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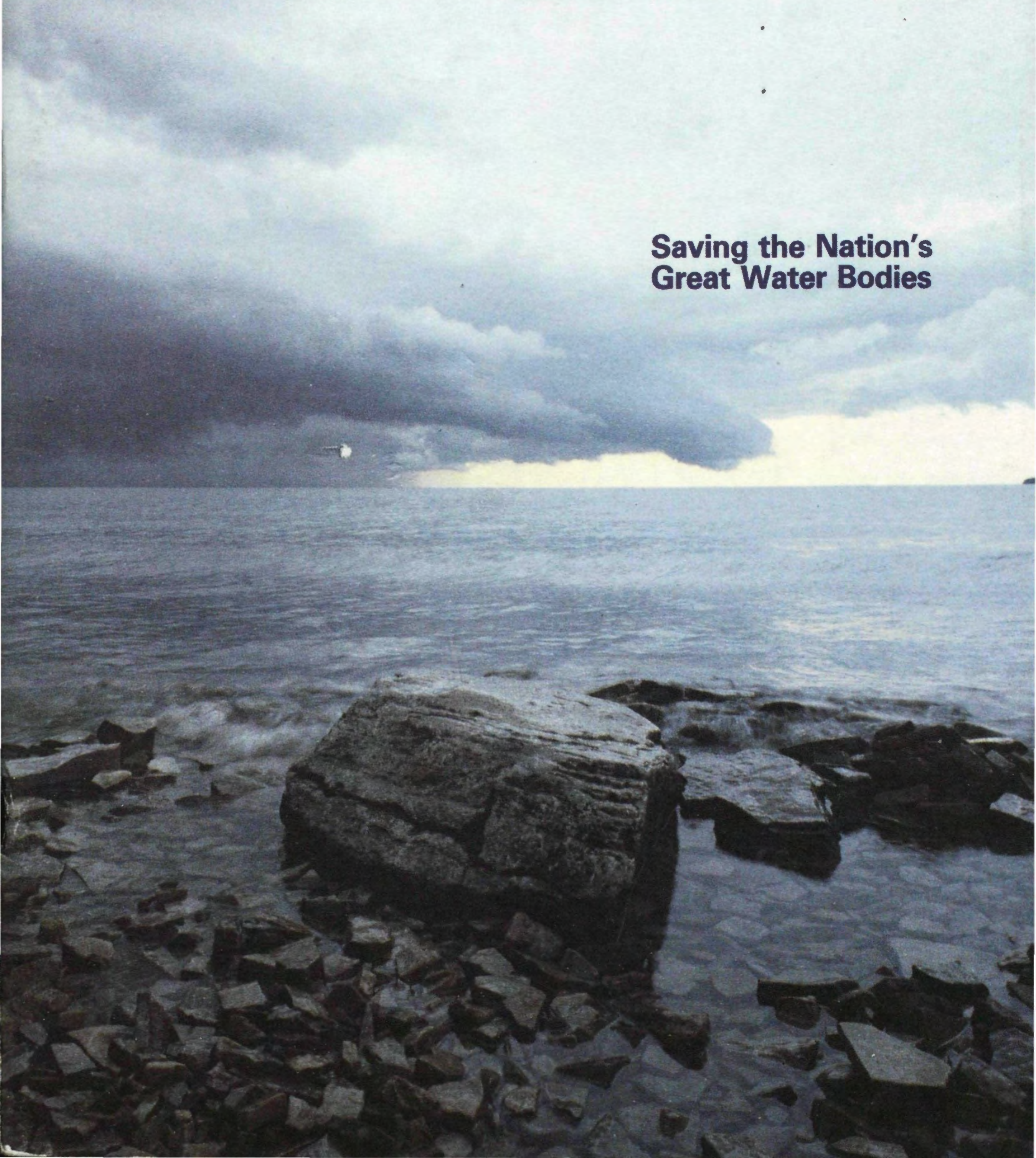

Saving the Nation's Great Water Bodies

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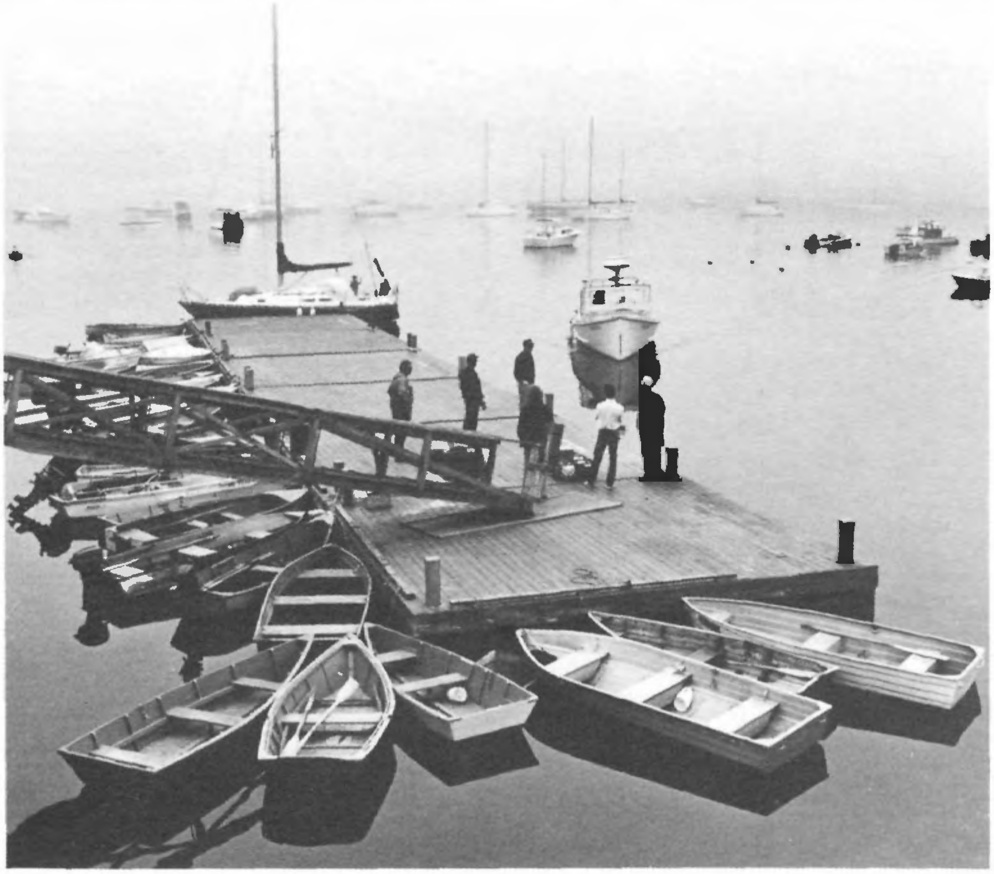
Front Cover: Lake Michigan on a cloudy day. See article on page 5. Photo by Mike Brisson.



Chris Ayres photo

Great American water bodies ranging from San Francisco Bay in the West to Long Island Sound in the eastern United States are endangered in a number of ways, as articles in this issue of *EPA Journal* illustrate. The problems range from habitat destruction to toxic contamination, from depleted oxygen levels to the diversion of tributary waters.

How can these national treasures be saved? The predominant theme in this special report of the magazine is that there is no single solution. The problems are too diverse; the personalities of the water bodies are too different.

Instead, in a point introduced by Administrator Reilly and reinforced by other contributors, it is proving necessary to fashion strategies tailormade to particular water bodies. This emerging approach reflects lessons learned over 20 years and new insights earned as the nation's water-quality efforts move into another decade of tough environmental challenges.

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A Strategy to Save the Great Water Bodies

by William K. Reilly

Mike Brisson photo.

Their very names—Ogallala and Ontario, Champlain and Chesapeake, Mississippi and Michigan—echo with the poetry of American legend and evoke the glories of American history. Our heritage as a civilization is indelibly intertwined with the cadence of these, the names of the nation's great waters.

Yet despite their inestimable value, both cultural and practical, the nation's waters have been damaged by the poisonous by-products of 20th century society. Whatever their specific designation—lake, estuary, or aquifer; sound, bight, or gulf; bay, wetland, or river—our great water ecosystems are increasingly troubled. As these huge basins accumulate contaminants, they lose their bounty and beauty. They become septic tanks and toxic sinks. The final verdict on our turn-of-the-millennium civilization may well rest in substantial part on our ability to restore the vast productivity of our nation's great bodies of water.

Obviously, the great water bodies are directly affected by the human activities that surround them; and, perhaps less obviously, the fate of these ecosystems will, in turn, directly affect the lives of the great majority of Americans. Our coasts and estuaries are suffering the effects of one of the great migrations of modern times: In 1987, more than 125 million people—over half the total U.S. population—lived on the 10 percent of the nation's land that falls within 50 miles of a coastline; by the year 2000, three-quarters or more of our people will live on that narrow slice of land along the coasts.

Coastal waters, therefore, are bearing an unsustainable burden. They receive the pollution generated by millions of people who live and work nearby, and they are loaded with the cumulative impacts over years of discharges from thousands of upstream and watershed sources.

About one-third of the nation's sewage effluents in 1980, for example, were discharged into coastal and marine waters. Habitat destruction, industrial and municipal discharges,

We are a highly compartmentalized agency, organized to control and clean up pollution . . . not to prevent it.

runoff, and atmospheric deposits (in the early 1980s I recall being surprised at learning that up to three-fourths of the PCBs in the Great Lakes were thought to come from air deposition): the combined burden is clearly overwhelming some of our most valuable, productive ecosystems.

Water bodies such as the Chesapeake Bay and the great rivers of the Middle West provide critical habitat for migratory waterfowl and other species. Yet this valuable habitat has degraded to the point of endangering many waterfowl species. Estuaries and wetlands serve as nurseries or spawning grounds for most commercially important species of fish and shellfish. Yet valuable shellfisheries have vanished completely from many estuaries. Oyster harvests in the Chesapeake, for instance, are at a historic low. One hundred years ago, there were so many oysters in the bay that they filtered the entire volume of water every four or five days. Today, it takes about a year to accomplish the same task. Legendary fish species are in trouble, deep trouble: The striped bass, Maryland's beloved "rockfish" (also in the Chesapeake), comes to mind.

Meanwhile, ground-water withdrawals have tripled since 1950 to more than 95 billion gallons a day. (See story on the Ogallala Aquifer on page 42). In some places, ground water that remains is threatened by injection of waste and contaminated waters, seeping pesticides, failing septic systems, landfills and surface impoundments, accidental spills, and general nonpoint runoff.

And finally, rare and critical aquatic habitats everywhere are threatened. Arctic tundra, subtropical mangrove swamps, temperate prairie pot holes, wild rivers, pristine lakes: These are truly unique ecosystems, and they support a rich mix of wildlife, some endangered. Indeed, we are only now beginning to understand the important role they play in the wider ecosystem. Yet they are all disappearing at an astonishing rate—faster, in fact, than we are rescuing them.

What is to be done? How can we address these vexing problems?

Shortly after I became Administrator, I asked EPA's Science Advisory Board (SAB) to review the Agency's ability to identify and solve our most serious environmental issues. The SAB report, *Reducing Risk: Setting Priorities and Strategies for Environmental Protection*, released this past September, spotlighted EPA's continuing neglect of natural ecosystems—wetlands, estuaries, and forests.

For years, the SAB noted, EPA and its statutes have focused the Agency's

(Reilly is Administrator of EPA.)

The challenge posed by our great water bodies: protecting a resource that benefits society in many ways.

attention chiefly on risks to human health, less so on ecological degradation. The SAB found this balance to be insufficient. Natural ecosystems support all human activities, including, of course, economic enterprises. They also have intrinsic values independent of human use that are worthy of protection. Accordingly, the SAB urged EPA to attach as much importance to ecological values as to human health risks.

This recommendation comes as no surprise. In fact, it calls attention once again to EPA's original mission—to see the world whole, to see it as diverse, productive, and interconnected. Unfortunately, time, turf, and the balkanized nature of environmental legislation have taken their toll on the vision that initially was to guide EPA. We are a highly compartmentalized agency, organized to control and clean up pollution, medium-by-medium, chemical-by-chemical—not to prevent it. As a result, we often have simply been cycling problems through our system, seldom really solving them. We took toxics from smokestacks, turned them into sludge, dumped the sludge somewhere on the landscape, and then watched the inevitable runoff and leachate contaminate our water. Indeed, nowhere has this frustrating cycle been more apparent than in our efforts to deal with water quality.

In the Great Lakes, fortunately, a model approach based on ecological perspectives is taking shape.

In response, in part, the 1987 amendments to the Clean Water Act established the National Estuary Program to bring a collective focus to

Skip Brown photo. Maryland Sea Grant.

Coastal waters are bearing an unsustainable burden due in part to the large, continuing influx of residents and vacationers to shoreline areas.

federal, state, and local efforts to protect the nation's most significant estuaries. The idea is to bring to bear the best efforts of public entities and private groups, to apply the range of available tools and techniques to the unique problems of an estuary. Regulatory tools that different governments have at their disposal include standards, permits, enforcement, local zoning ordinances, and building codes; nonregulatory techniques include education, technical assistance, voluntary action, and negotiations. There are now 17 designated estuaries. The estuary program anticipates two distinct phases: first, problem identification and planning; and second, implementation. Most estuary programs are still in the planning phase. If this approach is to meet its objectives and prove useful for targeting other water resources—such as lakes, rivers, and wetlands—then we need to speed the process along.

In the Great Lakes, fortunately, a model approach based on ecological perspectives is taking shape. In this unsurpassed watershed, we are pursuing restoration through a variety of methods. The need for flexibility is dictated by the immense variety and complexity of the watershed itself: Lake Superior, for example, remote and relatively underpopulated; or Lake Erie, with vastly different problems, once choked by eutrophication, now sporting a variety of fish life, yet also plagued by new invaders such as the zebra mussels, an exotic species with as yet no predator to check its numbers (see story on page 51).

EPA is trying an approach of whole-systems environmentalism. We are trying to use the most advanced technology available, including satellite imagery, to identify the hot spots in the Great Lakes ecosystem. Then, like the estuary program, using a variety of methods, we will craft solutions tailored to local circumstances. In developing the strategies, we will address at least three persistent problems: the deposition of pollutants through the air; runoff from agricultural, urban, and other nonpoint sources; and restoration of critical habitat.

We already know that air sources are major contributors of both toxic and acidic pollutants to the Great Lakes. The new Clean Air Act will help to curb this problem. But we probably need to do more. We intend to go beyond traditional enforcement, fashioning voluntary agreements with the major sources of air pollution to protect these magnificent waters. A new generation of industrial leadership is emerging, and we want to work with this group wherever we can to cut toxic emissions voluntarily, cut them sharply, cut them soon. We also are strengthening our multi-media enforcement capabilities so that, as warranted, we look at the overall pollution problem at a facility—not piecemeal, not medium-by-medium, not air or water, but in its entirety.

Nonpoint runoff is another major problem with no easy answers. The region around the Great Lakes suffers from all of the usual sources of runoff, including farms and urban surfaces. Because the economy of the basin is essentially industrial, the region also suffers significant runoff problems from industrial sites and mining operations. These sources continue to contribute pollutants that contaminate bottom sediments and accumulate in fish and wildlife. And eutrophication from excess nutrients is still more than a nuisance in many areas.

Protecting critical habitat will require restoring habitat such as submerged aquatic vegetation and riparian zones. And it will require implementing President Bush's "no-net-loss" goal for wetlands as soon as possible in the Great Lakes. To achieve this goal, we must gain the public's cooperation and improve its understanding of the pivotal role of wetlands in the overall functioning of ecosystems—particularly those that are highly stressed, such as some found in the Great Lakes system.

We may want to explore classification systems to assure that the fullest protection is afforded to high-value wetlands. This is not a new idea; it does require improving the state of wetlands science and crafting a protection scheme that respects the great diversity of wetlands. It needs to overcome the perception that it is tantamount to writing off certain wetlands. Its potential is to reconcile the engine of development—particularly the highways and airports and other projects that bring local economic benefits—with the wetlands that provide essential ecological benefits.

In putting all these pieces together, we are seeking the support and involvement of the states and the national and provincial governments of Canada. The states in the region, with four new governors, have a crucial role. Not only do they bring additional resources, but they traditionally have authority in many areas of land use and water planning critical to restoring the lakes.

Citizen groups, too, have an essential role. The mushrooming land trust movement, public-private partnerships such as the Des Plaines wetlands restoration project, which I recently visited, voluntary education and tree-planting programs: Government cannot do the job alone, and the Great Lakes benefit handsomely from the energy and imagination of private groups. Thus, outreach, consultation, and communication are increasingly important activities.

Realizing our ambitious goals for the Great Lakes will require the best efforts of our Great Lakes Program and our regional and program offices. It's worth it. The potential payoff is enormous, not just for the Great Lakes but in fashioning a model for how we move forward, from planning to implementation, to protect and restore the nation's other great water bodies.

A decade ago one of the world's leading naturalists, Jacques Cousteau, was walking with his son Jean-Michel along a riverbank in the Amazon. After a while, Jacques turned to Jean-Michel and said, "If we want to save anything, we have to remember that people protect what they love."

Cousteau's words, so eloquent with respect to the magnificent Amazon rainforest, ring equally true with respect to the great water bodies and other aquatic systems of the United States. Whether it is Long Island Sound or Puget Sound, San Francisco Bay or the Chesapeake, the Gulf of Mexico or the Arctic tundra, it is time to get serious about protecting what we love. Clearly we *do* love our great water bodies: We flock to them to live, to work, and to play. They are part of our heritage, part of our consciousness. Let us vow not to let their glory pass from this good Earth. □

Toxics in the Great Lakes

by Theo Colborn
and Richard A. Liroff

The Great Lakes hold approximately 20 percent of the world's supply of fresh surface water. Because of their vast size and favorable habitat, the lakes and their environs serve as nesting grounds to innumerable animal species. The Great Lakes basin is home to 35 million Americans and Canadians.

Superficially, the recovery of the lakes from their degraded condition of the late 1960s, when the press pronounced Lake Erie dead or dying and television viewers watched Cleveland's Cuyahoga River flaming up from its surface, suggests that the Great Lakes are an environmental success story. But a more thorough review of the health of the Great Lakes ecosystem suggests another, more sobering conclusion: Persistent toxic substances continue to circulate within the system.

Determining the source of these substances has led to even more sobering conclusions. In some instances, the major sources are believed to be thousands of miles away. Airborne pesticides, such as DDT and toxaphene; industrial chemicals, such as PCBs; and metals, such as mercury and cadmium, are entering the Great Lakes on air currents from outside the lakes' basin.

