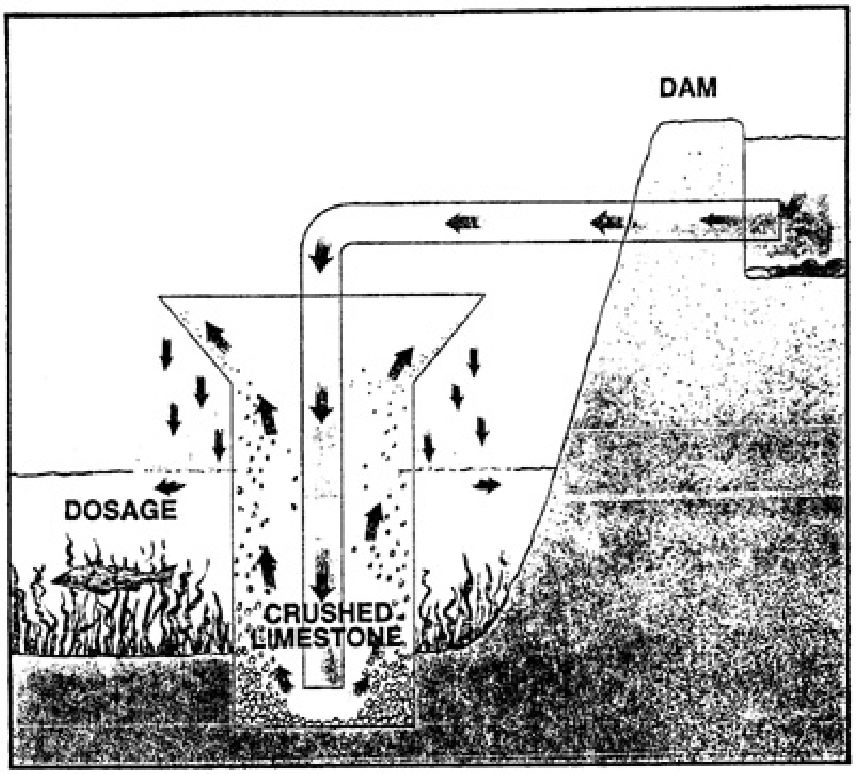

Figure 1. Schematic arrangement of a typical diversion well (from Cementa Movab 1983).

My involvement in acid rain mitigation, sometimes using adaptations of techniques that had been used for acid mine drainage treatment, led to the question of the reverse use. Thus, in response to many inquiries, I am now exploring the use of diversion wells in particular as a low-cost, potentially effective treatment method for acid mine drainage.

EXPERIMENTAL INSTALLATION SITES

Rausch Creek / Stony Creek Our first installation was completed in 1986 in cooperation with the Dauphin County Chapter of Trout Unlimited, who obtained all materials and provided volunteer labor and equipment. The Pennsylvania National Guard also provided equipment. This well is intended to improve the water quality of Rausch Creek and thus Stony Creek into which it flows. The watershed is quite narrow and the upper 15 miles (24 km) of stream are within Pennsylvania State Game Lands No. 211, otherwise known as Saint Anthony's Wilderness (Figure 2). The valley is long, narrow, and rocky. Rausch Creek enters Stony Creek from its north side quite high in the watershed. The diversion well is located on Rausch Creek at the point where it is crossed by the single access road, a former railroad grade. Stony Creek enters the Susquehanna River at Dauphin, shortly after the valley broadens out and joins that of the river. it provides an important outdoor recreational resource to the large concentration of residents in the Harrisburg area, and contains some important examples of unusual flora and fauna (Bonta 1985).

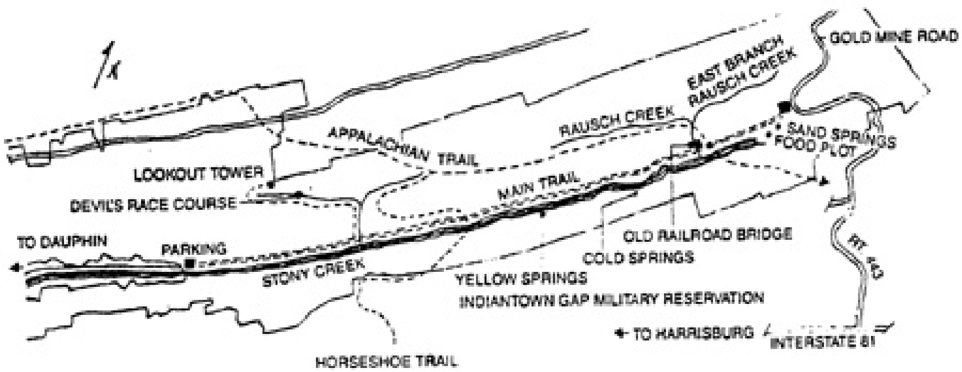

Figure 2. Stony Creek Valley, Dauphin and Lebanon Counties, Pennsylvania. Modified from Bonta, 1985.

