Preserving

Water covers 70 percent of our planet's surface but is becoming an increasingly scarce resource. As the earth's population continues to expand, the amount of potable water is becoming severely limited. Exacerbated by global warming, the evaporation of freshwater into the atmosphere is progressing at faster rates, and water is cycling back to earth where it is not necessarily needed. And a small amount that dissipates into the atmosphere is lost forever. Engineers are equipped to create structures that contain water efficiently and help prevent its evaporation. Spatial structures and tensioned membrane structures are ideally suited to the task of protecting this most vital of resources.

By Matthys Levy, P.E., F.ASCE

BILLIONS of years ago, icy comets passed through the inner solar system and flew near the planet we now call earth. The heat from the young sun caused water to boil off these comets and become trapped by the earth's gravity. This unique event is

A number of alternative configurations were considered in a study for a cover for New York's Hillview Reservoir. The reservoir covers 365,000 m² and is divided with a concrete wall into two sections so that one section may be cleaned while the other remains in operation.

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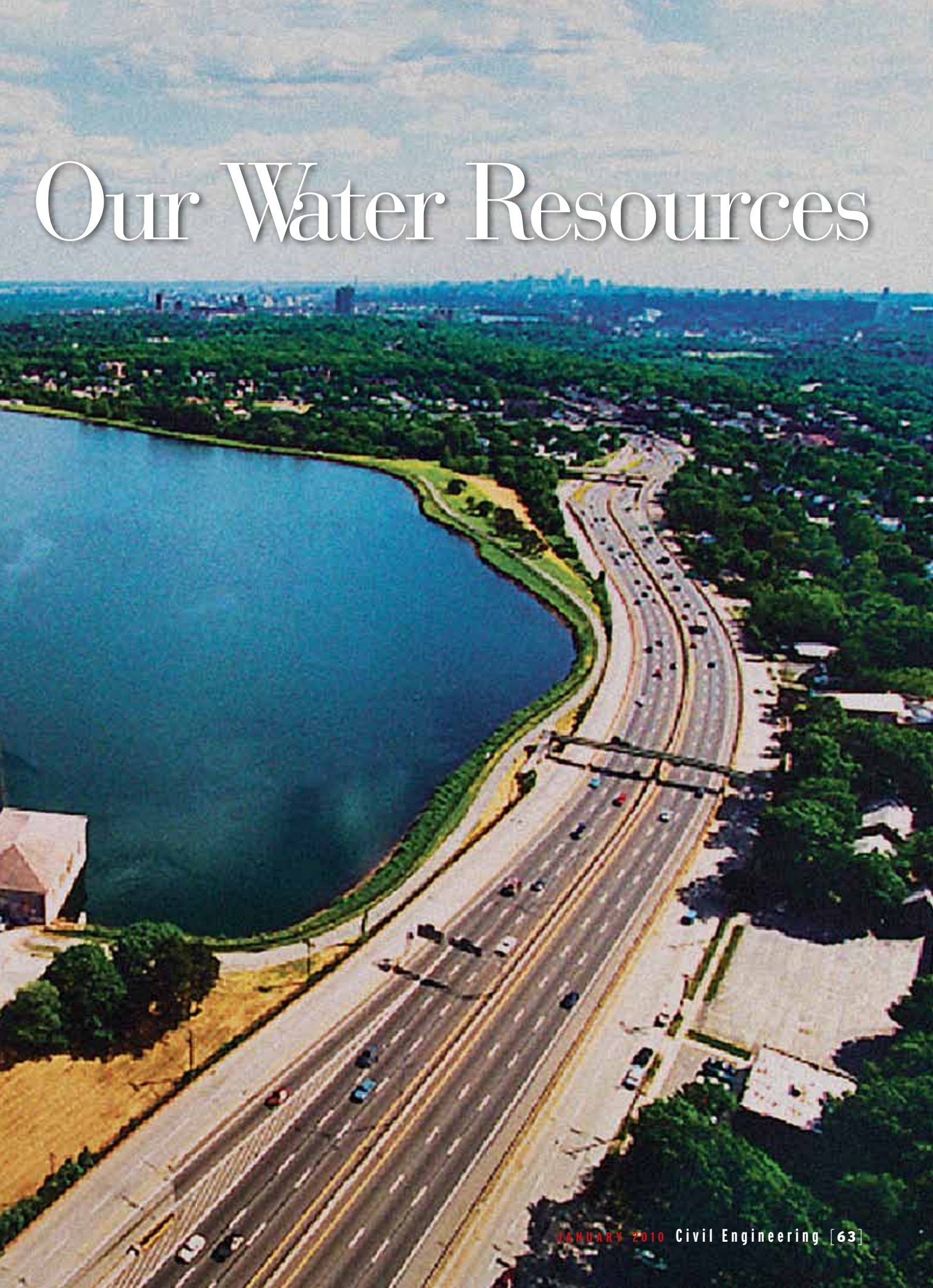
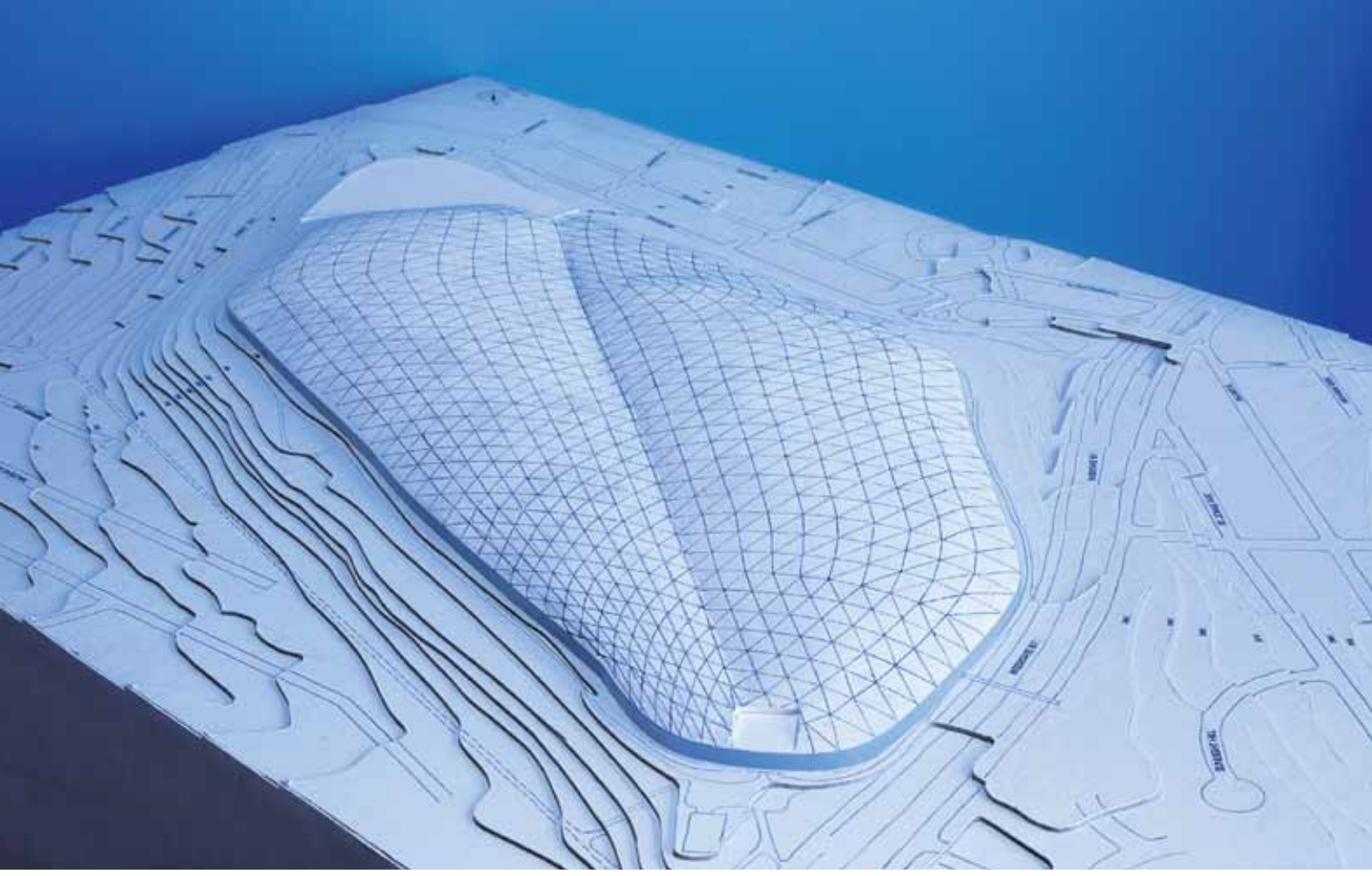
Our Water Resources