Even worse, through their magnification in the food web, these substances pose a threat to the wildlife and human residents of the Great Lakes basin who consume fish from the lakes. The persistence and biomagnification of toxic substances in aquatic ecosystems in the Great Lakes are of global significance.

Weaving the Threads of the Toxics Story

In 1987, World Wildlife Fund and The Conservation Foundation in Washington, DC, and The Institute for Research and Public Policy in Ottawa, Ontario, launched a two-year project to produce a "State of the Environment" report for the Great Lakes basin. We found that the Great Lakes had been diligently researched by a community of wildlife biologists whose studies had driven wildlife toxicology to its cutting edge. But the many sources of data still needed to be synthesized and made meaningful for policymakers. Not until we completed our survey of the existing scientific literature, making new linkages, did we appreciate the true dimensions of the toxics problem.

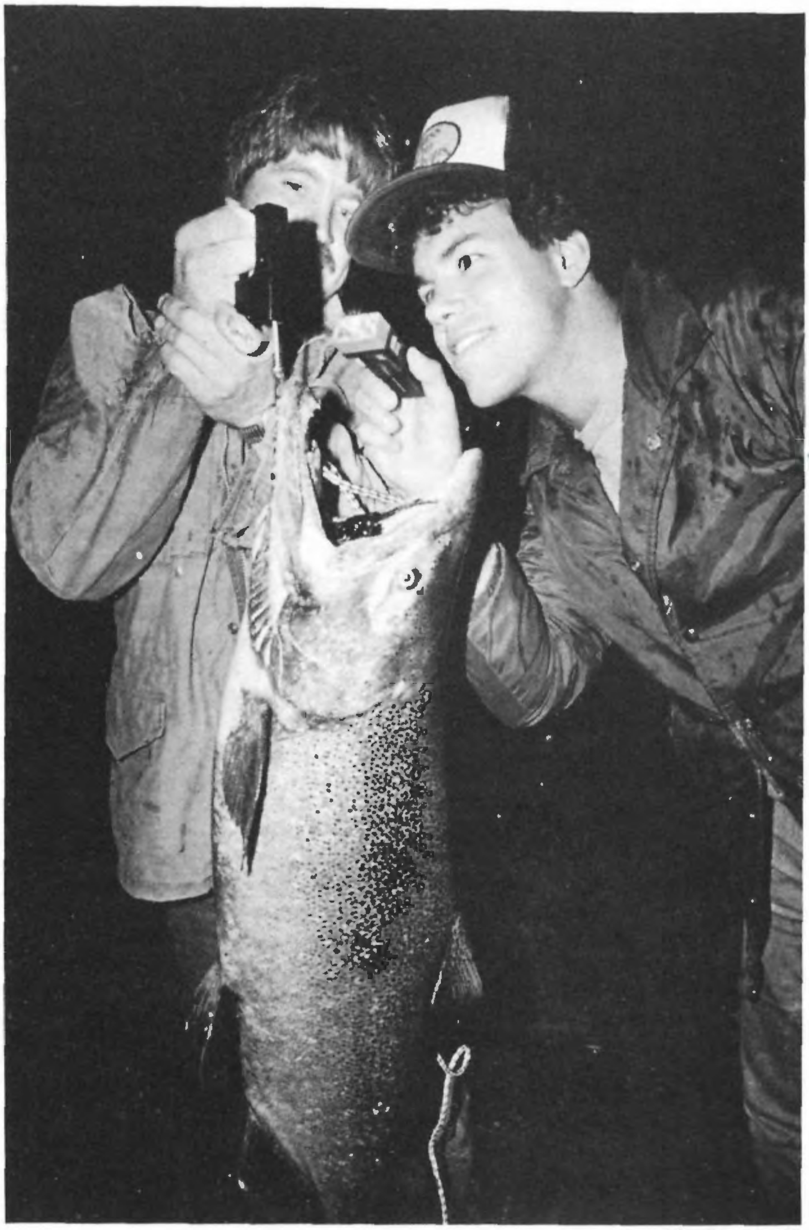
The poisoning of the lakes' wildlife has its roots in industrial and agricultural development. Following World War II, the Great Lakes basin attracted large chemical and manufacturing complexes. Its agricultural sector boomed. The lakes became convenient receptacles for the wastes of these activities. It is not surprising that beginning in the mid-1950s, and continuing to the present, numerous reports about unhealthy animals in the Great Lakes basin have appeared in scientific literature and government reports. Populations of top predator animals in the basin suffered—and still suffer—seriously.

The plight of the animals raised questions concerning the risks to humans who depend upon the same resources as the wildlife. In essence, the Great Lakes basin became a natural laboratory in which to test the association between health problems and persistent toxic substances. At peak contamination levels in the late 1960s and early 1970s, numerous wildlife species were exhibiting severe population stress.

Prompted by concerns about human health, policymakers made great strides in restricting the use of such major contaminants as DDT, dieldrin, and PCBs. They instituted permit systems to manage direct discharges of wastes into the lakes. Concentrations of many chemicals declined strikingly in sediments and fish and wildlife tissues in the late 1970s. However, reductions in contamination tapered off around 1980-1981, and concentrations are holding at levels serious enough to cause public health authorities to issue

(Colborn is a Senior Fellow at World Wildlife Fund and The Conservation Foundation and a Fellow at the W. Alton Jones Foundation. Liroff directs the Central and Eastern Europe Program at World Wildlife Fund and The Conservation Foundation. Both are co-authors of Great Lakes, Great Legacy?, the report on which this article is based.)

Although big fish are fun to catch, people are being urged not to eat older, heavier trout and salmon caught in the Great Lakes.



Mike Brisson photo.

warnings about eating certain sizes and species of fish.

Current concentrations of all the above chemicals still affect wildlife that use the lakes as their home or nesting ground, especially those that are dependent upon fish from the lakes.

Most importantly, the individual animals suffering the most in wildlife populations are the young. Young birds, fish, mammals, and reptiles exhibit a suite of untoward health effects that eventually cause premature death or abnormal development. These include metabolic changes manifested in a condition called "wasting": animals appear lethargic, lose their appetites and weight, and die prematurely. More subtle changes include organ damage. These include: thyroid and heart problems; a liver condition called porphyria, or abnormal metabolism of iron; reduced levels of vitamin A in critical tissues; male birds growing ovarian tissue, and female birds growing excessive oviduct tissue; male fish not reaching full sexual maturity; and hermaphroditism in fish. In addition, there are such obvious effects as birth defects and behavioral changes. Cancer is not as prevalent a problem as these other effects.

The problems in the offspring are the last stage in a sequence of events that begins with maternal exposure to one or more toxicants and transfer of those toxicants to the egg or fetus. In most cases, the adult animals show no visible signs of ill health, except abnormal behavior.

The fate of bald eagles in the Great Lakes basin illustrates the association of population effects and toxic substances. It now appears that the lakes have become an ecological black hole for the eagle. Healthy, immigrant

Toxic Substance Effects on Cells

Almost all the toxic substances discussed in this article affect developing cells in two and sometimes three ways. First, they block communication between cells. During early stages of development, messages can be interrupted that tell immature cells how to migrate and differentiate as they produce tissue: nerves, brain, spinal cord, bones, appendages, gonads, heart, and so forth.

Second, the chemicals activate enzyme systems that under normal conditions would not be activated. These enzyme systems can interfere with normal development. For example, as a result of specific enzyme activation, a developing organism may flush fat-soluble hormones from the body that are essential for triggering normal endocrine development. Third, the chemicals can act as female hormones, interfering with the differentiation of the endocrine system. For example, they can imprint a female message in the brain (hypothalamus gland) regardless of the chromosomal sex determination of the individual. In all these cases, timing of exposure is critical.

birds establish territories along the shoreline, but after two years of feeding on Great Lakes prey, they start losing their ability to raise viable young. These shoreline populations have higher concentrations of toxic substances, such as PCBs and DDE, than inland populations.

Laboratory studies of toxic contaminants of concern in the Great Lakes reinforce these conclusions. These include PCBs, dioxins, furans, dieldrin, HCB (hexachlorobenzene), lindane, mirex, toxaphene, and mercury, to mention a few. The same chemicals found in wildlife induce the same suite of health effects in a number of laboratory animals. For example, PCBs and dioxins have been associated in the laboratory with wasting, loss of vitamin A, immune suppression, feminization, porphyria, organ damage, and birth defects. A number of dose-response studies in the field and the laboratory support these associations.

A Misplaced Emphasis on Cancer?

The evidence from the Great Lakes indicates that the current emphasis in national environmental health policy on cancer may be drawing attention away from other health effects that may be even more prevalent. The chemicals found in the Great Lakes ecosystem, and in almost every other highly industrialized and agrichemical area, can cause changes in body functions, such as the nervous, immune, and endocrine systems. They act as functional teratogens. They do not cause obvious gross birth defects or cancer at the doses to which most human populations are exposed.

The same chemicals found in wildlife are found in human blood and fat. More importantly, they are found in all tissues and organs associated with the human reproductive system—semen, testicles, follicular fluid in the ovaries, placentae, and breast milk.

There is an urgent need to learn more about the effects of their presence in these tissues. The effects in human offspring resulting from prenatal and postnatal low-dose exposure to lead, alcohol, and cigarette smoke are now widely accepted, but only after many years of denial by skeptics. In a related vein, it has been demonstrated that, almost 10 years after their birth, those offspring of women who ate one or two meals a month of Great Lakes fish for at least six years prior to their pregnancy do indeed experience subtle, but measurable and significant deficits in intelligence, behavior, and motor coordination.

The effects are truly subtle; they are apparent only to scientists and in carefully conceived experiments. These experiments reveal children disadvantaged because their cognitive, social, and behavioral skills are less than might be expected under normal circumstances. The long-term social and economic effects of this damage, from the individual to the national level, are not yet fully understood.

More resources must be made available so that Great Lakes environmental, wildlife, public health, and medical professionals can share their research findings to better assess the subtle effects of toxic chemicals on wild and human populations. We are certain that as this idea spreads, public health agencies will develop improved research protocols that include endocrine, neurological, and immunological considerations.

As funds are redirected to these endpoints, biologic markers of exposure and subsequent markers of abnormal development will be identified. Building upon this base, regulators can then give greater weight to the functional teratogenic effects of toxic substances.

Long-Range Atmospheric Transport of Pollutants

Some of the more troublesome pollutants are generated beyond the watersheds of the Great Lakes. For example, Lake Superior is generally acknowledged to be the cleanest of the Great Lakes. Fewer humans inhabit its watershed, and the watershed has much less industrial and agricultural activity than the other Great Lakes watersheds. Yet anglers fishing in Lake Superior are warned not to consume lake trout larger than 30 inches because of PCB contamination. Scientists estimate that approximately 90 percent of the PCBs in Lake Superior enter the lake from the atmosphere.

This long-range transport is not unusual. The atmosphere is the primary source of mercury contamination in northern Minnesota. (See article on page 45.) Sediment mercury concentrations there have increased two percent per year since 1938. As a result, the rate of fish-tissue mercury uptake has increased. The fresh DDT in the lakes is suspected to come from Central America. It comes as no surprise, then, that elevated concentrations of contaminants are found in wildlife in remote areas around the globe: for example, the Arctic. These concentrations, attributable to the phenomenon of long-range atmospheric transport, remind us that the problems found in

Greater Cleveland Growth Association photo.

Cleveland's Cuyahoga River has made a dramatic recovery since its notorious surface fire in the late 1960s.

the Great Lakes signal more widespread problems.

New Policy and Research Directions

The Great Lakes experience reveals that traditional environmental protection programs have been inadequate for lowering persistent toxic substances to safe levels in the environment, and public health programs have not been properly oriented to assess the human health effects of these substances. Public health remains at risk. New approaches are necessary. For example, national public health programs should be redirected to account more fully for the non-cancer, developmental impacts of chemicals on human health. The subtle health effects manifested in wildlife offspring and in the children of Lake Michigan fish-eaters (see box on page 7) cannot be ignored.

Several actions taken within the last two years are steps in the right direction. First, EPA Administrator William K. Reilly announced earlier this year that membership of the Great Lakes Advisory Committee would be expanded to include all of EPA's Assistant Administrators; that representatives of major EPA programs would meet monthly to explore options for attacking the Great Lakes' toxic problems. This acknowledges, in effect, that what worked for phosphates in the lakes won't work for toxic substances. EPA is not organized to deal with the toxic chemicals in the Great Lakes. The Great Lakes cannot be protected solely by a traditional water-pollution control program. If the Assistant Administrators develop a successful program, it could be a model for other areas of contamination.

Second, far-sighted officials are examining the science developed by wildlife toxicologists and ecologists in the basin and are exploring innovative adaptations of their techniques for assessing human health in areas of high contamination along the shorelines of the lakes. The International Joint Commission of Canada and the United States have been bringing together multidisciplinary experts to discuss toxics in wildlife and humans. In this way, the commissioners hope to motivate regulators to move beyond conventional approaches to solving contaminant problems.

Third, public officials are seeking alternatives to control strategies based on standards that measure concentrations of pollutants in water alone. Generally, the concentration in lake water of any one of the chemicals mentioned above is below the detection limit and thereby meets present water-quality standards. However, because of biomagnification, the chemicals can accumulate in fish tissue to levels that are harmful to wildlife and humans.

A new approach, in which concentration limits in specific wildlife species are used as indicators of water quality, has been endorsed by the International Joint Commission and a number of environmental organizations. For example, a committee reporting to the International Joint Commission has recommended that, because it sits at the top of the Great Lakes food web and is so sensitive, the bald eagle should "be used as an ecosystem objective to define the virtual elimination of persistent toxic substances from the Great Lakes Basin Ecosystem." The objective would specify how many pairs of eagles live around the lakes, how productive they are, and what should be the maximum concentrations of toxic substances in eagle eggs and brains. A flourishing bald eagle population around the lakes would signal a truly meaningful improvement in the integrity of the Great Lakes ecosystem. □

Citizens and the Gulf of Mexico

by Wesley Marx

Along the Gulf of Mexico's crescent shore, stretching 1,631 miles from Brownsville, Texas, to the Florida Keys, more and more concerned citizens are joining the challenge to protect a remarkable marine heritage. The gulf sustains 40 percent of the nation's commercial fish catch by volume and one-third of the nation's marine sport-fishing activity. Over 90 percent of the fishing stocks, from shrimp to flounder, rely on bays and coastal wetlands to spawn, nurse, and rear. Today, these estuarine and coastal areas are being overtaken by some of the nation's worst extremes in pollution and habitat loss.

- Nearly 60 percent of the region's shellfish growing areas are subject to permanent or periodic public-health closures.
- Toxic red tides are becoming more frequent and severe. In 1986, one red tide in Texas killed some 22 million fish. Nutrient-rich farm runoff and urban sewage may help nurture the noxious algal blooms.
- Texas spends $14 million a year to prevent its beaches from being buried by trash. Padre Island National Seashore absorbs up to 10 tons of trash per mile each year!
- In Florida, urban development has destroyed 22,000 acres of another critical coastal habitat, mangrove forests. Galveston Bay in Texas has lost 96 percent of its seagrass beds to dredge and fill operations.
- Loss of sand dunes and other natural storm buffers can contribute to the region's soaring disaster liability. Since 1969, Louisiana has received 26 Presidential disaster relief designations, with all but two related to floods and hurricanes. The state leads the nation in repeat damage claims to the National Flood Insurance Program.

There are no easy solutions to such awesome problems. Take the problem of delta land loss. Over geologic time, deltas gain and lose land as sediment-bearing rivers change channels. But manmade changes can accelerate this process.

Levees protect delta cities from floods. They also block the overflows of river silt that form and sustain the delta plain. Ergo, the delta retreats; the gulf advances. Oil company canals that slice through remaining wetlands permit more salt water to intrude. More freshwater marsh and cypress forests die. The land that erodes also sinks as oil pumping reduces underground pressures.

How do you convince a region to change the very activities that sustain its economy? Enter the citizen environmentalist.

Coalition to Restore Coastal Louisiana

Rob Gorman is a Catholic Church social worker who wants to save marshes, swamp forests, and oyster beds: "If the delta drowns, we lose a land that has sustained thousands of families for generations. That is not just an environmental tragedy. That is a social tragedy."

Gorman helped found the Coalition to Restore Coastal Louisiana in 1986. The Coalition brings together over 100 clubs and businesses, including the Louisiana Wildlife Federation, the Terrebone Parish government, and the League of Women voters. The Coalition works for major policy initiatives that treat the delta as a dynamic ecosystem, not just a piecemeal resource. A task force has been created in the

(Marx is the author of The Frail Ocean *(1967; revised edition forthcoming in 1991) and* The Oceans: Our Last Resource *(1982).)*

Governor's office to plan and coordinate wetland protection. In 1988, state voters, by a three-to-one majority, created a wetland restoration fund supported by gas and oil revenues that added up, in 1990, to $26 million. In 1990, Congress passed a bill sponsored by Louisiana Senator John Breaux that provides $35 million a year for more wetland projects.

Old or abandoned canals are being backfilled or plugged to resist salt-water intrusion. Sand dunes are being restored. Freshwater flows are being returned to some marshlands. Borrowing from a Dutch technique, the coalition will deploy 250,000 used Christmas trees as silt-trapping brush fences. Such fences dampen or reduce wave action. Silt can settle out and rebuild marshland.

Will such projects slow down or eventually halt erosion of the delta? It is too early to tell. "We have established a citizen Coast Watch to monitor wetland projects. We want to ensure that funds are spent wisely," says Gorman. Tough policy decisions lie ahead. Gates installed in levees can restore flows of fresh water and silt to dying marshlands. However, such projects can be opposed by delta residents who don't want to be relocated from revived floodways.

Texas Beach Party

In 1986, Linda Maraniss, after sidestepping trash on a Texas beach, decided to throw a new form of beach party. Now the director of the Texas branch of the center for Marine Conservation, she works with the Texas State Land Office to coordinate annual beach cleanups that involve up to 8,700 volunteers.

"We collect data as well as garbage," explains Maraniss. Debris surveys help explain why the Texas shore is so trash-prone. Up to 75 percent of the trash comes not from beachgoers but from offshore sources—cleaning bottles from merchant vessels, egg cartons from naval ships, fishing gear, hard hats from offshore oil crews.