Coal mining took place in the watershed for some time in the first half of the nineteenth century, but the mines closed around 1856. Unfortunately they continue (135 years later!) to discharge some acid mine drainage water at all times. This gives rise to a rather unusual situation wherein the acidity of the water in Rausch Creek is usually greater during low-flow periods than at time of high water. This is the opposite of the usual situation. In addition, the thin soils and insoluble bedrock of the area lack much ability to neutralize the acidity of acid precipitation. Thus the project had dual objectives of mitigating both acid precipitation and acid mine drainage. Historically, water quality in Stony Creek has been poor, and in recent years fishing has been primarily sustained by stocking. There have, however, been sparse populations of several other fish species present so far back as records exist (Gash and Friday 1972, Denoncourt 1974, 1975). Also, while aquatic invertebrates are not particularly abundant, there is a good variety of species representing most groups. Aquatic plant growth is abundant in Stony Creek, but is nearly absent in Rausch Creek, the principal mine drainage tributary.

Lick Creek/Babb Creek Representatives of the Pennsylvania Environmental Defense Fund contacted the author in early 1990 concerning the possibility of treating a long-standing mine drainage problem in north central Pennsylvania with diversion wells. A sum of money had become available as the result of a court case brought by the Fund, and was designated for improvement of water quality somewhere in the Pine Creek watershed. Pine Creek is an important recreational resource for the large area which it drains. It traverses the well-known Grand Canyon of Pennsylvania and enters the West Branch of the Susquehanna River near the city of Jersey Shore. Its major tributary from the east is Babb Creek.

Although many mine drainage and other pollution problems in the Pine Creek watershed have been corrected, Babb Creek remains a source of serious deterioration in water quality. Two streams compose the bulk of the problem. Wilson Creek is heavily polluted with acid drainage from several abandoned mines and is known as the stream that turns Babb Creek orange. Lick

Creek is a higher tributary with lower flow and fewer, smaller acid sources than Wilson Creek (Boyer, Kantz et al. 1976). Above Lick Creek, Babb Creek is an excellent woodland trout stream for several miles. Both Babb and Lick Creeks flow mostly through lands of the Tioga State Forest. Thus it was decided to attempt extending the "trout zone" another 6 miles (9.7 km) downstream (to Wilson Creek) by treating Lick Creek (Figure 3). A site for the diversion well was chosen high in the watershed of Lick Creek, about 1 mile (1.6 km) below the village of Arnot. In order to strengthen the treatment and provide for a greater range of flow capability, two diversion wells were constructed side-by-side.

Construction of the Lick Creek diversion wells involved a cooperative effort among our Unit, the Pennsylvania Department of Environmental Resources, Pennsylvania Environmental Defense Fund, and local sportsmen's groups. Operation began in November 1990. Although routine maintenance and monitoring are being done by Tioga State Forest personnel and the Pine Creek Watershed Association, I am seeking outside funding to support a scientific research study of the operation and effect of these wells.

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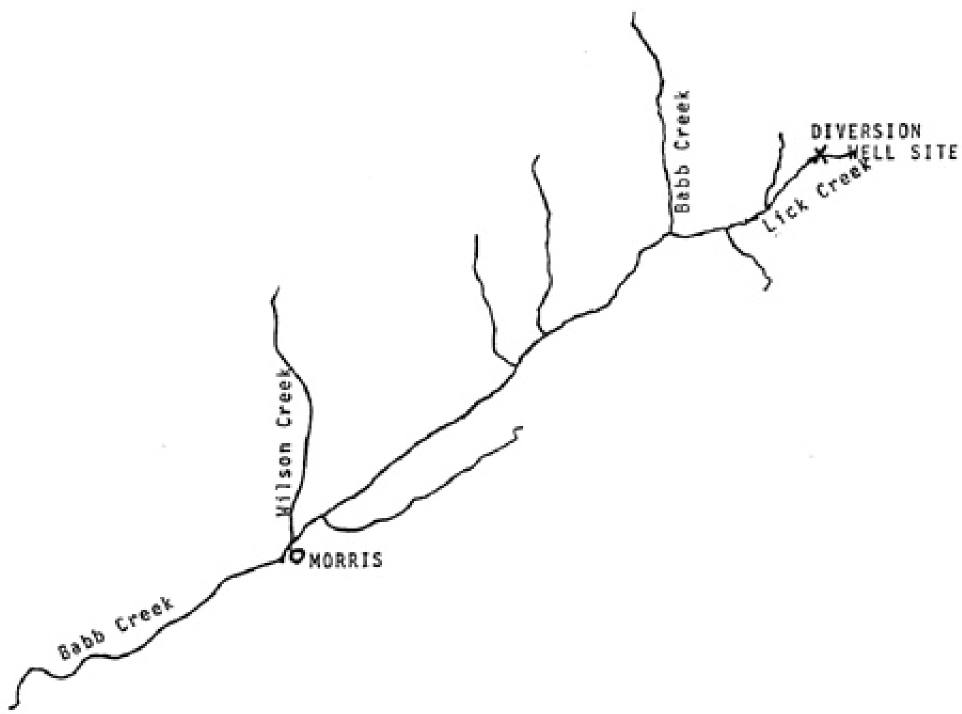