The results of the cover study for New York's Hillview Reservoir showed that an air-supported fabric cover best satisfied the objectives. That scheme required the development of anchorages on the east and west sides of the ring beam circling the reservoir and the construction of a series of posts on top of the dividing wall.

widely believed to be the reason that 70 percent of our planet's surface is covered with water and the earth is known as the Blue Planet. When life first appeared on earth, it did so because of the presence of water. No other planet in our solar system was as lucky—as far as we know. In examinations of other planets, we have found only barren wastes or poisonous atmospheres. Water, then, is the key to our development and our survival. In the distant future, 6 billion years from now, our sun will become a giant star with a power output 5,000 times greater than today. Our oceans will boil off, and earth will become a hot rocky planet no longer fit for human habitation. At present we have more immediate concerns.

Of all the water on the planet, only 3 percent is freshwater; the balance is saline ocean water. And two-thirds of this freshwater is trapped in ice caps and glaciers, leaving only one-third available for our use. But even that is not the end of the story, because this small remainder is available both as groundwater and as surface water in lakes and rivers. The bottom line is that very little water is available for human use, and of the freshwater that is available 70 percent is used for agriculture, the cultivation of rice, cotton, and sugar being the most water intensive. There are more than 6 billion people in the world today. Of this total, 1 billion lack access to freshwater, and almost 3 billion lack adequate sanitation facilities. Considering that each of us needs approximately 30 L of water per day to survive, where will we continue to obtain this required water, especially in light of the fact that by the end of the century our population is expected to grow to 10 billion?

Looking at the world from space, those areas with the greatest population growth—Africa, Southeast Asia, and the southwestern part of the United States—are in the greatest danger of suffering from water scarcity. "Water will be the defining issue of the century," says Natasha Iskander, Ph.D., an assistant professor of public policy at New York University. As she puts it, "While we have enough land to feed the world's growing population, we may not have enough water unless we discover new ways of using it much more efficiently." There is no question that the water crisis is partly the result of the current global warming trend, but that is too easy

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an answer. The reality is that we waste a great deal of water and do not treat it as the precious commodity it is. Consider the following:

• In the western United States, water is transported hundreds of miles from the lush north to the desert south to support wasteful water-intensive agriculture (spray or channel irrigation rather than more frugal drip irrigation). This water is also captured behind dams to feed cities in areas that would not otherwise support life. Lake Powell, behind the Glen Canyon Dam, took 17 years to fill after it was completed, in 1966, and it is now rapidly drying up as a result of a long-term drought. (It is now at 60 percent of capacity.) The city of Las Vegas depends for its very existence on the waters of Lake Powell and may soon find itself unable to supply its growing population with freshwater.