Instead of transporting such throwaways out of the gulf, the looping gulf currents move the garbage in circles and eventually onto beaches. Nearly 70 percent of the trash items are plastic, which can endure for a century and more. Such long-lived litter can be lethal. Plastic netting can entangle seabirds. Plastic bags can clog the digestive tract of endangered marine turtles.

As the Texas surveys showed, controlling marine debris can require a

Wesley Marx photo.

regional and even international response. In 1987, Congress ratified an international treaty, Annex 5 of MARPOL, that bans marine dumping of plastics. Annex 5 came into force in 1988. Maraniss now uses the debris surveys to monitor compliance. "Indicator trash items can tell us how well certain marine activities are complying," she says. The annual beach cleanup and debris survey is now a gulfwide, and nationwide, event.

Galveston Bay Foundation

The most productive bay in Texas is also the most threatened. Galveston Bay, which provides nursery and spawning grounds for 30 percent of the fishing stocks harvested along the Texas coast, is flanked by the nation's largest petrochemical complex and its eighth largest metropolitan area. The Galveston Bay Foundation (GBF), founded in 1987, is a coalition of environmental and bay user groups that serves as an advocate for the bay.

"We are actively opposing a proposed water storage dam, Wallisville, which would reduce freshwater inflows to the bay," explains Linda Shead, executive director of GBF. Freshwater inflows supply nutrients and sustain lower salinity levels vital to the bay's most valuable crop, oysters. A major channel-dredging project would have dumped dredge spoil in the bay, endangering valuable oyster grounds. GBF, teaming up with the Texas Parks and Wildlife Department and with fishing groups like the Gulf Coast Conservation Association, convinced the Army Corps of Engineers to modify the project to eliminate unconfined open-water dredge disposal.

GBF recruited 100 community volunteers to transplant cordgrass along a section of eroding tidal shore. "The cordgrass will retard erosion and provide habitat for shrimp and other marine life," says Shead. To restore more habitat, volunteers planted 5,000 young cypress trees in the Trinity River Delta.

Friends of Perdido Bay

Jackie Lane lives beside Perdido Bay, a small estuary on the Alabama-Florida border. A biologist who teaches at Penascola Junior College, she first became concerned about the bay in 1985. The waters had turned dark brown and smelly. There were fish kills. A small clam species that Lane was studying disappeared. "You felt filthy after swimming in the bay. I was disgusted," recalls Lane. With other concerned residents, she formed Friends of Perdido Bay.

Today, under a pilot project with EPA's Near Coastal Waters Program, the Friends help operate a volunteer monitoring project. "We collect data on such things as dissolved oxygen levels, nutrient levels, and rainfall." The project uses eight stations in the bay, eight dock sampling stations, three remote weather stations, and three rainfall stations. "We use hand-held computer systems to record and transfer data to a computer system in an EPA laboratory at Gulf Breeze." Such data help record trends in bay conditions. The major discharger into the bay is a paper mill located on a bay tributary, Twelvemile Creek. "We operate a station in the creek to help monitor the mill discharge."

Initial efforts to clean up discharges into the bay were hampered by split jurisdiction between Alabama and Florida. With support from the Friends, the two states formed a joint Water Management Council to better coordinate water quality programs. Lane has noticed some gains. "The water is no longer dark brown. But we continue to have noxious blooms of scum algae. We are concerned about nutrient loadings and dioxin emissions from the paper mill. Elevated levels of dioxin have been found in speckled trout throughout the bay."

National Estuary Program for Sarasota Bay

The dedication and talent of gulf citizen groups are being tapped by EPA's National Estuary Program for Florida's Sarasota Bay. The NEP Sarasota Bay project has identified restoration of inter-tidal habitat as a key opportunity in the ongoing development of a comprehensive action plan. Under EPA's Early Action Program, a grant was awarded to help fund a demonstration restoration project. The Florida Department of Natural Resources provided matching funds and design expertise to transform a bayfront parking lot into inter-tidal habitat. The City of Sarasota, which owns the site, acted as lead agency in doing the actual excavation and restoration work.

The work required the planting of 19,000 plugs of cordgrass as well as numerous young mangrove trees. The city asked for volunteers. Groups like the Florida Conservation Association, the Sarasota Sport Fishing Club, and the Sarasota County Drop-Out Prevention Program responded. In the first week of December 1990, over 100 volunteers materialized to undertake the greening of the former parking lot. Next on the restoration list: an eight-acre site on Leffis Key in Manatee County that will become more inter-tidal habitat.

In another Early Action Program, some 325 feet of seawall will give way to another inter-tidal area on the bayfront campus of New College in Sarasota. The NEP Program has

Advertising riches from the Gulf of Mexico, sea-food stands like this one in Aransas Pass, Texas, are part of the local culture.

contracted with the College to accomplish this. "The lawn behind the seawall will become a seagrass meadows. Seawall rubble will go to a facility that recycles old cement," says Judith Morris, who coordinates the college's Environmental Studies Program with her husband, Jono Miller.

Gulf of Mexico Program

Since marine life throughout the gulf is so dependent on coastal habitat, protecting this habitat in one state benefits the other four gulf states. Conversely, one state's effort to conserve can be offset by another state's inaction.

Recognizing the need for a regional focus, EPA in 1988 established the Gulf of Mexico Program. Located in the Stennis Space Center near Bay St. Louis, Mississippi, GMP receives active support from 15 federal and state resource agencies. Technical committees are working on action plans to address habitat loss, nutrient enrichment, and other key issues on a regional, intergovernmental level.

"We have established a Citizens Advisory Committee to insure greater public participation and information exchange in such planning," says Program Director Doug Lipka. In December 1990, GMP held its first biennial symposium on the environmental and economic status of the gulf in New Orleans, bringing together citizen groups, regulatory officials, and policymakers.

Building on efforts of the Center for Marine Conservation and the Oceanic Society, GMP has worked to secure more protection for the Gulf from marine debris. Under international law, semi-enclosed seas vulnerable to debris washups can be designated Special Areas; marine dumping of most trash, not just plastics, is banned. The Mediterranean, Baltic, Black, and Red seas, along with the Persian and Oman gulfs, have been so designated by the International Maritime Organization.

EPA photo

EPA employees and other interested citizens helped in a recent Gulf of Mexico clean-up drive.

GMP worked on a technical document to support this designation for the Gulf of Mexico. In November 1990, the IMO set in motion the process to approve this. The throwaway trash ban will extend to the Carribean. Nations like Mexico and Cuba don't want marine dumpers to substitute their shores for U.S. shores.

Dr. Larry McKinney, director of the Texas Parks and Wildlife Department, nominates another issue for more regional attention—"the region's almost total inability to adequately address major oil and chemical spills." According to McKinney, "The potential for an environmental disaster will grow, especially in the confined estuaries of the region that also contain concentrations of petroleum-refining capacity."

As public concern over the gulf's future grows, the GMP is becoming a key catalyst in developing long-term solutions. As McKinney has noted, "The Gulf Program can provide the weave to knit the fabric of an effective gulf-wide entity to accomplish the goal of maintaining a healthy and productive Gulf of Mexico: America's Sea." □

Runoff and the Chesapeake Bay

by William C. Baker and Tom Horton

(Baker is President of the Chesapeake Bay Foundation and Horton is senior writer for the Foundation.)

The Chesapeake Bay is North America's greatest estuary. In the Chesapeake, fresh water flowing seaward from nearly 50 rivers mixes with sea water from the Atlantic ocean pushing inland as far as 200 miles. The Chesapeake still supports several thousand full-time commercial seafood harvesters and produces half the nation's catch of blue crabs and a fifth of its oysters. Well over two million people still fish and hunt for sport there each year.

However, in the last quarter century the great bay of Maryland and Virginia has lost to pollution 80 to 90 percent of its underwater grass beds that are critical habitat for a multitude of birds and fish, and a key means by which the estuary cleans itself from sediment and other pollutants. In the same period, dramatic downturns have occurred in its populations of striped bass, or rockfish, its American and hickory shad, yellow perch, alewife and blueback herring, white perch, and other species. Oyster populations, hit by a combination of disease, overfishing, and pollution, are estimated to be about one percent of what they were a century ago.

In 1975, Congressional concern about environmental trends in the Chesapeake led to a major, multi-year study by EPA, the states surrounding the bay, and the District of Columbia. This resulted in 1983 in an unprecedented commitment on the part of these jurisdictions to restore the estuary to health, a task that would take years, and probably decades.

The restoration effort has proceeded on several fronts, ranging from the control of toxic chemicals to better fisheries management, to ambitious programs that place a permanent cap on pollution from human sewage, even as human population continues to increase.

This article examines nearly a decade of attempts to control pollution affecting the Chesapeake in one of the most challenging of those arenas—the diffuse runoff of pollutants from land.

On most maps the Chesapeake Bay is a large body of water, some 200 miles long and up to 25 miles wide, stretching from Norfolk on its southern end to near the Pennsylvania border on its northern end. Its broad waters are fringed with the shoreline counties of Maryland and Virginia. At the top of the map a thin line intrudes: the bay's major tributary, the Susquehanna River.

In fact, the bay in proper perspective is about fourteen-fifteenths dry land. If we follow the upstream, branching paths of the Susquehanna and the dozens of other tributary rivers, including the Potomac and the James, they extend through nearly a sixth of the Eastern Seaboard: from near Vermont's southern border down close to North Carolina, from coal fields in West Virginia almost to Delaware's seacoast. This, the true scope of the Chesapeake system, comprises a 64,000-square-mile drainage basin, or watershed, sloping through all or part of five states, carrying in its runoff the byproducts of everything humans do on the land toward 4,400 square miles of water, including tributaries, at the bottom of the watershed.

There are methods that will control the runoff of nutrients from farmlands.

Yet another, even less obvious relation between the Chesapeake's lands and its waters reinforces its vulnerability to pollution. The bay, though long and broad, has very little water to absorb and dilute pollutants. It is incredibly shallow; its average depth less than 22 feet. In contrast to the size of the lands that drain to it, the Chesapeake has less than a tenth the volume of water of most of the world's great coastal and inland water bodies.

In such a context, we can begin to understand why land runoff has become such a factor in the quality of Chesapeake Bay. It is now generally acknowledged that the estuary cannot be restored to health without dramatic reductions in pollution from the land. Control of the more traditional sources, like sewage and industrial discharge pipes, is not enough.

Agricultural Runoff

Agriculture, principally in Virginia, Maryland, and Pennsylvania, involves more than a quarter of the bay's watershed. The runoff of "nutrients," the nitrogen and phosphorus that are prime culprits in the bay's decline, is several times as great from farmlands as it is from any other source.

Excessive nitrogen and phosphorus cause excessive growth of microscopic floating plant life, or phytoplankton. This helps shade out light needed for growth by the estuary's underwater grass beds. Overenrichment with plankton also contributes to frequent occurrences of low oxygen in the bay's bottom waters when the plankton decomposes.

Farming occupies less acreage in the watershed now than it did in 1950, before the bulk of the bay's decline in water quality began. But the tonnage of commercial fertilizers per acre has in many areas doubled or tripled since that time. In addition, modern animal agriculture during the same period has concentrated cows, hogs, and poultry in densities 5 to 100 times greater than in the 1950s, making it much more difficult to contain runoff of nutrient-laden manure. An extreme case, Lancaster County, Pennsylvania, in the Susquehanna river portion of the watershed, generates more than 10 billion pounds of manure annually.

Farmers in such areas often spread more manure on their land than the soil can use for growing crops. Frequently they apply commercial fertilizers as well. The result is soil that is saturated with excess nutrients. Attached to the soil, the nutrients wash toward the bay in overland runoff. They can also dissolve in water that percolates below the surface into streams and rivers flowing to the estuary. Polluted land equals polluted water.

A rough idea of agriculture's pollution potential is indicated by estimates that humans in the watershed each year generate by their wastes about 165 million pounds of nitrogen and phosphorus. Animal wastes and commercial fertilizers account for about a billion pounds. By no means do all these nutrients get into the bay. Sewage treatment removes some nitrogen and substantial quantities of phosphorus from human wastes; plants and crops remove large quantities of nutrients from farmlands.

Nevertheless, in an average rainfall year roughly 60 percent of the nitrogen and 40 percent of the phosphorus that does reach the bay are estimated to come from land runoff, and farms are the largest source. In dry years land runoff comprises a smaller proportion of the totals; in wet years, a larger proportion. These overall bay percentages vary widely among sub-drainage basins. The James, for example, the bay's third largest tributary, is overwhelmingly dominated by nutrients from sewage treatment plants.

A primary goal of the Chesapeake Bay clean-up effort since 1987 has been to reduce the amount of nutrients that get into the water. For sewage, the goal is to reduce nutrients by 40 percent from 1985 levels; for agricultural runoff, the goal is reduction by 40 percent from an average rainfall year. The reductions are supposed to be permanent. They are supposed to "cap" any further growth of nutrients polluting the bay, even as their sources continue to grow.

Such reductions from agriculture appear to be achievable and have been the focus of intensive efforts in all three principal bay states for several years now. However, the minimal results seen in water quality to date underscore the magnitude of the problem of runoff.

Alice Jane Lippson drawing. Reproduced with permission

Underwater plants, which are essential for aquatic life, can be suffocated by the excessive growth of phytoplankton caused by runoff of nutrients such as animal wastes and fertilizers.

Accounting for progress in controlling pollution that seeps from millions of acres of land, rather than from a relative handful of discharge pipes, has proven difficult in itself. EPA has estimated that between 1985 and 1990 agricultural phosphorus runoff has been reduced by 10.5 percent and nitrogen by 9.5 percent. This would appear to be a reasonably good start toward the goal of 40-percent reduction by the year 2000.

However, a recent study by the Metropolitan Washington Council of Governments estimated nutrient reductions from agriculture in counties drained by the Potomac to be 10 times less than reductions projected by using current federal and state accounting methods.

Officials have assumed that much of the task of nutrient control could be piggy-backed onto the traditional erosion control programs that have been administered for decades under agencies like the Soil Conservation Service (SCS). Accounting often has involved simply adding up the acres of farmland that have, in SCS jargon, been "benefitted" by such programs, and multiplying their number by a fixed tonnage of nitrogen and phosphorus per acre.

However, it turns out that controlling the movement of soil does not necessarily control the runoff of *nutrients placed on the soil. In some* cases, particularly with water-soluble nitrogen, retarding soil runoff only redirects the nutrient, concentrating pollution in ground water where it eventually makes its way into streams, rivers, and the bay. Worse yet, drain systems incorporated in some control methods actually hasten the passage of nutrients toward waterways.

In dry weather, ground water seeping into waterways is the source of virtually all the water flowing to the bay. This "invisible river" has been calculated to approximate roughly the magnitude of the James.

It is not surprising, then, that more than a decade of monitoring of nutrients flowing down the Susquehanna into the bay shows only a slight drop in phosphorus levels, and a modest increase in nitrogen levels.

There are methods that will control the runoff of nutrients from farmlands. Manure can be stored in concrete or steel pits. Winter "cover crops," like rye or winter wheat, will hold soil in place, take up excess nutrients left in the soil, and fix nitrogen from the air. After they've been plowed back into the soil the following spring, the farmer needs to add less fertilizer. The planting of forested buffer strips

A typical scene on the Chesapeake. Runoff from development as well as farming activities disturbs the bay's fragile ecosystem.

Skip Brown photo. Maryland Sea Grant College.

between farm fields and waterways appears a good bet to control both phosphorus and nitrogen. Providing farmers with more sophisticated soil analyses, so that they can apply only as much fertilizer as their crops require, has shown real success in places like Pennsylvania.

The problem is that these, like virtually all agricultural pollution-control programs, remain largely voluntary. The results have been that much of the bay states' spending on farm runoff control has been skewed to what farmers want, and this is often not what is most cost effective.

In sum, it appears that while meeting the ambitious reduction goals for agricultural runoff to the bay are possible, they are not likely to be achieved without substantial changes in current programs.

Runoff From Development

Although agricultural use of the watershed is the largest contributor to polluted land runoff, by far the fastest growing part of the problem is from the development of open space for residences and commerce.

During the next 30 years the watershed will go from 11 percent urban and suburban to about 15 percent, an alteration of 1.6 million acres of fields and forest. In Maryland, the most rapidly suburbanizing of the three principal bay states, acreage of developed land will nearly double.

Such development creates runoff problems that fall into two broad categories: sediment from lands bared for development, and stormwater carrying a host of pollutants off the impervious surfaces that have replaced the natural vegetation.

Whenever it rains, an acre of land cleared for construction can flush a hundred times the sediment into waterways as a well-managed farmland can, and up to a thousand times as much as a forest. The abrupt inflow of thousands of tons of soil into a stream can be as deadly as a spill of oil or raw sewage, more so perhaps, since sediment never degrades but keeps getting resuspended by tide and wind to cloud the water.

Sediment pollutes by smothering fish eggs, by tearing at the fragile gills of just-born fish, and by covering gravel bottoms that are prime habitats for fish spawning and for aquatic insects. Farther downriver it may cover oyster beds, thereby preventing the free-floating young of oysters from attaching to clean shells and then forming their own. Sediment also clouds the water, along with the plankton blooms fueled by excess nutrients, and cuts off sunlight to the bottom. The sunlight is necessary to the growth of the submerged grasses that are critical habitat in streams and in the Chesapeake proper.

Rainwater washing off urban pavement and other impervious surfaces can be shockingly polluted . . . .

During the 1970s all three bay states enacted laws designed to control sediment from developing lands. The "filter fences" of straw bales and black cloth that one sees staked into the ground around roadbuilding and other construction sites is one technique. Another is the building of settling ponds to catch and filter water draining from the sites.

These controls cannot eliminate sediment pollution, but they can reduce it by as much as 90 percent by weight. However, the finer, lighter particles of sediment escape the controls, and it is these particles that stay suspended in the water the longest. Water clarity may be degraded despite efficient sediment trapping.

How are the states doing? The Chesapeake Bay Foundation recently conducted random appraisals of sediment and stormwater controls in 31 counties and townships from Scranton, Pennsylvania, to Norfolk, Virginia. The survey was not intended to be a statistically precise representation of the entire watershed. However, it is probably the most in-depth, independent check in recent years on what progress state and local governments are making in controlling polluted runoff.

Overall, 26 percent of the construction sites were judged to be in full accordance with all requirements for sediment control by the applicable state. By state, Maryland had 42 percent of sites adequate, with Virginia at 19 percent and Pennsylvania, 13 percent. Pennsylvania's specifications were somewhat tougher than those of the other two states. Applying Maryland standards would have raised Pennsylvania to 26 percent adequate. Another 66 percent of all sites were rated inadequate, and five percent, all in Pennsylvania, showed no sign of using required sediment controls.

