A Great Lakes Sea Grant Network Publication

Sand Filter Intakes Could Safeguard Vital Water-Supply Systems from Zebra Mussels

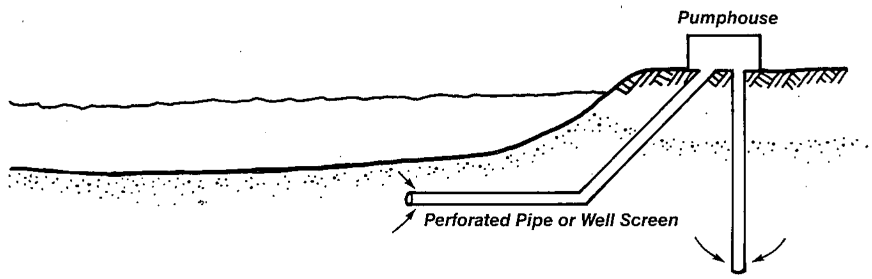
by Philip Keillor, Wisconsin Sea Grant Advisory Services

The zebra mussel (*Dreissena polymorpha*) invasion is threatening Great Lakes industrial and municipal water-supply systems. First reaching Lake St. Clair and Lake Erie during 1988, the invaders quickly infested and seriously impaired water intakes on the Detroit River and Lake Erie. Now, the menacing mollusk is spreading through the Great Lakes and into major inland rivers.

The municipal and industrial water-supply systems under attack have neither been designed for, nor exposed to, a mollusk with the anchoring tenacity and accreting ability of zebra mussels. They attach, grow and accrete; reproduce, die and rot; and clog, impair or shut down water-supply systems.

Figure 1

Horizontal and Vertical Wells with Bank Infiltration



A Measure of Prevention

Water-supply system operators have strategic options. They can attempt to "prevent" zebra mussel infestations by using sand filter intakes — or they can attempt to "cure" infestations with water treatment and amortize the costs of zebra mussel removal and system damage repair.

For decades, various types of sand filter intakes have been used in some municipal water-supply systems along the shores of the western Great Lakes and along the banks of inland rivers in North America.

How can sand filter intakes exclude zebra mussels? The zebra mussel in its smallest, larval form is 40 to 70 microns in diameter, about the size of silt particles. (One micron is equal to 0.00004 inch). At this size, they are not likely to pass through fine sand layers and would probably be destroyed while passing through the sharp edges found in coarse sand layers.

Consider that in the 1880s zebra mussel infestations impaired the Rhine River water intakes of Hamburg, Germany, until sand filters were installed. Thereafter, zebra mussels gradually disappeared from the city's water distribution system. Nearly a century later, the British observed that zebra mussel larvae were not found in water mains downstream of sand filters.

Types of Sand Filter Intakes

All sand filter intakes draw water through porous layers. Some use naturally layered soil and sediment, others use constructed layers, and various combinations are possible. Rapid sand filters