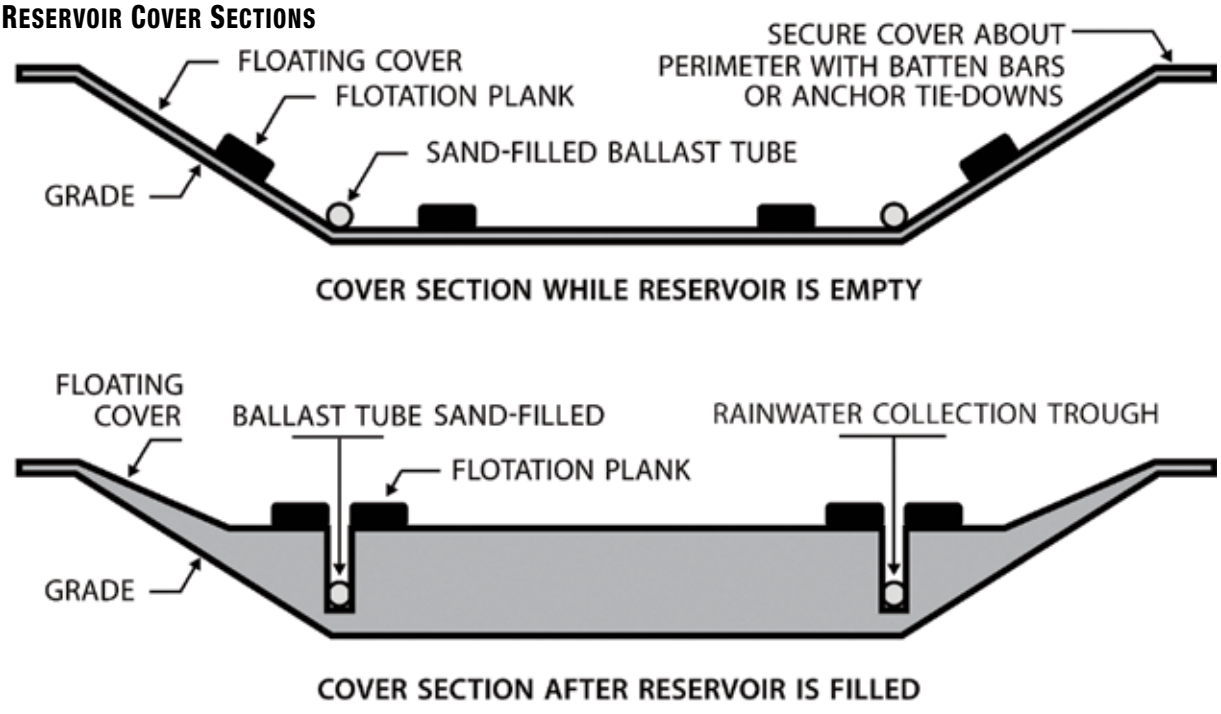
• "Most of the world's major waterways have been diverted or dammed or otherwise manipulated. In the United States, only two percent of rivers run unimpeded, and people now use half the world's readily accessible freshwater runoff." This is from "The Sixth Extinction?" an article by Elisabeth Kolbert that appeared in the May 25, 2009, edition of the *New Yorker.* Kolbert suggests that man is responsible for the die-off that will eliminate half of the world's current species and alleges that shortsighted water management is partially to blame.

• Silting of such dams as Egypt's Aswan Dam and China's Three Gorges Dam is expected to reduce their long-term capacity and effectiveness. Reversing the damage caused by the indiscriminate construction of thousands of dams worldwide over the past century will itself require a massive, costly effort. Also, as a result of global warming, the shrinking glaciers in the Alps, the Andes, the Himalayas, and Africa's Mount Kilimanjaro will lead to a reduction of water runoff and cause drought in the populated lower plains.

Unfortunately, even when people are convinced that there is reason for concern, they are not always logical or scientific in coming up with solutions. Impressed by the fact that much of the available freshwater is locked up in Antarctic ice, an entrepreneur in one of the Persian Gulf States suggested towing an iceberg to their country and parking it in a man-made basin, where it would provide an ample supply of water for a year. This folly is reminiscent of Ernest Hemingway's *The Old Man and the Sea,* in which the old sailor, Santiago, hooks a marlin and, after fighting for days to reel it in, ties it to the boat. On the way home, however, the bleeding fish is devoured by sharks, and only the skeleton remains when Santiago finally arrives in port.

Scientists have recognized for a long time that billions of people do not have access to freshwater for drinking and sanitation. Dean Kamen, the inventor of the gyroscopic-sensor-controlled Segway personal transporter, is one scientist and inventor who is doing something about the problem. He