All three states are upgrading their sediment control programs, but if the results of the survey are typical, large improvements could be made simply by enforcing what is already in place. However, it appears that there are limits to what sediment-control structures can contain. Some huge highway projects around Annapolis, for example, which were not part of the survey, have literally wiped out or jeopardized whole stream systems despite what is considered state-of-the-art attention to sediment control.

There also appears to be too much reliance on the use of structural controls like filter fences and sediment basins to keep pollution from the water. Requiring that natural vegetation be left between development and waterways, thereby preventing pollution from occurring in the first place, may be more effective.

Damage to the environment doesn't end once a development is complete even though sediment loads drop dramatically once a site has been paved and landscaped. Rainwater washing off urban pavement and other impervious surfaces can be shockingly polluted, especially the "first flush," in which dry-weather accumulations of pollutants that have fallen from the air, from car exhausts, and from accumulations of oxygen-demanding organic matter like grass clippings, all wash into storm drains and creeks. Pets are estimated to deposit more than seven million pounds of feces annually on streets in the District of Columbia alone.

In some urban areas, stormwater channeled through the sewage-treatment plant may so exceed the plant's capacity that it carries with it raw or poorly treated sewage as well as polluted runoff. This "combined sewer overflow" plagues Richmond and Washington. In a city like Baltimore, where the stormwater is not channeled through the treatment plant, it may just dump directly into waterways.

Stormwater can also severely degrade smaller waterways physically. Most people think of paved or impervious surfaces as roads and parking lots. But they also include roofs, driveways, sidewalks, patios, even car tops. It does not take extreme urbanization to "harden" as much as half of a developed piece of land.

Once that happens, rain that used to soak into the soil flows quickly and directly down gutters and drains and into streams. The stream is subject to fierce flooding for a few hours; then, when it is dry, it is no longer fed by slow seepage through its bed and banks. The water that used to seep underground, replenishing the water table, has run off from the new, paved environment.

Pets are estimated to deposit more than seven million pounds of feces annually on streets in the District of Columbia alone.

This feast-or-famine flow wreaks havoc on the stream's habitat. It is easy to see if one compares an urban to a rural creek. The channel will be widened and the banks eroded in the former setting. After a rain, it will surge wildly with water, then run almost dry within 24 hours. The country creek will be more stable, rising less in rainstorms, falling less in droughts. It will be, in short, a better place for fish to live.

Studies in various parts of the bay area have found that as the amount of paving in a stream's watershed goes up, aquatic life in the stream declines, even if there are no specific pollution sources present. Such degradation can start by the time 12 percent of the watershed is paved. That's equivalent to developing the entire watershed with suburban homes on two-acre lots. By the time imperviousness reaches 25 percent, equivalent to two homes per acre, degradation can be severe.

All three principal bay states have developed laws in the last decade or so aimed at controlling stormwater runoff from new development. Most developments affected by these new laws must include some sort of pond, basin, vegetated buffer strips, or other device designed to detain, slow, and even out the surges of stormwater.

However, there have been no state requirements that address the pollution carried by stormwater runoff and, not surprisingly, the 31 counties and townships in the Bay Foundation survey were found to be doing very little to check such pollution.

All told, the survey took in 90 sites in the three states. Information was available to assess 78 for stormwater controls. A quarter of these were exempt from using controls because of their small size, or because it seemed the controls would do more damage than not building them.

Nearly half of the 78 employ controls which do little to protect bay tributaries beyond minimizing flooding. Only eight percent employ measures that address the wider range of impacts associated with stormwater runoff.

As with sediment, all three states are upgrading their stormwater controls to improve the quality as well as reduce the quantity of runoff from lands under development. It has been calculated that stormwater pollution from the 78 sites is two to five times higher than it was prior to development. If the bay watershed is to accommodate the huge projected increases in land development, and at the same time bay water quality is going to be restored, then new development should aim, at a minimum, for a zero increase in polluted runoff from stormwater. The survey indicates that the region is a long way from this goal.

A thorough study of stormwater and sediment controls in the Washington Metropolitan Area concluded that even the best controls would merely slow the growth of pollution, not reduce it, or even hold the line. The best hope, the study said, lay in reducing the pollutants coming from existing development as well as new development.

Such urban "retrofit" may involve a range of techniques: frequent street sweeping and scooping up after pets, as practiced successfully in New York City; placing gravel-filled "infiltration trenches" on the edges of developments to let the "first flush" of stormwater soak into the ground; or trapping the super-polluted first flush, and sending only that portion of the stormwater runoff through sewage treatment plants.

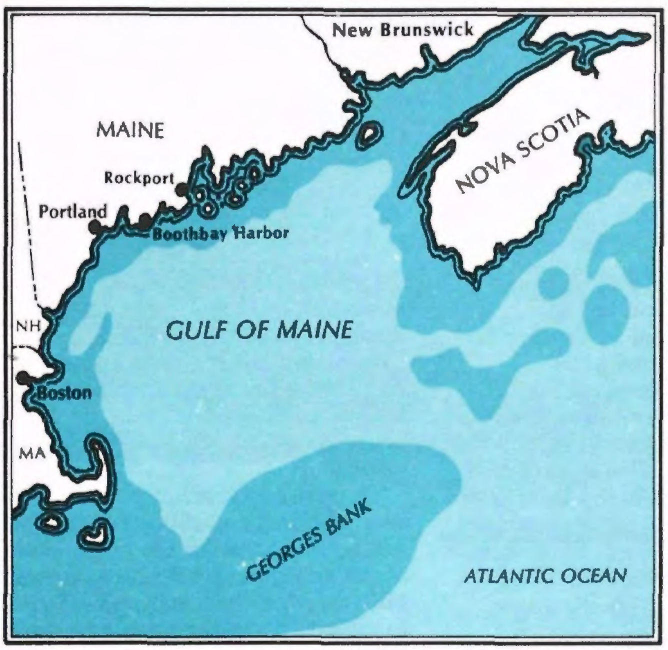
In sum, the Chesapeake Bay's restoration depends fully as much on controlling pollution running off the lands of its vast watershed as it does on controlling the more traditional sources, such as discharges from sewage and industrial pipes. □

When sediment covers oyster beds, free-floating oyster young have trouble attaching themselves to clean shells before forming their own.

Alice Jane Lippson drawing. Reprinted with permission.

Pollution-Prevention Tactics in the Gulf of Maine

by Melissa Waterman



We've all heard a relative or friend admonish in a cautionary tone: "Remember, an ounce of prevention is worth a pound of cure." While trite, this proverb may well hold true both for personal behavior and for the management of marine water bodies. Around the nation we see strong environmental protection programs emerging only after evidence of degradation of land, air, and water becomes inescapable. Millions of dollars are poured into the laudable task of "cleaning up" the Chesapeake or the Great Lakes. However, in New England the old proverb is being used as the philosophical foundation upon which to build a different kind of marine protection program.

The Gulf of Maine is one of the world's most productive water bodies. Its plentiful resources supported Native American populations and drew bevies of European settlers to its shores. The bottom contours of the gulf make it a semi-enclosed sea, almost entirely separated from the Atlantic by underwater banks, of which Georges Bank is the best known. The major avenue through which cold ocean waters enter the gulf is the 761-foot deep Northeast Channel.

(Waterman is a Program Planner for the Gulf of Maine at the Maine State Planning Agency.)

The gulf is surrounded by the states of Massachusetts, New Hampshire, and Maine and the provinces of New Brunswick and Nova Scotia. Recently, the states and provinces came together to create a program to protect the Gulf of Maine and its abundant natural resources before harm occurs.

The gulf's reputation as a rich fishing ground stems from a seasonal abundance of phytoplankton. To grow, these microscopic, free-floating plants depend upon available nutrients and sunlight. In the Gulf of Maine, phytoplankton are abundant because the surface and bottom waters mix vigorously. This vertical mixing is driven by the strong tides and currents that flow through the gulf. The gulf's counterclockwise current, in turn, is powered by 250 billion gallons of fresh water that enter the gulf each year from the region's rivers.

The vertical mixing brings critical nutrients into warmer, sunlit waters, where phytoplankton are able to grow, or "bloom." Phytoplankton are critical to the ecology of the gulf because they serve as the base of its diverse marine food chain. Over 100 species of birds, 73 species of fish, and 26 different species of whales, porpoises, and seals reside in the gulf.

In New England, an old proverb is being used as the philosophical foundation upon which to build a different kind of marine protection program.

Although the Gulf of Maine remains a fertile body of water, there are signs of changes occurring in its system. The effects of the states' and provinces' increasing populations are apparent not only on crowded highways and in coastal parks, but within the gulf itself.

In the years between 1950 and 1980, huge swaths of agricultural and forested lands disappeared from the gulf coast. In Rockport, Maine, for example, developed land within the town borders increased by 300 percent. As more land is developed, less land is available to act as a natural filter for runoff. As a result, more potentially harmful substances are swept into the gulf.

Large tracts of land developed for housing create a problem of sewage treatment. Much of the gulf coast is either rocky, and hence unsuitable for a standard tank and field septic system, or composed of sandy glacial outwash soils, which can only marginally filter the effluent of individual septic systems. In addition, as cities such as Portland and St. John grow, their antiquated sewage treatment systems provide only minimal treatment of

Bob Bowman photo. Allied Whale.

urban sewage. Combined sewer overflows in many cities allow nearly untreated sewage to enter the bays and harbors of the gulf. The result has been ever-increasing closures of productive shellfish flats due to contamination by fecal coliform bacteria.

The effects of population growth are most acute during the summer months. During recent decades, the gulf region has grown in status as a summer tourist destination. Acadia National Park in Maine and Canada's Fundy National Park in New Brunswick draw huge numbers of people each summer; in 1988 Acadia alone had over 4.5 million visitors. Many visitors travel along the scenic coastal routes, such as U.S. Route 1, contributing to nonpoint-source runoff from the roads to the Gulf of Maine and degrading the region's air quality.

A National Marine Fisheries Service study in 1982 in Boothbay Harbor, Maine, revealed lead levels in crabs as high as those found in animals from New York City and Philadelphia harbors. Research into the history of Boothbay Harbor unearthed no industrial activities that might account for the lead. Nor were the products of the municipal sewage treatment plant found to be the culprit. The study concluded that exhaust and oil drippings from the 5,000 cars that pass through Boothbay Harbor daily during the summer months could account for the lead levels. Studies such as this indicate that the steady increase in seasonal tourists, while beneficial for the immediate economy, may have a long-term effect on the gulf.

Over the centuries, both the provinces and states have converted many acres of coastal wetlands and mudflats by diking and filling. Estimates indicate that in the four Canadian maritime provinces, approximately 65 percent of tidal marshes and flats have been altered or lost entirely. An indeterminate number of acres of coastal wetlands have been filled along the coast of the three states.

The study concluded that exhaust and oil drippings from the 5,000 cars that pass through Boothbay Harbor daily during the summer months could account for the lead levels.

Some say the loss has affected gulf fisheries, since estuaries and associated wetlands serve as nurseries for a variety of commercially valuable species. The plummeting populations of black duck and other migratory bird species are further clues that critical coastal habitats along the entire eastern seaboard are disappearing.

Then there are the multiple toxic elements entering the Gulf of Maine system. Everyone is familiar with the highly degraded environment of Boston or Salem harbors. With varying degrees of severity, all the major ports along the gulf suffer from the effects of years of pollution. However, a less visible problem is posed by the numerous rivers that enter the gulf. Although the U.S. and Canadian federal governments regulate a limited number of identified toxic elements, a multitude of other substances for which standards have not yet been devised are discharged by industries into rivers that enter the gulf. Elevated levels of specific heavy metals have been found in the sediments that lie in the gulf's deep offshore basins, indicating that toxic contamination does not remain isolated to near-shore waters.

To date, instances of pollution have been relatively specific. Yet a growing sense of concern for the overall future of the gulf prompted environmental officials from the states and provinces to meet to discuss common issues. Although both the United States and Canada recognized intense harvesting of fish stocks as a profound problem, water quality and habitat protection were considered the paramount issues.

In late 1989, a working group from the states and provinces published a report, *The Gulf of Maine: Sustaining our Common Heritage*. The report detailed the environmental characteristics of the gulf, the human values drawn from it, and the growing stresses placed upon it. The group then hosted a Gulf of Maine conference in Portland, Maine, which was attended by over 250 scientists, fishermen, bureaucrats, academicians, and citizens. At the close of the conference, the Agreement on the Conservation of the Marine Environment of the Gulf of Maine was signed by the Governors and Premiers of the five states and provinces.

The agreement makes clear the intent of the states and provinces concerning future use of the gulf: "The Parties to this agreement recognize a shared duty to protect and conserve the renewable and non-renewable resources of the gulf for the use, benefit and enjoyment of all

A finback whale surfaces off the Maine Coast. In the background is the Mt. Desert Rock Marine Research Station of the College of the Atlantic.

Bob Bowman photo. Allied Whale.

With a little help from the National Audubon Society, Atlantic puffins are returning to former nesting islands in Maine. The Gulf of Maine is still relatively healthy as an ecosystem. Adjoining states and provinces are working together to keep it that way.

their citizens, including generations yet to come . . . ." With this language, the Governors and Premiers echoed the principles stated in the United Nations' report Our Common Future (1987), which called for sustainable development of the world's resources. The findings of the agreement acknowledged that the gulf in its present state is, for the most part, healthy. The fear was that without prompt protection efforts by the states and provinces, the long-term health of the gulf would be jeopardized.

The 1989 agreement established a Council on the Marine Environment as a new international organization. Composed of appointed members from the five jurisdictions, the council's responsibilities include developing a program for monitoring the quality of the region's marine environment and writing a 10-year Gulf of Maine Action Plan.

An initial draft of the action plan was released by the council in December 1990. Its thrust is prevention; its theme is cooperation. By fostering communication among the states and provinces, by improving availability of information throughout the region, by augmenting existing monitoring programs—by these and a multitude of other cooperative ventures, the plan paves the way for future compatible environmental protection activities by members of the council. Highlights from the action plan include:

- Reviewing state and provincial oil-spill contingency plans to identify methods for improved cooperation in the event of a major spill
- Developing a regional database of current and historic environmental data in a format accessible throughout the region
- Identifying additional sites within the gulf region that will provide habitat for migratory birds and devising a regional plan to support protection of the sites
- Evaluating the need for a common critical habitat mapping system
- Supporting a regional study and evaluation of restoration and mitigation techniques used in gulf coastal wetlands and other coastal habitats of regional concern
- Developing a Gulf of Maine Marine Mammals Protection Plan in order to set priorities for protection of critical habitats
- Initiating an agency personnel exchange program that will promote the exchange of ideas and information
- Establishing a Gulf of Maine Environmental Award program to give recognition to the pollution prevention activities of industry, organizations, and individuals.

It is anticipated that the council will adopt the draft action plan in June 1991. However, the plan will always be considered a blueprint and will be reviewed and revised within five years of adoption. With commitment and support over the next decade from the public, the state and provincial governments, and the two federal governments, the blueprint will grow into a sound and long-lived environmental protection program.

The Council on the Marine Environment, although still young, may turn out to be the best avenue for ongoing cooperation among the states and provinces on a spectrum of marine issues. Development of the action plan and initiation of a regional Monitoring Program are just two examples of the council's initiatives within the Gulf Program. Efforts to develop a regional environmental consciousness around the gulf find expression in a variety of public education materials, collaborative data-management projects, and professional workshops.

Historically, the Gulf of Maine has served as the physical and economic link between the three states and two provinces. In practice, this geo-political link has proved to be strong and productive, as the Gulf Working Group has shown. Clearly, the strength of the Gulf Program comes from its genesis as an indigenous effort of the states and provinces. Although it is too early to predict the outcome of the program, the congenial relations among the Working Group, the Gulf Council, and the governors and premiers hold great promise for improved stewardship of this fertile, but fragile water body. In this case, an ounce of prevention might eliminate the need for a cure. □

San Francisco Bay: Beset by Freshwater Diversion

by Harry Seraydarian

Water is the lifeblood of California. It fuels a multibillion dollar agricultural economy and quenches the thirst of increasing masses of people. The problem for California, however, is that water is not found in the same place it is needed and used. About 70 percent of the state's annual runoff occurs north of Sacramento, the capital that lies in the center of the state; 80 percent of the water consumption occurs south of this city. In order to compensate for this uneven distribution and ensure a more reliable water supply statewide, the state built the world's largest manmade water system to convey water from the north to the south.

Since the discovery of gold in 1849, the estuary has undergone tremendous change.

California's ongoing struggle for water centers largely on the San Francisco Bay-Delta Estuary as the major supplier of water for the entire state. Located at the mouth of the Sacramento-San Joaquin river system, it is the largest and most important estuary on the west coast of North and South America. It supports a complex ecosystem—including the state's largest anadromous fishery, provides fresh water for much of California's population, and supports its agricultural interests.

Since the discovery of gold in 1849, the estuary has undergone tremendous change. A huge increase in population, industrial development, the establishment of agricultural interests, and water diversions have altered the estuary forever. Today, the San Francisco Estuary is considered one of the most modified estuaries in the United States due to major changes to its waterways for purposes of navigation, water export, and flood control and the diversion of fresh water that historically flowed through the estuary.

The estuary is many things to many people. It is home for seven million Bay Area residents, a biological resource of enormous importance, a productive nursery for marine fish and crabs, an important wintering habitat for migratory birds, a beautiful harbor of international significance, a boater's paradise, and the source of drinking water for 40 percent of the state and irrigation water for much of the state's agricultural lands.

Like estuaries everywhere, the San Francisco Estuary is one of the most biologically productive environments on Earth. This unique ecosystem, with its mix of fresh water from the river and salt water from the ocean, is brimming with life. It provides habitat for millions of creatures. It supports over 150 species of fish, including a commercial fishing industry of herring and anchovies, and large recreational fisheries for salmon, striped bass, steelhead trout, shad, and sturgeon.

It contains the largest wetland habitat in the western United States and is an internationally significant shorebird area. Hundreds of thousands of shorebirds migrating along the coast route of the Pacific Flyway find their way to the estuary's wetlands to feed and rest. Loons, grebes, pelicans, cormorants, herons, swans, egrets, ducks, geese, rails, plovers, curlews, willets, and sandpipers congregate on the estuary's waters and shoreline. Many of the estuary's rare or endangered species, including the California clapper rail, California black

Bob Walker photo.