Figure 3. Babb Creek watershed, Tioga County, Pennsylvania.

CONSTRUCTION FEATURES

All three wells are sunk into the ground on the stream bank well above normal flood levels. About 8" of the well side is exposed, and a 12" x 8" (30 x 20 cm) notch in the lip of the well provides for the outflow, which is carried to the creek bed by a channel. At Rausch Creek the channel is natural stone masonry; at Lick Creek plastic corrugated 12" (30 cm) drain pipe cut in half lengthwise was used. The wells are composed of two precast concrete "manhole sections" set one atop the other, forming a cylinder 6 feet (1.8 m) deep and the same in inside diameter. A layer of reinforced concrete is poured in the bottom of the well after placement. At Rausch Creek we found it necessary to cover this bottom layer with a steel sheet to prevent erosion. This may eventually have to be done at Lick Creek as well. An 8" (20 cm) diameter hole is cut in the side of the well about 6" (15 cm) below the top for entrance of the water pipe. We investigated the use of more readily available material such as septic tanks and culvert sections, but they lacked sufficient sidewall strength for the purpose, or were not available in appropriate sizes.

All the wells are fed by 811 (20 cm) diameter heavy-duty polyvinylchloride (PVC) pipe with rubber-gasketed joints. Near bends the joints are secured by driving three equidistant 3/8" lag screws through the overlapping sections. It is necessary to apply about 8 feet (2.4 m) of hydraulic head above the well surface for proper operation. The supply pipes run upstream until at least that elevation has been reached, then end in a reverse "T" fitting which helps prevent leaf and trash intake (Figure 4). (Most leaves and sticks entering the intake will pass through the well without any problem, but occasionally an accumulation does form at bends in the pipe). The pipe intakes are fixed in a pool area of the stream and a low dam is constructed of native materials to maintain the water level over the intakes. The height of this dam is limited to 3 feet (0.9 m) by Pennsylvania regulations; higher dams involve extensive permit and monitoring requirements. There has been some trouble with air entrainment at the intakes due to vortex formation (and occasionally low flow); the air eventually accumulates in the pipe and reduces flow and well efficiency. We have installed small tubing standpipes at the upper end of the main pipe run and removable plugs (lag screws) at various locations along the pipe to allow manual bleeding off of accumulated air.

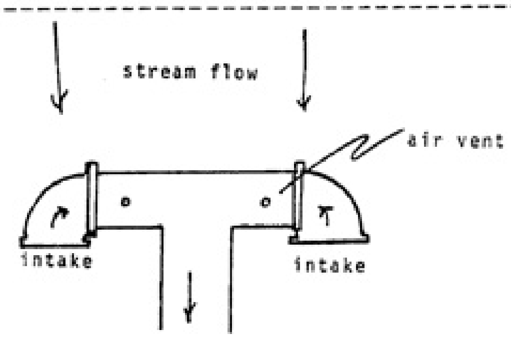

Figure 4. Arrangement of intake piping for diversion wells.

After entering the well, the pipe makes a 90-degree bend and extends vertically to within 2-3 inches (5-8 cm) from the bottom. Although the wells will work with this arrangement, efficiency has been improved by installation of a metal collar at this point having lateral holes so that the water is directed sideways rather than down against the bottom. To reduce vandalism and increase safety, a metal grid is fitted over the top of the well. This can be fabricated from rod stock or made of open steel bridge decking. Two useful tools for maintenance of the wells are a long metal rod with loop handle on the upper end and a short right angle section on the lower; and a section of 2" (50 cm) PVC pipe about 6 ft. (1.9 m) long. The pipe can be used as a "waterscope"; when its lower end is submerged the action of the moving stone can be observed by looking down the pipe.