Figure 2

Radial Collector Well with Bank Infiltration

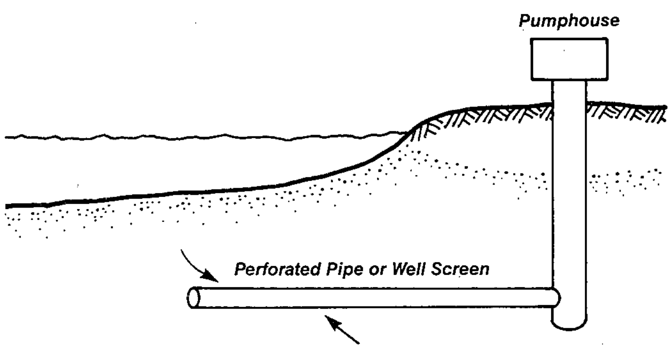


Figure 3

Buried Pipe Grid with Lakebed Infiltration

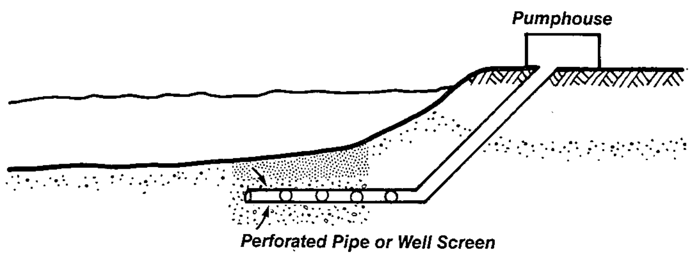


Figure 4

Infiltration Bed Using a PVC Pipe Grid Ludington, Michigan

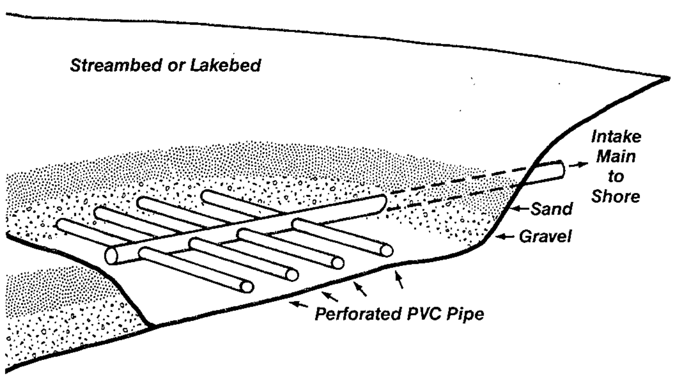
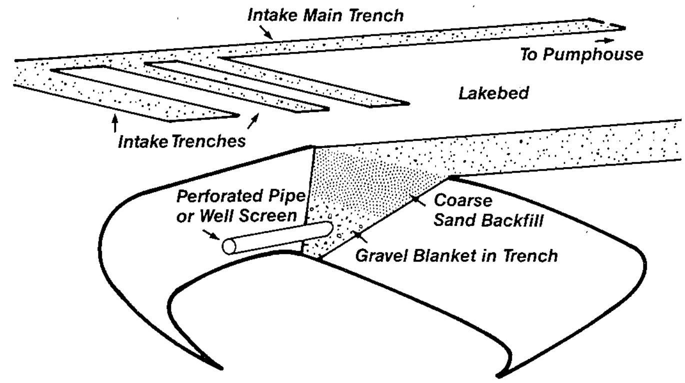


Figure 5

Sand Filter in Lakebed or Sreambed Trenches



typically have flow rates of 2-4 gallons per minute (gpm) per square foot of filter area; slow sand filters, 0.04-0.08 gpm per square foot.

Lakebank or riverbank filtration systems use horizontal water flow through the natural perimeter of a waterbody. Water withdrawal through bank filtration occurs at very low flow rates, similar to the flow rates of slow sand filters (Fig. 1).

Dusseldorf, Germany, has four riverbank intakes with a combined capacity of 135 million gallons per day (mgd). Riverbank filtration has been a common practice in Germany for a century.

Radial wells (also called Ranney wells) are a common form of bank filtration, used since the early 1930s, in Europe and the United States. They have one or more vertical caissons (or cylinders) sunk less than 100 feet into a permeable ground-water aquifer adjoining a waterbody. A number of well screen pipes extend horizontally from each caisson into the surrounding soil (Fig. 2).

Water is withdrawn through radial wells at very low infiltration rates, typically 0.01 to 1.20 feet per hour (fph). In comparison, a rapid sand filter intake can have an infiltration rate of 32 fph.

Radial well systems have been built for capacities up to 144 mgd, a capacity typical of the municipal water needs of a large city. Smaller radial wells at Grand Haven, Mich., and Manitowoc, Wis., have been in operation for more than 45 years.

Lakebed or riverbed infiltration systems typically use a grid of pipes buried beneath a thick layer of gravel and sand overlain with natural sediments (Fig. 3).

A Lake Michigan lakebed intake at Ludington, Mich., has pipes buried in 6 feet of gravel overlain with 2 feet of coarse, graded sand and 8 feet of lakebed sand. This intake has been in operation for over 20 years and has seldom clogged (Fig. 4).

The Ludington intake withdraws 8 mgd through a 1-acre filter bed at an infiltration rate of 0.12 gpm per square foot of filter area. This rate is similar to that of a radial well and slightly higher than that of a slow sand filter.

One variation of the lakebed infiltration bed is a trench-type filter bed. Superior, Wis., has successfully used a number of trenched filter beds for 100 years to withdraw 2.5 mgd from Lake Superior. Charlevoix, Mich., has had some clogging problems with their 2 mgd trenched intake built in 1987 (Fig. 5).

Can, or should, sand filter intake designs be scaled-up to accommodate the large water-supply systems of major cities and power plants? Previous consideration of large sand filter intakes resulted in mixed opinions about their feasibility. Outdoor, rapid sand filter bed designs were considered in the 1970s for intakes as a way to exclude larval fish and fish eggs from large nuclear power plant systems.

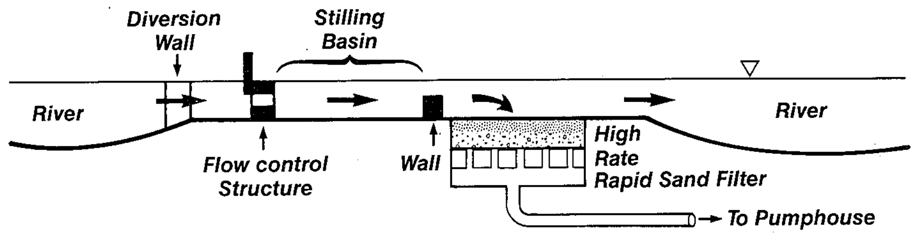
A conceptual design was developed for a 969-mgd capacity sand filter intake on the Columbia River (Figs. 6 and 7). The design flow rate was 8.8 gpm per square foot of filter area. Another design was considered and pilot-tested for a large power plant on Puget Sound. It was a 2.1 acre filter intake with 969-mgd capacity at a filtration rate of 7.5- to 10.5-gpm per square foot. Even larger filter bed intakes were proposed for a water diversion project on the Sacramento River (Fig. 8). They would be self-cleaning, direct sand filters with filtration rates of 4.9 gpm per square foot. A 10.5-acre filter bed would have a capacity of 3,230 mgd. A 42-acre filter bed would have a capacity of 12,920 mgd. None of these conceptual designs was implemented although some engineering opinion was favorable.