(Seraydarian is Director of the Water Management Division in EPA's Region 9 and Chair of the San Francisco Estuary Project's Management Committee.)

rail, and salt marsh song sparrow, are dependent upon its wetland habitats.

In addition to sustaining this important ecosystem, the San Francisco Estuary also attempts to meet the needs of an $18 billion agricultural industry. Eighty-five percent of the state's managed water supply is used for farm irrigation. California produces over 200 crops, including 45 percent of all the fruits and vegetables consumed in the United States. The introduction of irrigation (using fresh water diverted from the estuary) has transformed the arid, 500-mile long Central Valley from a near-desert into a lush garden land.

The estuary also supplies 40 percent of the state's drinking water. As more and more people migrate to California, attracted by the mild, Mediterranean climate—wet winters and dry summers—the demand for water will continue to escalate. Southern California, which receives most of the population increase, is now growing at the astronomical rate of 350,000 persons a year.

Until recently, the illusion has prevailed that there was enough water to serve all of these diverse uses; however, it is now apparent that some needs have been met at the expense of others. The symptoms and danger signs are everywhere.

Fish populations in the estuary have plummeted. Natural salmon populations have declined 75 percent from historic levels. The number of striped bass, an indicator species used to gauge the health of aquatic life in the estuary, has decreased 70 percent since 1960. Fishery agencies attribute these declines to a number of factors related to water diversions.

Historically, the average annual fresh water flow to the bay and Delta in nondrought years has ranged from 19 to 27.5 million acre-feet. Today, nearly 40 percent of the historic flow is removed for local consumption upstream and within the Delta. Another 24 percent is diverted from the delta through the state and federal water projects for agricultural and municipal use in central and southern California.

Low flows interfere with the migration and spawning of anadromous fish such as salmon and striped bass. These fish spend their juvenile lives in the fresh water of the river, move downstream into the saltier ocean waters to feed and grow, and ultimately return upstream years later to spawn and die. As juveniles, they seek out a particularly rich feeding area found immediately downstream from the freshwater-saltwater interchange.

This region, known as the entrapment zone, is a highly productive area that serves as the basis of the food chain upon which the estuary's shrimp, clams, fish, and waterfowl depend. The location of the entrapment zone, which moves depending on whether water flows are heavy or light, is most important during the crucial spring months when newly hatched fish move downstream to feed. When the river flows are low, the entrapment zone is pushed upstream into the narrower, deeper river channels resulting in a loss of food abundance.

To make matters worse, millions of juvenile salmon and striped bass are sucked into the diversion pumps at the south end of the delta each year because of a peculiar reverse river flow created by the powerful pumps during the dry season. This reverse flow confuses migrating fish, and in spite of protective devices, the pumps destroy hundreds of millions of juvenile fish and fish eggs each year. Various mitigation measures continue to be tested to reduce this critical loss of fish to the pumps.

Low flows also increase salinity and temperature levels affecting the distribution and abundance of many organisms. A complex community of interdependent plant and animal life thrives in the estuary and is dependent for its survival on a consistent and adequate supply of fresh water.

Water quantity has a direct impact on water quality. Water quality in the estuary cannot be sustained without sufficient fresh water flows. As more fresh water is diverted and ocean water intrudes further upstream, salinity becomes a problem affecting the quality of water used for human consumption and crop irrigation. And the diversion of fresh water has exacerbated problems including drastic losses of tidal wetlands and wildlife habitat, intensified land-use pressure, and increased pollutants.

But not just the biological resources of the San Francisco Estuary are at risk: The survival of southern California's economy and way of life are also at stake. Southern California's lifeline is directly connected to the waters of the estuary. Faced with a burgeoning population and reduced allocations from their Mono Lake and Colorado River water supplies, southern Californians view with alarm any suggestions to cut their water allotments from the north.

California's agricultural industry is even more reliant upon the water diverted from the estuary than California's proliferating population. Agriculture currently uses about five

California has constructed an elaborate system to carry water from north to south, diverting much fresh water from the San Francisco estuary in the process. This aqueduct crosses the state's Central Valley.

times the amount of water consumed by households and industry in the state.

Unfortunately, the prospect of finding untapped water supplies for the state is slim. Meanwhile, the health of the estuary continues to deteriorate.

Who has responsibility for resolving California's water conflicts?

The State Water Resources Control Board (State Board) plays a key role in water decisions in California as it has authority both to set water quality standards and to allocate water rights. Its mandate is to balance the needs of the environment, agriculture, and urban users. It is now conducting hearings to determine how to balance environmental protection for the estuary with other statewide water needs. The State Board must develop water-quality standards to protect the estuary and may, consequently, revise water allocations. Such revision powers place the State Board under tremendous pressure from the environmental community on the one side and on the other from central and southern California water contractors, who are jealously protective of their water rights.

If the State Board fails to set water quality standards which provide adequate protections for the estuary, under the Clean Water Act, EPA can disapprove the state's standards and promulgate its own. EPA prefers to defer to the State Board's process to develop standards. However, if the State Board is too slow in adopting standards that meet federal requirements, EPA may have to intervene.

The 1987 amendments to the Clean Water Act established the National Estuary Program to restore and protect important coastal resources, including the San Francisco Bay-Delta Estuary. The San Francisco Estuary Project, a cooperative effort involving EPA and the State Board, is also looking at the subject of fresh water flows and will make management recommendations for the protection and restoration of the estuary in its Comprehensive Conservation and Management Plan due out in late 1992.

The estuary is in distress. That reality can no longer be ignored. Fresh water is critical to protecting this valuable resource. But exactly how much is needed to protect the estuary is unknown. Estimates range widely from 1.5 to 5 or 6 million acre feet of water. (For comparison, one acre foot—or roughly 326,000 gallons of water—will support a family of five for one year.)

Fresh water is critical to protecting this valuable resource.

One thing is certain. The estuary cannot meet all of California's projected increasing water needs.

In a recent draft Bay-Delta report, the State Board acknowledged that "full protection of all beneficial uses in all water years is impossible. There simply is not enough water.... Some accommodation has to occur."

Given the unlikely prospect of new water supplies, it is essential that Californians learn to use the water they already have more efficiently. While water conservation and reclamation are not the sole answers to a limited water supply, they are both an integral part of any solution. California's past four years of drought conditions have provided some valuable examples.

Many communities have dramatically reduced water consumption by installing low-flow shower heads, toilets, and faucets; fixing leaky fixtures; converting landscape to drought-tolerant plants; and installing drip irrigation systems.

Agriculture, as the state's primary water user, is a prime candidate for conservation. Water is a highly subsidized commodity for many farmers, and there is little incentive to use it efficiently. Agricultural users currently pay from $3 to $15 per acre-foot for federally subsidized water and $50 per acre foot for state water, while urban users generally pay from $150 to $300 for an acre-foot. Four water-intensive crops—cotton, rice, alfalfa, and irrigated pasture—use over half of agriculture's water supplies in California but return less than a tenth of the value of other crops. If California's farmers conserved 10 percent of their normal water use, three million acre feet of water would be available for other purposes.

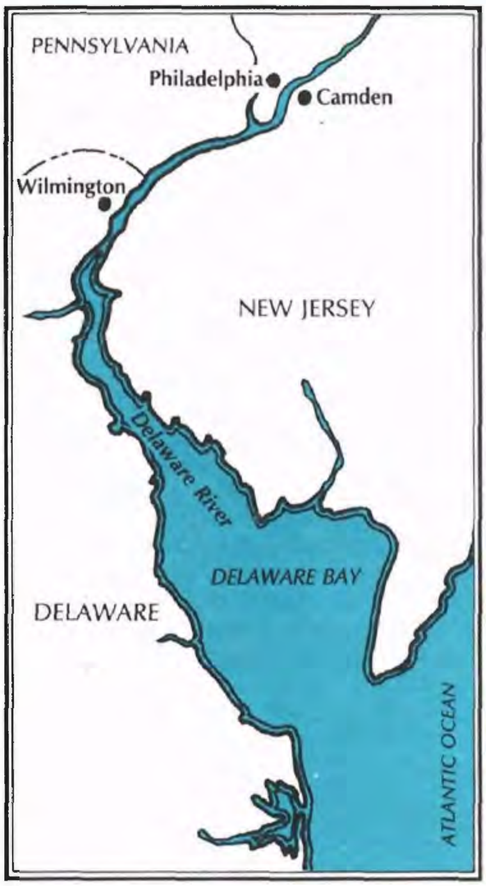
Water marketing is also being tried. Farmers have the option of selling water which they do not use. The potential profit from this unused water provides an incentive to conserve. Urban water users and other potential buyers are the beneficiaries. Although water marketing is controversial and there are significant institutional barriers to overcome, Southern California's Metropolitan Water District, assisted by the Environmental Defense Fund, is experimenting with this concept and has contracted for water conserved by Imperial Valley farmers.

California has been in the forefront of reclamation research and has encouraged local and regional programs. Reclamation programs now being developed will reuse treated wastewater. Treated sewage can be used for landscape or agricultural irrigation or pumped underground to replenish ground-water supplies for future use.

But time is running out for the estuary. Only a major shift in the way Californians think about and use water will save it. If all Californians take responsibility for using water responsibly, the estuary may have a chance. Then, future generations will know an estuary which is vital, beautiful, and teeming with life. □

An Early Success for the Delaware Bay

by Bruce Stutz



(Stutz, who writes on science, natural history, and the environment, is writing a book on the Delaware River.)

By 1945, after three centuries of hard use, the Delaware Bay was almost used up. Its shellfisheries were in decline, its shad and sturgeon fisheries decimated, its shorelines often awash with human and industrial waste.

It once had a more pleasing aspect. Historically, its shores were lined with great stands of oak, hickory, and pine; its tidewater swamps full of cedar, its marshes full of roosting seabirds or flocks of migrating waterfowl.

"I have nowhere seen so many ducks together," a 17th century journalist wrote of a Delaware wetland. "The water was so black with them that it seemed when you looked from the land below upon the water, as if it were a mass of filth or turf, and when they flew up there was a rushing and vibration of the air like a great storm coming through the trees, and even like the rumbling of distant thunder ...."

Shoreline towns with names like Caviar, Shellpile, and Bivalve boasted of the productivity of the bay's waters. Schooners from as far north as Philadelphia worked the seemingly limitless oyster beds. Travelers in the upper Delaware Bay wrote of schools of leaping sturgeon that tipped small vessels. Shad made spring runs to the freshwater reaches of all the bay's tributaries. Even dolphins once schooled up the bay as far as Philadelphia.

But as elsewhere, settlers along the bay and Delaware River —the Swedes, Dutch, and English—began changing the land. To gain pasture and grazing land, farmers built earthen banks 5 to 10 feet high around the marshes, dammed the streams that ran through them, and then dug a grid of ditches to drain them dry. The damming and draining very soon became institutionalized on both shores of the bay as companies formed to build and maintain the banks, sluices, ditches, and dams. Waterfowl had fewer feeding grounds; fish had fewer streams in which to spawn. The clearing of forests along the bay tributaries and in the mountains of the upper Delaware River also had its effect, causing soil to run off into streams, the silt eventually reaching the bay.

Nevertheless, well into the 19th century the fisheries seemed to flourish. Railcars full of oysters were shipped daily from Port Norris. Sturgeon were so plentiful that once the fish were stripped of their roe, their carcasses were dumped back into the bay. Between 1896 and 1901, the catches of shad in the Delaware River alone were greater than in any other river along the Atlantic coast. Such catches almost made both fishermen and scientists forget the sudden decline in the number of fish caught only a few years before, including sturgeon catches, which dropped precipitously.

By 1945, after three centuries of hard use, the Delaware Bay was almost used up.

According to the 1895 report of the Pennsylvania Fish Commission, "The general impression among the fishermen is that the decrease in the catch during the past four springs is due to the increase of coal oil, gas, and bone factories along the Delaware River. The obnoxious poisons and gasses are all turned into the river, killing the young fry; at least we believe that to be the main cause of destruction of millions of young shad. . . ."

As early as the 18th century, dams along the Susquehanna and other rivers blocked the movement of shad upstream to their spawning grounds. The Delaware remained mostly free of such obstructions, and shad made spring runs as far north as Deposit, New York, some 350 miles from the mouth of the bay. But while the Delaware fish had no concrete impediments to their progress, they had another that eventually proved just as

"Penn's Voyage up the Delaware," undated drawing by F. O. C. Darley. Penn sailed up the Delaware in 1682 and saw his namesake colony for the first time.

Courtesy of the Historical Society of Delaware.

impassable. The following is from the 1895 report quoted above:

> Regarding the pollution of the Delaware, the writer was told that the river below Philadelphia is so impregnated with coal oil that its peculiar flavor can be detected in the shad if they are detained long in the vicinity where the refuse from the coal oil factories is emptied into the water. Whether this is true or not, no one will deny that the discharge of waste into the river from the numerous refineries that are located only a short distance below Philadelphia fills the water with poisonous substances which would probably prevent shad from attempting the ascent of this stream except for the combined instincts of nativity and procreation—impulses so overmastering that nothing but death or impassible barriers will restrain them.

In fact, this 19th century writer underestimated the pollution and its cumulative effect. Within a few years of Philadelphia's founding in the late 17th century, the nearby forests had been denuded, the streams and shoreline silting in; the Dock Creek, into which William Penn first sailed, had become fouled with garbage and the waste of shoreside tanneries. By 1750 the creek had to be filled in and paved over.

Trenton, Philadelphia, Camden, and Wilmington waterfronts all suffered from the concentration of iron foundries and tanneries. From the founding of the first mills below the falls of the Delaware at Trenton, industry crowded along the waterfront for the next 50 miles. With the discovery of oil in Pennsylvania in the 1850s, refineries were established along the river at Philadelphia and Wilmington. Shipyards, coalyards, and factories lined both banks of the Delaware. The populations of the cities grew, and so did the amounts of human and animal waste flowing out of the sewers into the river and bay. (Currently the population around the estuary, which covers a relatively small area, is some 6 million.)

The waters between Wilmington and Trenton had been the major spawning grounds for the shad. Unable to deal with the pollution, both state and federal fish commissions attempted to spawn and raise shad for release into the river. These efforts were fruitless, however. The catch—up to 15 million pounds for the bay and tidal rivers in 1896—dropped to 5 million pounds in 1904. In 1921, the catch was barely a quarter of a million pounds and remained at that level as the commercial fisheries became losing propositions, declined, and nearly died out.

The waters had become deadly. By the 1940s, some 500 million gallons of raw sewage and untreated industrial waste were being dumped into the Delaware. Bacteria in the river, fed by the nutrients, used up the oxygen. Shad and herring attempting spring runs upriver were found dead by the thousands along the river shores of Philadelphia and Camden.

The severity of the problem made it impossible to ignore. The smell of hydrogen sulfide gas felled dock workers. Wastes clogged ships' cooling systems. The waters, slick with greases and oils, corroded the metal of ships. (Navy fliers landing in Philadelphia were reportedly told not to worry about the smell at 5,000 feet: It was wafting up from the river below.)

In 1946, the U.S. Fish & Wildlife Service found 20 miles of the upper estuary to be anoxic (oxygen-deficient) from the surface to the bottom. Philadelphia, which took half of its drinking water from the Delaware, had already begun treating the water but was still concerned over its further deterioration.

The fish could not wait. The lack of dissolved oxygen in the stretch of river between Wilmington and Philadelphia literally choked the adult fish returning to spawn in the spring. Those that made it through what became known as the "pollution block" to spawn in the cleaner upriver waters more often than not died on their return. And the young of the year, struggling downstream in the late summer to head to sea for the first time, often didn't make it.

In the early years of the century, New York City had announced a plan to dam the upper reaches of the Delaware and create a water supply system for the growing city. Concern rose in all

Philadelphia Water Department photo.

In recent decades, wastewater treatment has been vastly improved along the Delaware. This is the Northeast Water Pollution Control Plant serving the Philadelphia area.

Rebecca Barger photo. Copyright The Philadelphia Inquirer.

A success story in the making. Fishing guide Edward M. Marks is happy that shad catches in the Delaware River are increasing every year.

three downstream states about the effects of such water withdrawals on the river. New York, New Jersey, and Pennsylvania had already tried to work together on water supply problems through a Delaware River Treaty Commission, created in 1923. This commission developed a Delaware River compact to govern water use. The compact was rejected, but following New York's announcement, the states still insisted that no single state could control the flow of the river.

The case over New York's dams went to the Supreme Court. The court allowed the withdrawals but agreed there must be sufficient water to share downstream.

By 1936, only five years after the Supreme Court decision, the states of New Jersey, New York, and Pennsylvania had formed Commissions of Interstate Cooperation. And out of the states' awareness of the need to work together on both the use and the problems of the Delaware (if only out of concern for their own piece of the river), they created the Interstate Commission on the Delaware River Basin (INCODEL). This was in the midst of the Depression; although money might be available for dams, the states, anxious about their autonomy, were concerned about the federal government coming in to build them. A cleanup, however, was one thing the states could agree on, and they proceeded to plan ways to reduce the load of waste entering their Delaware waters.

They began by developing and adopting interstate water- quality standards which demanded at least primary, and in some cases secondary, treatment of sewage discharge into the river and estuary. This would be a major effort since the sewers of Philadelphia and other towns and cities around the estuary had grown along with the population, with little design except to get the discharge out to the nearest stream. Nonetheless, INCODEL— which had no legal power—got each state to push through legislation on water pollution and begin building sewage treatment plants.

World War II interrupted these efforts. However, research done by Richard Albert, who is on the water-quality staff of the present Delaware River Basin Commission, shows that by the end of the 1950s, 75 percent of the Delaware Basin communities had what was considered adequate sewage treatment, as opposed to only 20 percent before INCODEL's founding. INCODEL also took on the cleanup of some 30 million tons of coal silt that had run downstream from the coal regions in the Pennsylvania mountains and lay in the river sediments.

INCODEL, according to Albert, also promoted studies which found that the freshwater aquifer from which Camden and southern New Jersey communities drew their water was recharged by the water of the Delaware estuary—another reason why the quality of the waters had to be protected.

All these early efforts had some effect. The water quality—especially as measured by oxygen content—had nowhere to go but up, and dissolved oxygen began to improve measurably.