RESERVOIR COVER SECTIONS



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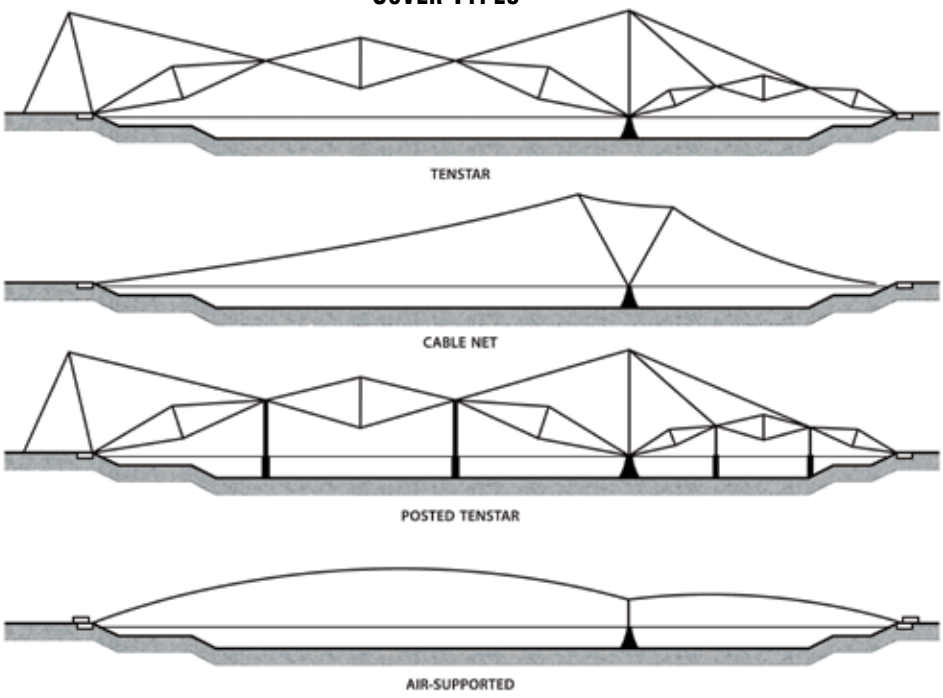
realized that there were really two problems that needed to be solved: how to turn brackish water into potable water and, if a device were devised, how to power that device when no electric power was available. His cleverly named solution, Slingshot, is a generator unit that combines a Stirling engine power source with a vapor compression water distiller. (The name is said to be a reference to the story of David and Goliath. Kamen believes that waterborne disease is a "goliath" of a problem and that technology is the slingshot.) Each machine is housed in its own black box roughly the size of a dormitory refrigerator. The generator has a power of 200 W at 20 percent efficiency and can run on a variety of fuels, including cow dung, which makes it ideal for use in Third World villages, where the need is greatest. Also its waste heat can be used in the filter. The distiller makes 100 L per day of clean water from wastewater in a machine that doesn't need osmosis membranes or activated charcoal. In fact, it requires no consumables whatsoever and is therefore ideally suited for use in isolated locations. Both components have been tested and work beautifully. They need only volume demand to make them economically feasible.

COVER TYPES



Water management has added a new word to our vocabulary: "hydropolitical." It encompasses, for instance, development of the watershed of the Jordan River, which is vital to both Jordan and Israel and is perhaps one of the few issues that have led to cooperation between the countries involved. The watershed is just one example of the cross-border problems created by waterways that spill over national or regional boundaries, as illustrated by the following list of similar challenges:

- Hungarian Dam Controversy;
- San Diego Tijuana Water Problems;
- Ataturk Dam and Environment;
- Colorado River Dispute;
- Israel/Jordan Water Dispute;
- Lesotho Water Exports;
- Mekong River Dam;
- Baikal Wood Pulp Pollution;
- James Bay Project;
- Aral Sea Loss and Cotton;
- The Los Angeles Aqueduct and the Owens and Mono Lakes;
- Israel and Lebanon's Conflict over the Litani;
- Nile River and Conflict;
- Danube Pollution;
- Assyrian Water Warfare;
- Dead Sea Canal.

All of these controversies relating to the use of precious water are either ongoing or have been only partly resolved.

How can engineers contribute to solving some of these water-related problems? Apart from doing whatever they can to alleviate the current global warming problem, which, as mentioned earlier, is partly responsible for the stress on our water resources, there are clearly areas of investigation that are worth pursuing. The most promising are as follows:

- Cisterns;
- Reservoir covers;
- Water canals and piping;
- Desalinization;
- Filtration;
- Windmill pumps.

This issue can be rephrased: how does the water crisis intersect with shell and spatial structures? Reservoir covers offer the best opportunities for innovation, as every town or city in the world has to minimize evaporation of its water supply and prevent the introduction of contaminants into its water storage facilities. Birds treat reservoirs as their natural habitat and pollute the water with fecal matter and even disease-causing germs. New York City faced this issue a number of years ago when it was given the option by health authorities of either subjecting the principal water reservoir for the city to filtration or providing a cover for it. As the cost of filtration was extremely high, the option of a reservoir cover appeared attractive.