A Ludington-design intake sized for a power plant using 35 mgd of makeup water would require at least 5 acres of lakebed infiltration area. A Ludington-design intake with a 600-900 mgd capacity, to serve the needs of a city the size of Chicago or to provide once-through cooling water for a large power plant, would require at least 74-111 acres of lakebed infiltration area.

Another intake design option is a large trench-type sand filter intake. If the trench filter were 6-feet wide with a flow rate comparable to that of the Ludington design, 6 miles of filter trenches would provide a capacity of 35 mgd. A capacity of 600-900 mgd would require at least 100-150 miles of filter trenches (Fig. 5).

Figure 6

Conceptual Outdoor Rapid Sand Filtration Columbia River



The Pros and Cons

Sand filter intakes could exclude zebra mussels from water-supply systems. Moreover, maintenance costs for sand filter intakes are likely to be lower than the costs of zebra mussel infestation treatments, which involve additional water purification along with periodic scraping, removal and disposal of dead zebra mussels.

The costs for constructing sand filter intakes have been comparable to those for more conventional intakes, and sand filter intakes reduce the need for pre-treatment of raw water.

However, sand filter intakes can clog, reducing infiltration rates — a potential problem that can be reduced by oversizing the infiltration area, by careful siting or by providing a back-up storage reservoir.

Sand filter intakes have been used to provide a wide range of water-supply capacities for many years. Yet, though technically feasible, they have not been used for the largest capacity water-supply systems (in excess of 144 mgd).

In evaluating the "prevention" option of sand filter intakes versus the "cure" option of water treatment and scraping of mussels, it is important to estimate the risks and likely costs of those risks for both options. The risks and costs of zebra mussel penetration of a water system that is treated and mechanically scrapped free of mussels are just as important to consider as the risks and costs of possible sand filter intake clogging.

For further information, contact: Philip Keillor, Coastal Engineer, University of Wisconsin Sea Grant Advisory Services, 1800 University Ave., Madison, WI 53705-4094; phone: (608) 263-5133; fax: (608) 263-2063.

Figure 7

Conceptual Rapid Sand Filter Facility Columbia River

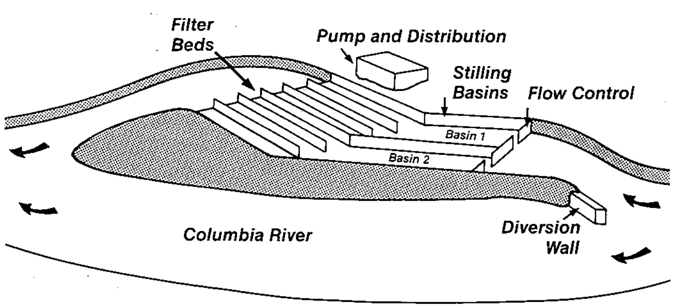
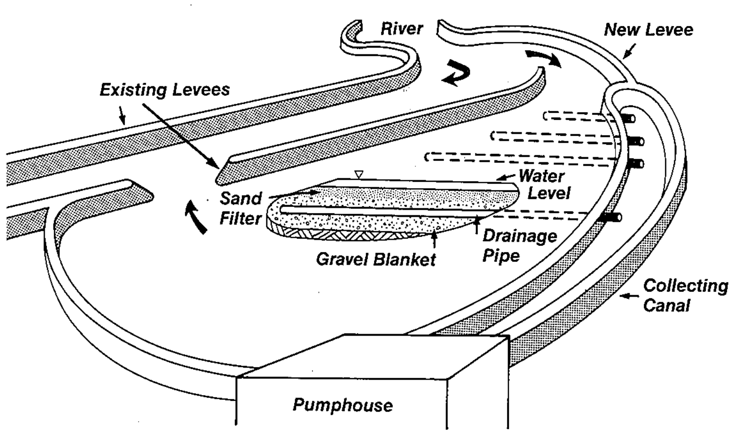


Figure 8

Conceptual Large Capacity Sand Filter Intake System Sacramento River



This publication resulted from the activities of the Great Lakes Sea Grant Network, which consists of university-based programs in Illinois-Indiana, Michigan, Minnesota, New York, Ohio and Wisconsin.

This work was supported by the University of Wisconsin Sea Grant Institute with funding from the National Sea Grant College Program, National Oceanic & Atmospheric Administration, U.S. Department of Commerce, and from the State of Wisconsin (federal grants NA16RG0273 and NA90AA-D-SG469, projects A/AS-1, A/AS-2 and A/AS-28).