After the summer flood of 1955, inquiries into water use and flood prevention on the Delaware heightened concern about water quality. A U.S. Army Corps of Engineers study gave rise to a Delaware Estuary Comprehensive Study, which developed a model for raising water quality standards. Based on recommendations from the Engineers Corps study, INCODEL was replaced by the Delaware River Basin Commission (DRBC) in 1961. The DRBC came into being under a Delaware River Basin Compact entered into by the states and the federal government. Each of these had a representative with equal power on the commission; in this way, a more secure legislative mandate was formed to regulate not only the pollution that went into the river and estuary, but also to control water diversion.

With its legislative mandate, the DRBC could ask for and get compliance with the more exacting standards. Higher standards were set to keep the water quality from getting worse and to begin improving it. DRBC standards soon became state standards, and the state standards were accepted by the Federal Water Pollution Control Administration, a forerunner of EPA.

The 1972 passage of the Federal Water Pollution Control Act amendments enhanced the DRBC cleanup already under way by adding both federal enforcement and funding for construction of new treatment plants. As a result, the depletion of oxygen in the water was cut in half between 1958 and 1983. This reduced the area and length of time that pollution blocked the shad. Even if the fish couldn't spawn in their old grounds, they might make it upstream to others.

And the number and kinds of fish in the upper estuary increased. This year the DRBC recommended further efforts to increase the level of dissolved oxygen in the river areas where fish still cannot spawn. The change ought to bring more shad, striped bass, and herring to areas of the upper estuary where a 1973 EPA study said there would be no chance for recovery, as Albert points out.

The Delaware still has problems, however. Basin states are concerned about toxic wastes in the river—more than 100 chemical manufacturing plants and oil refineries line the banks of the bay—and the threats, posed by development, to the remaining natural habitats along the bay and its tributaries. The problems these cause are not nearly as vivid and immediate as those of sewage waste, and so they are too often set aside.

It took a half century to comprehend and begin to cope with the problems of human waste in the river and some $1.5 billion to increase the dissolved oxygen level in the Delaware at Philadelphia by barely 2 milligrams per liter. In the meantime, some species were nearly lost along with most of the fisheries. The remaining shad fishermen on the bay report their catches increasing each year. The hope is that with a continued cooperative working method—including the EPA's estuarine research program—the next improvements won't be quite so long in coming. □

Long Island Sound: Facing Tough Choices

by J. R. Schubel

Long Island Sound is unusual not only in its natural features but also in the range and intensity of uses society makes of it. For these reasons, the sound deserves special attention. If management strategies are to be effective, they must be carefully tailored to the special features of the system.

Long Island Sound lies in the most densely populated region of the United States, a distinction the region has held since before European settlement. The greatest population growth occurred between 1940 and 1970, when the population of the region grew by a whopping 78 percent. Since 1970, the rate of growth has been less than one-tenth the national average and is projected to remain low for the next several decades; for the next two decades (1990-2010), it is projected to average less than 0.3 percent per year. Nevertheless, the region will remain the most densely populated in the nation, exceeding the national average by nearly 40-fold.

Today, more than 14.6 million people live in counties directly bordering Long Island Sound. Besides being home to millions of people, the sound provides opportunities for shipping and transportation, for recreation, and for waste disposal for more people than any other estuary in the nation.

Long Island Sound has two connections to the ocean—one at each end. (Most estuaries have only one.) The major source of fresh water, the Connecticut River, enters near the mouth. In most estuaries, the major source of fresh water enters at the head.

At its "head," the sound has the East River, not really a river at all, but a tidal strait connecting the sound to the New York-New Jersey Harbor. Although the net flow through the East River is small—only a few hundred cubic meters per second—the East River has major influences on the sound. Flow through the East River is divided into two layers: an upper layer and a lower layer. The direction of the long-term net flow through the entire cross section of the East River is toward New York Harbor, but the direction of net flow of the upper layer is toward the sound. Most of the wastewater introduced into the East River becomes concentrated in the upper layer because it is fresher and less dense than the receiving waters. Because of this, the East River carries large amounts of wastes into the sound. It also drives the estuarine circulation in the western sound which is superimposed on the oscillatory tidal currents, leading to a slow net flow of the upper layer to the east (toward Block Island Sound) and of the lower layer to the west (toward the East River).

The estuarine circulation converts the entire sound into a trap for suspended particles and associated contaminants. The trap is particularly effective in the sluggish reaches of the western sound, where suspended particles are retained and sink into the lower layer. In addition, fine suspended matter from throughout the sound that sinks into the lower layer is carried to the west, where it accumulates.

At the head of the sound—the western end—is the largest city in the United States, one of the largest in the world: a city with more than 400 combined sewer outfalls which discharge raw sewage and untreated stormwater runoff with every rainfall that exceeds a few tenths of an inch over a few hours. But New York City is not the only source of pollutants to Long Island Sound. Much pollution comes from point and nonpoint sources along the sound's coast and throughout its drainage basin. In fact, the impacts of New York City on the sound may be

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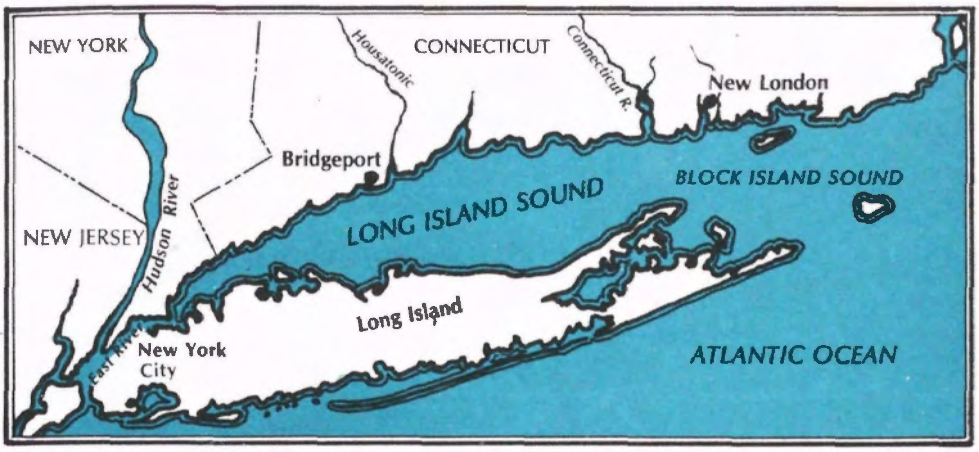
SUNY Stony Brook photo.



declining while impacts from the east are increasing.

Most of Long Island Sound's important water-quality parameters (nutrients, pathogens, and toxics) show steep gradients along the axis of the sound, falling rapidly from high levels in the East River and western sound to relatively low values in the open waters of the central and eastern sound. These gradients in water quality reflect the large inputs of wastes from the metropolitan area as well as the natural estuarine circulation. Many of the tributary embayments throughout the sound system have been impacted by loadings of nutrients, pathogens, and contaminants and deserve special attention. Most of the problems of the central and eastern sound are in the harbors.

The combination of natural and human factors (the natural circulation and the large inputs of waste materials) conspires to produce high concentrations of organic-rich, contaminant-laden particles in the waters and on the bottom of the western sound. The sediments of the western sound are highly reactive chemically and exert considerable influence on the quality of the overlying waters. Summertime hypoxia (low dissolved oxygen) is one consequence of the high concentrations of nutrients and organic matter.

The phenomenon is not new. Even before European settlers arrived, summertime levels of dissolved oxygen in the waters of the western sound often were low—low relative to the rest of the sound and sometimes perhaps even low relative to present New York State water-quality standards. To this natural situation, add excess nutrients from waste disposal and land-use practices from a large fraction of the 14.6 million people who live in the counties bordering the sound, and you have an estuary that typically experiences hypoxia in summer.

Long Island Sound, famed for recreational boating.

The problem is concentrated in the western third of the sound, but the concern is that oxygen deficiency may occur earlier in the summer, last longer, and stretch over a larger region of the sound than in the past. While the scientific documentation of these trends is sketchy, there is reason for concern. The summers of 1987 and 1989 were particularly bad, and the change from an oxygenated system to an anoxic, sulphide system can occur quickly, with little warning, causing catastrophic effects. Once it happens, remediation is costly and uncertain. Prevention is a far better strategy.

Roughly 50 percent of the total nitrogen input to the sound comes from point sources—mostly treatment plants—and the remaining 50 percent from nonpoint sources. Point sources are easier to identify and to quantify. They also are easier to control technologically; all it takes is money—lots of it. The cost estimates for removing nitrogen at about 20 coastal publicly owned treatment plants in the western sound range from \$6 to 10 billion in one-time capital costs and from \$50 to 100 million per year in additional operating costs.

While it's clear that the inputs of nutrients to the sound need to be reduced, the best way to accomplish this goal is less clear. In selecting the most appropriate strategy, a variety of environmental, technological, institutional, demographic, and economic factors need to be considered. Cost is a factor. The public made a clear and unequivocal statement about balancing environmental protection and economics in the last election (November 6, 1990).

Given the prospects for the nation's, and particularly for the region's, economy over the next few years, short-term economic considerations will be even more important than in the past. This will pose an even greater challenge to decisionmakers, scientists and engineers, and public interest groups to work together to select the strategies that will have the greatest environmental benefits, particularly long-term benefits, at the lowest cost.

While New York City's population is not growing, the population of the counties bordering the sound is increasing slowly. The net result of these demographic shifts is that the inputs of nutrients from sewage-treatment plants in New York City are stable or declining, while point and nonpoint inputs from the east are increasing. Continued upgrading of New York City's sewage-treatment plants to full secondary status is contributing to these declines. So is implementation of the combined sewer overflow abatement program.

Meanwhile, the inputs of nutrients from sewage-treatment plants outside the city—from Westchester County, Long Island, and coastal Connecticut—and from nonpoint sources in these areas are increasing. The impacts are experienced largely in embayments which receive the bulk of the inputs.

The direct loadings of contaminants, such as metals and chlorinated organic compounds, are decreasing throughout the region because of industrial pre-treatment programs and the flight of industry from the area. Because of these trends, I believe the first step should be to cap nutrient inputs from Connecticut and Long Island treatment plants. The next steps should be to reduce the aggregate nutrient inputs from these plants, from New York City plants, and from nonpoint sources. Public education must play a major role in nonpoint-source reduction by communicating how individual activities—the use of fertilizers, pesticides, and thoughtless discarding of wastes—conspire to degrade the sound. People *can* make a difference.

Long Island Sound is a magnet for recreational use, and the strength of that attraction remains strong, making it one of the most valuable estuaries in the world. The major recreational activities of the sound are boating, swimming, and fishing. The sound is home to one of the largest fleets of recreational boats of any coastal body in the world. On a summer weekend day, the number of sunbathers, swimmers, and boaters around the sound often is greater than the combined populations of Delaware and

Copyright 1990 John Cornell, Newsday.

A cove on Long Island Sound awaits development.

Alaska. The value of the sound's recreational fisheries exceeds those of the Chesapeake Bay.

The major impediments to these recreational activities are:

- Pathogens, which lead to the closing of beaches and shellfishing areas
- Floatables, which are repulsive to swimmers, beachcombers, and boaters, and sometimes lead to the closing of beaches
- Nutrients, which lead to hypoxia and associated loss of habitat and of living marine resources
- Contaminants, which lead to restrictions or warnings on the consumption of fish and which may lead to declines of living resources. Access, of course, is also a limiting factor.

But there is also a perceptual problem concerning the sound. Several years ago, we asked a Third Grade class to draw posters to illustrate their views of the condition of the Long Island Sound. Most expressed gloom and doom: "The Sound is dead" or "dying"; "no fish live there anymore." The reality is quite different.

Certainly the large population surrounding the sound makes intensive, varied, and sometimes conflicting uses of the sound—uses that have affected the system and its living resources. Moreover, land-use practices throughout the drainage basin affect the quality of the sound and its living resources. Although there are problems that require attention, much of the main body of the sound is in remarkably good condition. The most serious problems are localized in the western sound and in the embayments.

Only recently has the sound begun to receive the kind of attention it deserves from scientists, environmental advocates, environmental managers, and elected officials. In our efforts to gain the attention of the public about environmental problems, often we have resorted to the "two-by-four" strategy that works so well with mules, and humans. The strategy gets attention, but it may have created some unfortunate consequences, particularly among young people. There is a sense of despair, of helplessness; a sense of a lack of empowerment.

We need a different approach, a different strategy to conserve and when necessary—as in the case of Long Island Sound—to rehabilitate our estuaries. With 6 percent of the nation's population living in the counties that border it, Long Island Sound cannot be restored to the natural, pristine conditions that European settlers found upon arriving more than 300 years ago, any more than Connecticut, Long Island, and Manhattan can be restored to their conditions at that time. Perhaps society's expectations for estuaries like Long Island Sound, New York-New Jersey Harbor, Boston Harbor, and others in heavily urbanized and suburbanized areas should be different from those for estuaries in much less populous regions. Not lower—different.

Our environmental goals for the sound should be ambitious, visionary, and long-term. They should be framed in terms of the uses and values that are important to and cherished by society; they should be expressed in terms that have meaning to the public. Environmental goals should reflect not only the desires of present society, but our responsibility to future generations. In addition, water-quality standards should have defensible scientific and technical bases to ensure that they are consistent with natural environmental processes. For example, proposing a goal for dissolved oxygen in the western sound that is higher than the levels Giovanni Verrazano or Adrian Block found upon their arrival more than 300 years ago is not visionary; it is delusionary.

In addition to ambitious, visionary goals, more specific objectives should be spelled out. Progress in meeting those objectives should be monitored and the results reported widely. Specific water-quality objectives should be consistent with evolving technology, and the strategies adopted should be flexible enough to exploit advances in understanding and technology. Indeed, environmental objectives and goals should encourage development of new technologies.

When expenditures of billions of dollars are called for, they should be invested in those management actions that will have the greatest benefit to the environment and to society, now and for the future. There should be accountability as to how well the investments pay off in conserving, or restoring, resources that are valued by the public. Protection of these human values and uses will ensure the integrity of the ecosystem.

The management of Long Island Sound illustrates some important environmental management principles. The first priority should be preventive environmental medicine: conservation of those parts of the environment which are in good condition and which directly and indirectly support important uses. We must not focus our attention so closely on the problems of the western sound that we neglect to provide adequate protection of the values and uses sustained by the central and eastern Sound.

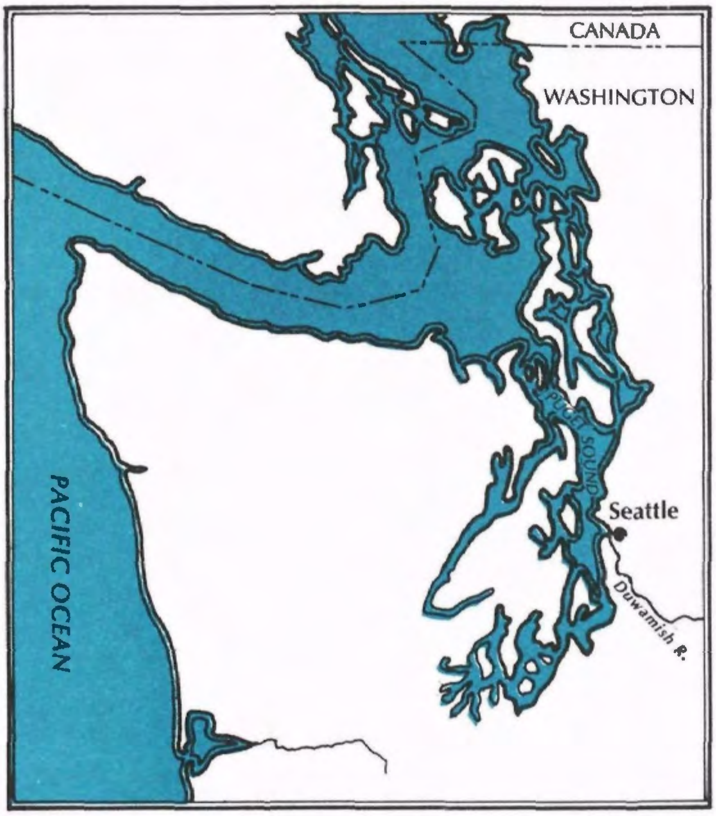
Because of the estuarine circulation pattern, water quality in the western sound reflects contaminant inputs from throughout the whole system: This is important to keep in mind. It means that better management of contaminant inputs from Long Island and Connecticut will not only protect the central and eastern sound but also contribute to better environmental quality in the western sound.

If our efforts are concentrated on New York City, only marginal improvements may result in the western sound while the remainder of the system—including the tributary embayments—may experience increasing impacts. A gain in the average quality of the sound as a whole that is achieved by gains in the west offsetting losses in the central and eastern sound may, in fact, not be a gain either for society or for the Long Island Sound ecosystem.

As the late H.L. Mencken once observed, "Every human situation has a simple solution—neat, plausible, and wrong." If we want to create a better future for Long Island Sound, we can't afford to be wrong. □

Financing the Cleanup of Puget Sound

by Annette Frahm



(Frahm is Publications Manager for the Puget Sound Water Quality Authority.)

Protecting the water quality in Puget Sound is a Mom-and-apple-pie issue. According to a recent survey, more than half of Washington state residents thought water pollution in the estuary was a serious problem, and two-thirds were willing to pay an extra dollar per month per household to clean it up.

The difficulty comes when one starts trying to make those abstract dollars a funding reality. Government at all levels—federal, state, local—has gotten the message that people don't like taxes. Moreover, Puget Sound doesn't show as many signs of pollution as some other estuaries in areas that have been developed longer, so the need for clean-up funds doesn't seem as pressing as it might elsewhere.

In fact, Puget Sound, located in the northwestern corner of Washington state, seems rather pristine on the surface. The sound's deep, cold depths help keep the water clear. Daily tides move the pollution out toward the Pacific Ocean.

But when scientists looked deeper into the sound, they found a series of sills (shallow areas) that stop most of the water—and the pollution it carries—from reaching the ocean. Instead, most of the pollutants sink to the bottom of the sound and stay there. This leads to toxic "hot spots" along the bottom of the sound's urban bays—and liver tumors and reproductive failures in the bottom-dwelling fish there.

There are other problems. Nine commercial shellfish beds were closed between 1986 and 1990 because of bacterial pollution from failing septic systems and farm animals—a problem made worse by increasing rural development. The region's overall rapid pace of development (population is projected to increase by 40 percent by the year 2010) also results in a continuing loss of wetlands and other fish and wildlife habitat.

In 1985 the Washington State Legislature, seeking a solution to these

Chris Ayres photo.

problems, created the Puget Sound Water Quality Authority to develop a comprehensive plan to protect and improve the water quality in Puget Sound. In developing the plan, the Authority studied a number of pollution problems, what was being done to address them, and what could be done to improve the efforts. One difficulty the Authority found was a chronic lack of money for state and local governments to address water quality problems.