Many reservoirs in the past have relied on concrete covers, essentially placing the reservoir underground. This type of solution is very costly and introduces a forest of columns into the reservoir. An aluminum dome supported by a reticulated structure is another possible design solution, but it can be used only to cover reservoirs that are circular or at least oval in plan.

As most reservoirs are not regularly shaped, another option is to use a floating cover, or flexible membrane, made of polypropylene, polyethylene, or a combination of

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Scientists have recognized for a long time that billions of people do not have access to freshwater for drinking and sanitation.

materials. The membrane must be resistant to ultraviolet radiation and suitable for the environment in which it is to be installed. In cold weather, when ice can form, the cover may be subject to bending and twisting caused by ice movement and fluctuations in water level. Reinforced membranes have been designed to solve some of these problems, and the materials have included Hypalon (a product of E.I. du Pont de Nemours and Company, of Wilmington, Delaware), high-density polyethylene, and a number of composites with Dacron fibers (also from DuPont) and complex filler compounds. Removing debris and standing water from such covers is another problem. The introduction of troughs for water collection and wash down, as shown on page 65, is one possibility.

In a study for a cover for New York's Hillview Reservoir, a number of alternative configurations were considered. The reservoir covers 365,000 m² and is divided with a concrete wall into two sections so that one section can be cleaned while the other remains in operation. The irregularly shaped plan results in maximum spans on each side of the dividing wall of 290 and 114 m. The objectives of the study were to design a cover that would offer the following:

- Present minimum maintenance requirements;
- Be self-cleaning, durable, easily repairable, and resistant to vermin;
- Be aesthetically pleasing and in keeping with its urban environment;
- Have minimal effect on air and water quality and on fish and wildlife;
- Be economical and provide the least impact from construction.

Several alternatives were considered:

- A tower-supported Tenstar cover (a cable dome system pioneered and patented by Weidlinger Associates, Inc., of New York City; see "Floating Fabric over Georgia Dome," *Civil Engineering,* November 1991);
- A cable net cover;
- A posted Tenstar cover;
- An air-supported cover (see illustrations opposite).

The results of the study indicated that an air-supported fabric cover would best meet the objectives. This scheme required the development of anchorages on the east and west sides of the ring beam circling the reservoir and the construction of a series of posts on top of the dividing wall. Also included were a series of 10 inflation units designed to maintain pressure under the roof under normal conditions as well as during high winds and heavy snows. Normal seam and joint leaks were assumed, as well as leakage caused by accidental damage or loss of a fabric panel. For efficient construction, the use of barges on the reservoir to assemble the cable net was contemplated. The city ultimately decided to use chemical disinfection rather than a cover.

In the distant past, Greek, Indian, and Chinese philosophers independently recognized the existence of our planet's four classical elements: earth, air, water, and fire. Today, mankind is well on its way to destroying three of these. We abuse the earth with litter and indiscriminate mining, pollute the water with chemicals and waste, and poison the air with greenhouse gases. The fourth, fire, escapes our wrath, but even though it provides us with light and heat, it is itself a destroyer, burning forests and homes and using precious oxygen in the process. Clearly, our planet is out of balance, and the first problems that we must address are political and psychological—apathy, obsolete government policies, and ingrained habits and attitudes—before we can redirect mankind and forge a new environmental consciousness. Some of these issues have penetrated our consciousness and made us aware of problems and solutions. In the past few years, we have focused our attention on the issue of global warming. And we are aware of the destruction of the earth and have initiated recycling to reuse materials torn from the earth and have undertaken rehabilitation efforts to repair the damage caused by mining and deforestation.

Seventy percent of the earth's surface is covered with water, and water is the key to our development and our survival.

Moreover, there is now general consensus that a problem exists and that we must take action to change the way we use and dispose of carbon products so that we can return the planet's atmosphere to the balance that existed a century and a half ago. The issue of water conservation is only now coming into focus, and this article is meant to sound the alarm for water conservation and to get out the message that there is much work to be done by motivated scientists beyond forecasting our doom. **CE**

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