CHOICE OF STONE

Although the limestone used depends to some extent on economical transport distance, some effort should be made to locate the best available material. We have tried material ranging from flakes about 1/2" (1.2 cm) in longest dimension to chunks about 1" (2.5 cm) or larger in diameter. The smaller materials tend to wash out of the well more easily, while the larger require considerably more water flow and also provide less surface area for chemical reaction. We are now using material in the range of 1/2" - 3/4" (1-2 cm) in diameter quite successfully.

Originally, from our work with powdered limestone "dosers", I felt that it was crucial to have the maximum possible content of calcium carbonate ($CaCO_3$) in the stone, at least greater than 90 per cent. After considerable experience and many discussions with geologists and quarrymen, I have come to feel that hardness of the stone is as important, up to a point, as calcium content. A very hard, dolomitic limestone will react more slowly and be more resistant to grinding than a soft, calcitic variety. Most quarries have at least basic information on hardness and calcium content, although I have found their specific promises concerning material characteristics and delivery to be untrustworthy in many cases.

Stone consumption rate depends on many factors including hardness and chemical characteristics of the stone, water chemistry, original size, and flow rate. Generally the dosers we have built use less than a cubic yard (0.7 m^3) per week (one or two wheelbarrow loads). The makeup stone is simply dumped into the well by hand to maintain a stone depth about one-half the depth of the well. Although other workers have gone to considerable lengths to calculate the exact consumption rate and particle size distribution under various conditions (Sverdrup, 1983; Fraser et al. 1985), 1 feel that local variation will in most cases negate the accuracy of such calculations and that a trial-and-error process is necessary to achieve optimum results.

PRELIMINARY RESULTS

During much of the operational time of the diversion wells we have been experimenting with different types of stone, and our financial ability to do intensive monitoring has been limited. In general, it appears that for flows up to about 5 cfs (0.14 m^3/sec), diversion wells have the capability of producing a rise in pH of one to two units, depending on flow and initial pH. A corresponding rise in alkalinity may be expected, although total alkalinity levels may remain quite low. Some preliminary results are illustrated in Figure 5.

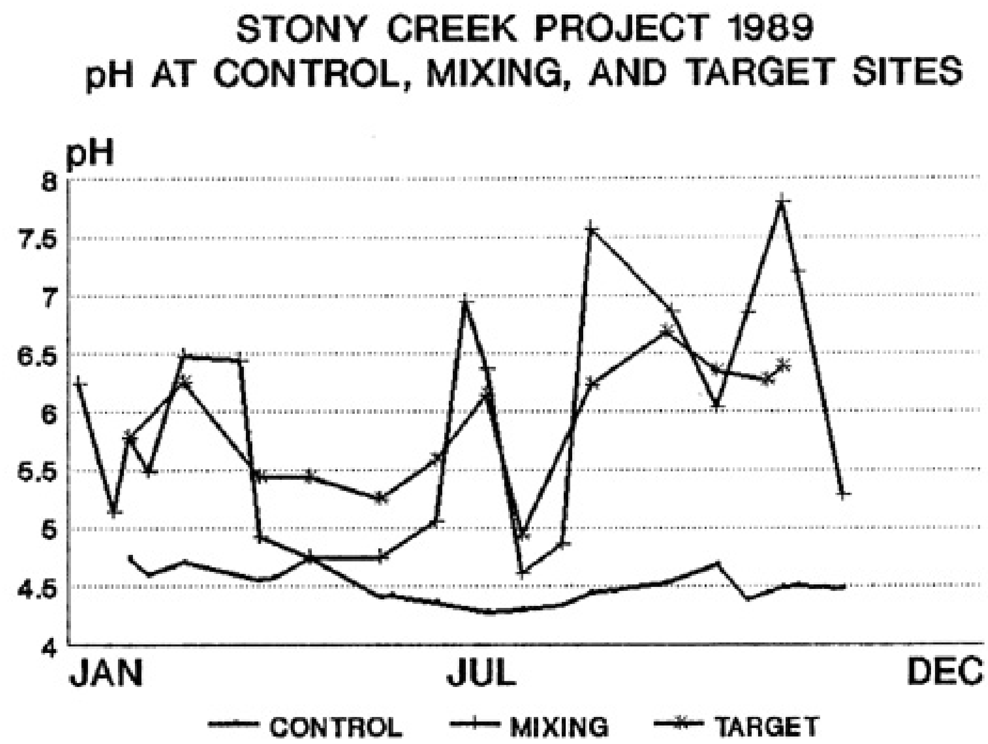

Figure 5. Preliminary results of diversion well treatment of Rausch Creek and Stony Creek, Lebanon County, Pennsylvania.

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