The 1986 state legislature took steps to address the funding problem by increasing the tax on cigarettes and other tobacco products. The 8-cents-per-pack tax provides about $45 million a year statewide to support local water quality projects in the form of grants. The state pays 50 percent of the cost for water quality facilities, such as sewage treatment plants, and 75 percent of the cost for activities such as planning and education. The cigarette tax has proven to be an important, though limited, source of funding for local water quality projects.

Sometimes great results can come from relatively small sums of money.

Puget Sound wetlands provide key habitat for birds and other wildlife. Washington state and private non-profit groups are allied in efforts to acquire and protect wetlands.

Over the last four years, the Puget Sound Authority has received $2 million from the cigarette tax for its Public Involvement and Education (PIE) Fund. The PIE-Fund has financed 100 projects reaching a variety of audiences, from builders to farmers, school children to community residents. Over a million people have already been reached in some way, and many projects have found other funding to continue. Over time, these outreach ventures should greatly reduce water pollution.

While the cigarette tax is a good start, unfortunately, it isn't nearly enough. It will cost about $600 million to upgrade the remaining primary sewage treatment plants to secondary treatment. Reducing pollution from stormwater may cost $50 to $160 million per year. Ongoing efforts to reduce nonpoint-source pollution are expected to cost $12 million per year. Monitoring, wetlands protection, reducing pollution to "hot spots" and eventually cleaning them up, spill prevention, education: All these are pressing needs. And the state general fund is spread thin by other needs, such as education, social and health services, and transportation.

In its initial plan, adopted in 1986, the Authority proposed another source of funds: a higher fee for water quality discharge permits. The funds would be used to improve the state Department of Ecology's regulation of discharge permits.

After much controversy and debate, in 1987 the state legislature did approve a higher discharge permit fee, but imposed a $3.6 million per year cap statewide. The following year, however, state voters approved a toxics initiative which removed the cap and called for the Department of Ecology to set the fee high enough to fully fund its discharge permit program. The initiative also established a tax on hazardous products: the tax money goes toward cleaning up toxic "hot spots" and for education on the proper disposal of household hazardous wastes.

The Department of Ecology is currently collecting $3.6 million per year from the permit fee and intends to raise the fee over time. The increased funding has enabled the department to hire new staff for its discharge-permit program and to begin writing new permits that include limits on the discharge of toxicants. Over time, these stricter permits are expected to reduce a chronic source of pollution to Puget Sound.

Sometimes great results can come from relatively small sums of money.

Local governments have also been seeking and finding new sources of funds. Several cities and counties have created self-supporting stormwater utilities to provide funding both for "hardware"—such as detention ponds and infiltration basins—and for education programs to reduce stormwater pollution at the source. Most stormwater utilities are funded through monthly rates, often based on the contribution of the business or household to pollution (such as the amount of pavement on the property). Some counties have also taken initial steps to create septic system inspection and maintenance districts.

Private efforts on behalf of Puget Sound have also had some success, most notably in the acquisition of key wetlands and other habitats. A 95-group coalition succeeded in obtaining $53 million from the legislature in 1990 for acquisition of wildlife and recreation lands statewide, together with a promise of more funding over time. Between 1987 and 1989 a joint state-nonprofit campaign raised $5.3 million for wetlands acquisition, using a 3-1 state match.

Some federal funding has been available for Puget Sound through Sections 319 and 320 of the Clean Water Act. The Washington State Congressional delegation is also seeking a line-item appropriation for increased funding for the Puget Sound Estuary Program.

The newly created Puget Sound Foundation should also help fund research and education over time. In its 1990 session, the state legislature authorized the Authority to create the foundation as a public nonprofit corporation, with a charter to support education and research. The foundation will seek funding from corporations and other private donors and will provide grants on a competitive basis.

All of these funding endeavors still fall short. Recognizing that chronic funding shortages would continue, in 1988 the Authority created the Puget Sound Finance Committee to look for new funding sources. EPA funded a study to support the committee's work, along with a guidebook for local governments on financing options. The committee considered a wide range of possible funding sources, from a real estate excise tax to a toilet-paper tax.

In its final report, the committee proposed four new sources: a tax on commercial marine fuels (currently exempt from state tax), a fee charged to motor vehicle manufacturers for each new car or truck registered in the state, increases to the fish and shellfish tax, and an excise tax on the leasing of public lands. The Authority is including the marine fuels tax and the motor vehicle manufacturers' fee in its 1991 legislative proposals. Their fate in the legislature is uncertain.

As the search for additional funding

sources continues, changing circumstances make the need more urgent. Among the nation's great water bodies, Puget Sound is by no means alone in facing problems exacerbated by rapid growth.

While we're working to clean up existing pollution in our aquatic resources, and to put standards and plans in place to prevent future pollution, the gains we make can be countervailed by another subdivision or industrial park. Like Alice and the Red Queen, we may be running as fast as we can just to stay in the same place. Where can we find the money to keep up with pollution, let alone gain on it?

At a recent national estuary program conference in Seattle, participants agreed that creative funding approaches are essential. Among the ideas presented: a $100 million Great Lakes Protection Fund, financed by an endowment from the eight Great Lakes states; a surcharge in Rhode Island on items that are "hard to dispose of," such as tires and organic solvents; and a program to provide subsidized loans to communities in Massachusetts for water quality projects, using a combination of federal and state funds.

In Puget Sound, we have sought to ease the strain on the state general fund

The Soundkeeper

by Mary Ann Gwinn

A local kayaker has a joke about the ungainly, squawking herons who live on the Duwamish River—that they were graceful loons before they drank from the Duwamish. But the birds have gumption—they make a living, heron-style, on a river whose banks have been covered over with dredge spoils and whose sediments contain some of the most toxic junk ever spewed into a stream.

On this day, the herons are raising hell about a man in a red kayak. They are croaking and lifting their great wings in offended dignity as he passes under their perches. The man is skimming the edge of the river, in and out of the rusted hulls of ships, under the cool cave of a concrete dock. He is taking an excessive interest in the little pipes that dribble this and that out of industrial property and into the river.

These herons should raise a greeting, not a ruckus. This man is the Soundkeeper.

Ken Moser is the red-haired gent in the red kayak and the point man for a tough new program designed to protect Puget Sound. Moser, 38, a former advertising man, merchant seaman and skipper for yachts of the rich and famous, was hired by the Puget Sound Alliance to find polluters of Puget Sound.

He is the symbol of a new watchfulness on the part of local environmental groups, an acknowledgement that the sweep of environmental legislation enacted in the last two decades is a mile wide and an inch deep. It's illegal to pollute. But people do it every day, either because they don't know or they don't get caught, and because society hires cops to keep people from hurting each other, not other species.

(Gwinn is a Seattle Times reporter.)

Moser's aim is to educate polluters, and if that doesn't work, to catch them, and if that doesn't work, to sue them.

He's being trained in sampling and chain-of-evidence procedures. He has a toll-free number people can call when they see pollution of Puget Sound. He plans to train a citizen army—a group of fisherman, kayakers, birdwatchers and anyone else who knows the nooks and crannies of Puget Sound—to call to account degradation of the Sound, which Moser calls "the heart of the Northwest."

"People who have lived here any length of time know the Sound, whether it's South Sound or Useless Bay or Admiralty Inlet," he says. "Now they know they can call and say, 'There's something going on here.'"

And people have called. Since the program began in July, the Alliance's membership has swelled from 200 to 600, the result, says the Alliance's Kathy Callison, "of people wanting to do something for the Sound."

"We believe in education." Moser says with a small smile, "but we have discovered that litigation can be an effective tool for educating people."

The Soundkeeper's number is 1-800-42-PUGET.

The Soundkeeper program is modeled on similar programs throughout the country, including those at Long Island Sound, San Francisco Bay and the Hudson River.

The Hudson Riverkeeper is the grandfather of all such programs and owes its continuing existence to one of the most cunning pieces of environmental piracy ever discovered.

The first Keeper program was founded by Pete Seeger, the folk singer, to watchdog the cleanup of the Hudson. Seeger's group had hired John Cronin, the first Riverkeeper, who was on the job when he got a tip about some very peculiar activities taking place on Exxon Corporation tankers in the Hudson.

It seems Exxon was unloading its oil, filling its ballast tanks with water, flushing the oil residue into the Hudson and then refilling them with clear Hudson River water. This water went to the Dutch island of Aruba, off the Venezuelan coast, where it was used in an Exxon refinery and the balance given to the president of Aruba for his water supply. Some of it even filled his swimming pool.

The Hudson River Fisherman's Association threatened to sue. Exxon settled out of court for $500,000, a chunk of which has funded the Riverkeeper program ever since.

The Soundkeeper program was started with seed money from Starbuck's Coffee, KING-TV and the Puget Sound Water Quality Authority. The Puget Sound Alliance, an umbrella organization of environmental groups concerned with the health of the Sound, placed an ad in The Weekly. Moser, who had recently quit a high-paying job in the San Francisco advertising industry to return to Seattle, answered it.

Moser's biggest accomplishment in the ad industry had been to write a reggae-inspired jingle extolling Clorox bleach, a substance harmful to the environment when it gets flushed down the drain. It still makes him gloomy to think about it.

"The strategy was, you never thought about Clorox," he recalls. "You never thought about dirty clothes. You thought about bright, clean, happy children. What we're talking about is habits people have. They think it goes away. Where do they think it goes?"

He was hired both for his marine skills—he's licensed to skipper vessels under 100 tons—and for his ability to mount a public-relations campaign. Moser knows there's no way for him to by developing new and innovative funding sources. But the way is hard, and the outcome doubtful. Each crisis brings a flurry of activity and support—which soon dies down until the next crisis.

It's hard to gain stable, long-term support in such an environment. Education is one key: As residents and businesses learn more about their contributions to pollution, they often become more willing to contribute to the solutions.

Showing results is also important. Short-term successes can help gain support for long-term funding. We have to become more efficient and effective in how we spend our money. And we must continue to be creative: finding new sources of funds and smart ways to get optimum results from the money we have available. □

Tom Reese photo. Seattle Times.

Patrolling in his red kayak, Soundkeeper Ken Moser hunts for polluters.

police 2,000 miles of the shores of Puget Sound alone. The Alliance hopes to train a sort of "environmental navy" to spot pollution all over the Sound. Lee Moyer, a local kayaker who accompanied Moser on his Duwamish tour, is evidence it works.

Moyer, who owns Pacific Water Sports, a kayak sales and rental business, was on the Duwamish one day about five years ago. He spotted a milky pond spreading out from a half-concealed outfall.

Moyer called the Department of Ecology and the EPA. His tip ultimately ended the dumping of highly alkaline cement waste into the Duwamish. The company, Pioneer Construction Materials, was fined $150,000. It has since been sold.

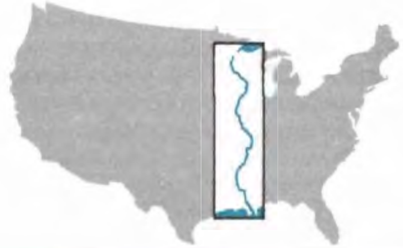
Soundkeeper Moser says his goal is to help citizens with a complaint penetrate the "alphabet soup" of agencies concerned with the environment. His first step might be to contact the polluter and ask them to stop. The next step might be to call the regulators. If the regulators can't or won't pursue the case, the Soundkeeper will.

His ultimate goal is to back up his work with an environmental law clinic, similar to one at New York's Pace University headed by Robert Kennedy Jr. The clinic has successfully litigated numerous pollution cases along the Hudson.

The Soundkeeper needs a boat; he currently hitches rides with allies such as Moyer. He's also getting training from local and federal agencies, including Metro and the National Oceanic and Atmospheric Administration. "I found out that all the agencies are made up of people," he says, "people who want to see the environment kept clean and who are frustrated at the lack of funding." □

(Story reprinted with permission, the Seattle Times.

An Environmental Snapshot of the Mississippi



by Reggie McLeod

(McLeod is a free-lance journalist who has written frequently about the Mississippi.)

Without the visitors, the beginning of the Mississippi River in northern Minnesota would be rather inauspicious—just a shallow, rocky stream spilling from a pine-ringed lake like 10,000 others. However, a steady stream of pilgrims comes here from all parts of the world to wade in the numbingly cold water or, at the very least, to crouch on the shore and rinse their hands in it, as though to seek a blessing from this great river.

As is the Ganges to India, the Nile to Egypt, and the Amazon to Brazil, so the Mississippi is to America: It offers us a reflection of ourselves—our strengths and weaknesses, our history and culture. We respect its power and unpredictability, but we want too much from it: a sewer and a source of drinking water, a highway and a playground, a prime piece of real estate and a refuge for wildlife.

At Lake Itasca things look pretty good. The water is clear, the air is heavy with the scent of pines, song birds welcome the morning, and loons summon the night. In spots, the modest Mississippi is too shallow to float a canoe. It enters and exits several big lakes—Bemidji, Cass, and Winnibigoshish. After travelling north, east, and southwest, the river begins its more-or-less southward course near Brainerd, describing a big question mark in the center of Minnesota.

As the river gathers the waters of other rivers and creeks, growing deeper and broader, signs of civilization along its banks become more frequent. Yet, it often flows for miles out of sight of any roads or homes.

The first dramatic change in the river occurs near the Twin Cities. Bluffs begin rising on both sides of it. The Upper St. Anthony Falls Lock and Dam marks the start of the river's commercial navigation channel in Minneapolis. A few miles downstream, the Minnesota River joins the Mississippi beneath the walls of Fort Snelling, built at this strategic spot in 1819 to protect fur traders from warring Sioux and Chippewa Indians. About 20 miles downstream, near Hastings, the St. Croix River adds to the Mississippi's strength as the river, after winding a quarter of its length within Minnesota, begins marking the border with Wisconsin.

In the 1980s the State of Wisconsin sued the Metropolitan Waste Commission to stop the flow of about 4.6 billion gallons of raw sewage from the Twin Cities into the river from old storm sewers that overflow into sanitary sewers during heavy rains. The suit was dismissed, but Minnesota agreed to replace the remaining outdated sewers by 1995.

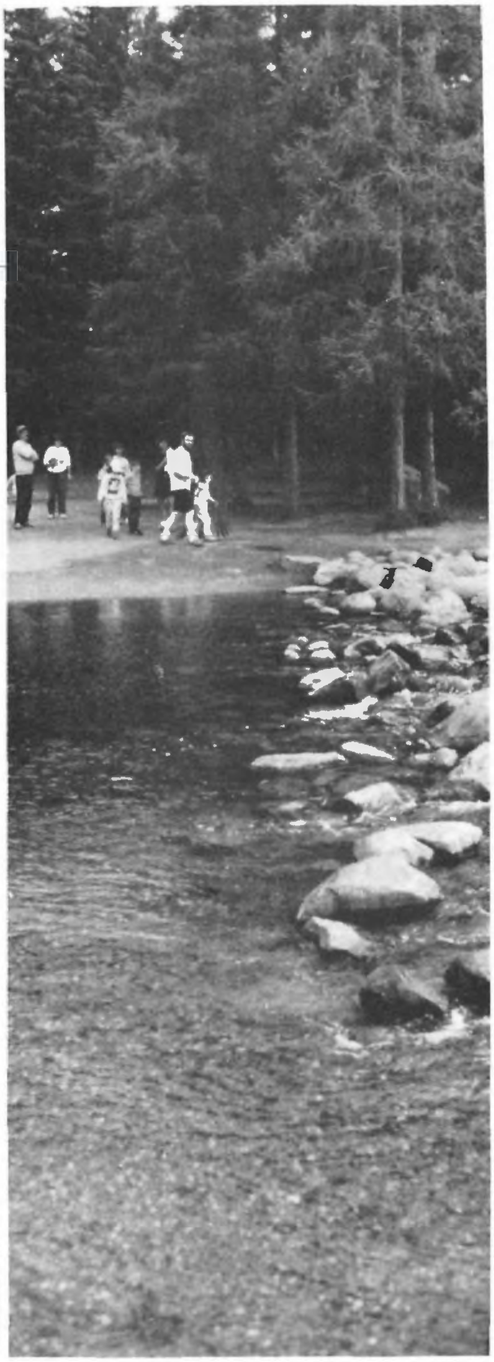
Despite sharp reductions in the discharge of untreated sewage and other pollutants, the Metropolitan Wastewater Treatment Plant's permit was delayed recently because it did not monitor the release of phosphates into the river. Experts fear that fish kills and the disappearance of water plants downstream may have been caused by dense algae blooms nourished by high concentrations of phosphates during the lower flow in the drought of 1988.

The dams may have created a problem for which there is no solution.

Carl Korschgen, wildlife specialist at the U.S. Fish and Wildlife laboratory in La Crosse, Wisconsin, says the loss of more than 90 percent of the wild celery beds in the river appears to be hurting populations of canvasback ducks who depended on them for food during migration. Other wildlife species are probably also suffering from this dramatic loss of water plants.

The face and personality of the upper Mississippi River changed in the late 1930s, when the U.S. Army Corps of Engineers began building 29 locks and dams from Minneapolis to St. Louis. Their sole purpose is to maintain a nine-foot channel for barge traffic. The dams, by creating a series of long lakes called pools, changed the profile of the river from a gradual slope to a series of steps. As a result, former bottom lands, islands, and backwaters at the lower ends of the pools are under several feet of water, while islands and maze-like backwater channels are plentiful below many dams.

This stretch of the river is full of long sandy islands covered with maples, cottonwoods, wild grapes, and poison ivy. The river valley is embraced by



Minnesota Office of Tourism photo.

Minnesota's Lake Itasca forms the headwaters of the Mississippi River.

steep, wooded, rocky bluffs that sometimes rise more than 400 feet above the river. Many of the islands and much of the shore from Lake Pepin to Rock Island, Illinois, is owned by the Corps of Engineers or the Fish and Wildlife Service, which manages it as a wildlife refuge. At some points, the river and bottoms are more than three miles wide and include a profusion of habitats: islands, marshes, lakes, and channels. In summer, an increasing number of boaters fish and camp on sandy beaches created with spoil dredged from the main channel. In fall and winter, trappers harvest muskrats, beavers, mink, and otters from the backwaters. When the ice thickens, barge traffic stops, and the best fishing spots are marked by clusters of ice-fishing shacks.

The dams may have created a problem for which there is no solution. The resulting long pools are sediment traps that capture much of the soil and sand washed into the river and its tributaries from eroding farmland and stream banks. Barge traffic and dredging on the main channel stir up river sediment. Backwater channels that were 10 feet deep a few decades ago have silted in. Backwater lakes have turned into thick cattail beds.

A few years ago, the Army Corps of Engineers started moving dredge spoils out of the floodplain, rather than just piling them up on islands where they washed back into the river. A number of projects funded by the Upper Mississippi River Environmental Management Plan are testing methods to restore or stabilize islands and backwaters by dredging, island building, and other techniques.

The Environmental Management Plan also funds a project to collect and organize an immense quantity of data about the upper Mississippi River. A computer at the Environmental Management Technical Center, in La Crosse, Wisconsin, is being fed information collected by dozens of workers in five states. It combines and compares that information with satellite images and past studies to create a dynamic image of the river. Engineers, boaters, or scientists can play "what if" with the river, asking the computer to

Wide World photo.

Barges line the Mississippi south of St. Louis. More than 61,000 barges passed through this area in 1989.

USDA photo.

speculate how a change might affect the river over decades.

The Illinois and Missouri rivers join the Mississippi just upstream from St. Louis, finally giving it enough water to float barges year round. Locks limit the size of a tow to 15 or 17 barges, but below the last lock, larger towboats can push tows of 40 or more barges up and down the river. In 1989, towboats pushed 61,200 barges loaded with 75 million tons of corn, soybeans, coal, fuel oil, steel, and other cargo through the last lock, at Granite City, Illinois, across from St. Louis.

A few miles downstream, in Cahokia, Illinois, a group of huge mounds marks the spot that probably served as the center of an empire more than 700 years ago. At that time, a stockade protected the center of a city where as many as 40,000 of the people archaeologists call the Mississippians lived. Other cities of the Mississippian culture have been studied near the river as far north as Wisconsin and downstream nearly to the Gulf of Mexico. The Mississippians also built stockaded cities along the Ohio and Missouri rivers and inland. They grew large fields of corn, beans, and squash and traded over much of what is now the central United States. Not a lot is known about them because they abandoned or were forced from their cities shortly before Columbus sailed to the West Indies.

This section of the river roughly follows a major earthquake fault centered at New Madrid, in southern Missouri. A powerful earthquake there in 1811 devastated towns, temporarily reversed the flow of the Mississippi, and created shock waves strong enough to ring church bells in Washington, DC.

The old notion of a river carrying away a city's waste is backwards; rivers bring it together . . . .

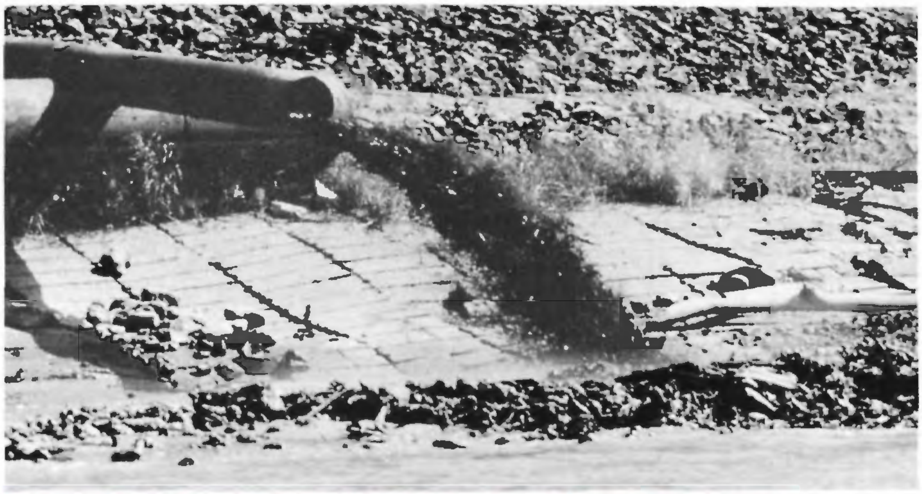
The river below St. Louis not only carries a lot of barge traffic, it also carries a heavy load of pollutants and sediment. The Missouri, Ohio, and upper Mississippi rivers drain a good share of the nation, from the Appalachian Mountains to the Rocky Mountains. They carry the agricultural chemicals washed by rains from millions of acres of cropland. They carry untreated sewage, toxic chemicals, and parking-lot runoff from Great Falls, Montana, from Minneapolis, from Pittsburgh, and dozens of cities in between. The old notion of a river carrying away a city's waste is backwards; rivers bring it together, and the inadequacies of much of our nation's pollution control comes together at St. Louis.

The Greenpeace report *We All Live Downstream: The Mississippi River and the National Toxics Crisis*, published in December 1989, claims that the St. Louis metro area is second only to Louisiana's "Chemical Corridor" in adding toxic chemicals to the Mississippi. "At least 10 major petrochemical facilities and 7,500 smaller industries discharge wastewater to the river, either directly or via the sewer systems of St. Louis or Sauget, Illinois, across the river from St. Louis," according to the report.

The report goes on at length about the Chemical Corridor, where many cities draw their drinking water from the river and cancer rates are high. Though the report has been criticized for ignoring some facts, such as higher-than-average cigarette consumption per capita in Louisiana, there is general agreement that more than 100 major industries along the 150-mile stretch between Baton Rouge and New Orleans contribute a huge quantity of pollution to the river and the rest of the environment. Greenpeace quotes the EPA's Toxic Release Inventory for 1987, stating that industries in the eight parishes along that 150-mile stretch release over 933 million pounds of toxic chemicals (excluding sodium sulfate) to the environment each year, 196 million pounds of which are discharged directly into the Mississippi River.

The Mississippi appears to be trying to avoid the Chemical Corridor (who

Fishing on a Mississippi tributary, with high hopes despite low water.



Copyright R. Winslow photo. Greenpeace.

Mississippi mud being dredged from the river near Memphis, Tennessee.

can blame it?) by taking a shortcut to the Gulf of Mexico. About every thousand years river sediment lengthens its route to the sea until it switches to a shorter route. It is now due for a change.

In the 1950s the Atchafalaya River carried close to a third of the Mississippi's water to the gulf by a route that is steeper and less than half the distance. The Atchafalaya was gaining steadily and seemed on the verge of capturing most of the flow and turning the channel that had carried so much commerce and prosperity to Baton Rouge and New Orleans into a sluggish bayou. In 1963, at Old River, 74 miles upriver from Baton Rouge, the Army Corps of Engineers opened a new lock and a structure to limit the flow of water from the Mississippi into the Atchafalaya. Though the structure has operated successfully for more than 17 years, some people insist that the river will win its struggle with the Corps.

At Baton Rouge, the Mississippi becomes deep enough to carry ocean-going ships. The ports along this stretch are busy exchanging cargos from those ships and the barges from the Mississippi and the east and west branches of the Gulf Intercoastal Waterway, and the products of the petrochemical plants that line the river banks.

About 5,000 ships and 50,000 barges move about 145 million tons of cargo a year over New Orleans' docks. Lake Ponchartrain borders the north edge of the city, and the Mississippi marks a curvey border on the south. If you climb the river levee near Jackson Square in the French Quarter, you may be surprised to find that the river is higher than the city below. Actually much of the city is below sea level and depends on 130 miles of levees and a gargantuan system of pumps to keep it from being flooded.

At this point 133 cubic miles of water, soil, effluent, and industrial waste from 31 states and two Canadian provinces flows into the Gulf each year.

The river continues past New Orleans for 115 miles on a tongue of land extending into the Gulf of Mexico. This narrow strip and much of southern Louisiana was created by sediment carried by the Mississippi. As sediment settles and the tongue extends farther into the sea, the rate of the river's fall is reduced and the river slows, which causes more sediment to be deposited, creating more incentive for the river to take the Atchafalaya shortcut.

At this point 133 cubic miles of water, soil, effluent, and industrial waste from 31 states and two Canadian provinces flows into the Gulf each year. Thanks to improved sewage treatment and concern for the environment, the water gets a little cleaner each year, but it is far from clean. Meanwhile, backwaters fill with sediment, plants and animals continue to disappear, and people along the river drink tainted water. Some of these effects are reversible, and some are not. But the sources of the problems are all within our control. □

The Southern California Bight: Where Traditional Approaches Won't Work

by Wesley Marx

The Southern California Bight borders a curve of the Pacific Coast that runs from Point Conception in Santa Barbara County, southeast 357 miles to Cabo Colnett, Baja California, in Mexico. Bounded on the west by the cool, south-flowing California Current, the bight covers more than 37,000 square miles of ocean.

The populous coastal strip bordering the bight is internationally known as a center for high-technology industry, mass entertainment, fast tract development, and auto-centered transportation. A combined U.S.-Mexican population of some 15 million currently resides in the bight's drainage basin. Residents enjoy such resources as the bight's bluff-backed beaches—Malibu, Rincon, Santa Monica, Huntington Beach, the Trestles, Baja's San Miguel. Annual beach attendance along Santa Monica Bay runs some 44 million. Offshore, more than 30,000 recreational boats cruise the waters. Scuba divers glide through lush submarine forests of kelp. Anglers pursue tuna, swordfish, and yellowtail.

Enter Environmental Overload

Each day, some 1.5 billion gallons of treated sewage are discharged to the bight. Storm drains, marina operations, and aerial fallout from smokestacks and auto exhaust add to the wasteload.

Rapid growth has taken its toll on the bight's resources. Among these are coastal wetland systems, which are important as feeding and resting stations for migratory waterfowl along the Pacific Flyway. They also serve as nursery grounds for important recreational and commercial fish stocks, including halibut and turbot. But too many wetlands, in the drive towards coastal buildout, have been converted into marinas, housing developments, and parking lots. For every acre of coastal wetland that remains, over three acres no longer exist. Some 75 percent have been lost.

Schools of steelhead trout in the bight once converged by the thousands to ascend coastal watersheds to spawn. Today, only remnant runs remain; dams block them from access to spawning grounds. Stream flows have been diverted to farm fields and urban reservoirs.

The chemical industry has played a prominent role in the region's rise to industrial prowess, but it has left environmental scars. In the 1960s and 1970s, uptake of DDT turned more fish-eating natives of the bight—brown pelicans, osprey, bald eagles, Peregrine falcons—into endangered species. DDT was banned from domestic use in 1972, but past marine discharges of this durable chemical continue to contaminate the bight's marine food chain.

The pace of development outstrips environmental safeguards. Repeated closures of San Diego's Mission Bay and Santa Monica Bay because of sewage spills have affirmed just how overloaded these systems were. EPA resorted to legal action against both San Diego and Los Angeles to secure compliance with federal water quality standards.

Keeping a lid on pollution with conventional measures is increasingly difficult. The region is trying to find answers to some basic questions. Can ways be found to recycle, reuse, and reduce the soaring wasteloads? Can storm drains and other uncontrolled pollution sources be cleaned up? Can coastal habitat be restored to help the region regain its natural marine heritage? Can the United States and Mexico cooperate in protecting a resource they both share? In short, can new environmental options be developed for a high-growth region that is outstripping conventional solutions?

(Marx served on the National Resource Council panel on marine monitoring in the Southern California Bight.)

Wesley Marx photo.

Sea lions are denizens of the California shoreline. This rookery is at San Miguel Island.

Some Hopeful Signs of a Comeback

Eldorado Nature Park in Long Beach has a lush landscape. The park is watered by treated effluent that was once routinely discharged into the bight. Reclaimed water is being used to cool industrial processes in Glendale, process wastepaper in Pomona, recharge ground water in Los Angeles, and stem salt-water intrusion in Orange County.

By recycling treated effluent, the region can reduce its reliance on water imported from the lower Colorado River, the Sacramento-San Joaquin delta, Mono Lake, and other stressed aquatic habitats. Treated effluent for reuse generally requires a higher level of treatment (tertiary) than that for ocean disposal (secondary). But reclaimed water can generate income. The Los Angeles Country Sanitation Districts (LACSD) gains about $700,000 a year from such sales. Buyers profit too. Reclaimed water costs less than imported water. The shift to water reuse is spreading, encouraged by the ongoing drought in California. San Diego, for example, is planning to construct six reclamation plants.

Wastewater reuse does require careful planning. Reclaimed water can not be used for direct reuse as a drinking water. It is limited to industrial uses, farm and landscape irrigation, and ground-water recharge. Reclaimed water lines must be separate from lines that carry drinking water. But lower water bills can justify installing a dual system. The farther away a large, central sewer plant is from customers, the longer the distribution lines. By opting for a series of smaller plants in its service area, LACSD expands its reuse options. Residential waste flows are preferred. Industrial flows are harder to treat for reuse.

Another treatment byproduct is being made to pay. LACSD once had to buy energy to run its major treatment plant. Today, the process to treat sewage sludge produces more than enough methane gas to meet LACSD energy needs. Under an EPA grant for innovative technology, LACSD has installed a gas turbine engine that burns the recovered gas more efficiently than an internal combustion engine, while reducing air emissions.

The region is also learning to reduce sewage flows and conserve treatment capacity. The City of Los Angeles and neighbors that use the city's sewage system are mandating use of ultra-low flow toilets. The City of Santa Monica recently approved construction of a large commercial office complex that would normally generate some 70,000 million gallons of sewage daily. With water-conservation fixtures, this projected daily flow will be cut to 40,000 million gallons.

More regulatory attention is being directed to uncontrolled sources of pollution. In Southern California, storm drains are separate from sewage drains. However, storm drains can still be contaminated by nonpoint sources: animal fecal matter, sewage spills and

Work crews rake and shovel oil-soaked straw during the famous 1969 Santa Barbara oil spill. The recent *Amoco Trader* spill off Orange County showed that clean-up efforts still need improvement—one of many challenges facing the Southern California Bight.

bypasses from clogged sewer lines, used oils and cleaning solvents.

The City of Santa Monica is now trying to clean up its infamous Pico-Kenter storm drain, which regularly dumps highly polluted flows into the surf zone in Santa Monica Bay. Bathers are warned to avoid the area. If the flows could be disinfected prior to discharge, the bay might be spared one more gross insult.

Chlorine, a standard disinfectant, is hazardous and costly to store. Ozone is not, and Santa Monica, with a grant from EPA, is evaluating its use to disinfect the flows. So far, test results are promising, and a second option is emerging. Treated flows may meet standards for landscape irrigation. Ergo, an expanded study to consider reuse of treated flows to water nearby freeway medians and cemeteries.

Controlling pollutants at the source is another way to cleanse storm drain flows. To reduce debris washing into the Pico-Kenter Drain, Santa Monica has stepped up street cleaning programs and placed debris traps on drain inlets. Sensors along the drain can detect hydrocarbon spills; an alarm sounds so that spills can be contained before reaching the surf zone. "Midnight" dumpers now risk being caught. Santa Monica's experience is proving helpful to other coastal communities that must now implement drain controls under the federal Water Quality Act.

Reclaiming seemingly lost habitat is becoming as promising an option as reclaiming wasteloads. By removing old salt-pond dikes and accumulated silt, the California Department of Fish and Game reopened a derelict section of Upper Newport Bay in Orange County to the tides. As the tides return, so do the fish, the shorebirds, and the salt marsh plants.

In Bolsa Chica marsh near Huntington Beach, another derelict wetlands area has been restored to 300 acres of prime salt marsh. The U.S. Fish and Wildlife Service plans to restore over 1,000 acres of salt ponds in south San Diego Bay.

Wesley Marx photo.

Brown kelp frequently washes onto California beaches. This underwater plant is a key link in the bight's marine ecosystem.

Steelhead salmon may get a new lease on life in the busy bight. A fish ladder has been installed on the Santa Clara River to help a remnant run of about 100 steelhead regain historic spawning grounds. Screens have been installed on canal diversions to prevent juvenile steelhead from straying into fatal dead ends. Farther south, a group called California Trout is working to install fish bypasses around barriers in Malibu Creek to help another remnant run of steelhead.

In February 1990, the oil spill from *American Trader* off Orange County not only perpetuated environmental concern in the bight over marine oil activities, but showed that clean-up efforts can still leave something to be desired. Some 400,000 gallons of Alaskan North Slope crude were spilt. Despite containment efforts at sea, oil washed up along 15 miles of coast. It was a month before the final beach closure could be lifted.

However, concern over oil activities in the bight can help spur the region's quest for resource alternatives. In 1990, the California Public Utilities Commission, working with major energy utilities and environmental groups like the Natural Resources Defense Council, began a major program to provide utility customers with rebates for purchasing energy-efficient furnaces, refrigerators, and water heaters. By shifting to energy conservation and alternative energy sources, Pacific Gas and Electric Company plans to save the equivalent of about 11 million barrels of oil per year.

The region is adopting a similar strategy in dealing with another pervasive environmental problem. To achieve EPA air quality standards for the smoggy Los Angeles basin, the California Air Resources Board is moving beyond the nation's most stringent tailpipe emission controls and mandating changes in car design, including cleaner burning fuels and engines. The 1990 federal Clean Air Act amendments reinforce this shift. More stringent air pollution controls will mean less aerial fallout of pollutants to the bight.

Historically, responsibility for protecting the bight from pollution has been split up among a maze of state, local, and federal agencies. This fragmented approach can hinder effective responses to critical areas of concern such as Santa Monica Bay. In 1988, the bay was made part of EPA's National Estuary Program, which provides a mechanism for coordinated action. Some 50 member organizations are collaborating in the Santa Monica Bay Restoration Project, created to develop a Comprehensive Conservation and Management Plan for the bay.

A 1990 National Research Council (NRC) report, *Monitoring Southern California's Coastal Waters*, recommended establishing a regional marine monitoring program. The report found that current monitoring efforts in water quality and marine resources are fragmented and uneven. The data collected can go unused. As the NRC report noted, "There currently is no effective system for reporting findings of monitoring programs to the public, the scientific community, or policy makers." One priority effort in the Santa Monica Bay Restoration Program will be to develop an integrated monitoring system for the bay.

Major industrial and population growth in the Baja area underscores the importance of a regional perspective. This growth is fueled, in part, by the Maquiladora program, under which businesses in the United States and other countries can establish production lines in Mexico's border cities to take advantage of lower labor and operating costs. Finished products can be shipped back across the border subject only to U.S. duties on the value added after assembly or processing. Over 300 Maquiladora plants in Tijuana pump an estimated $10 million a month into the city's economy. The city's population, currently an estimated 1.2 million, is expected eventually to exceed that of its neighbor, San Diego.

As can happen north of the border, Tijuana's explosive growth can outstrip public services. As much as 10 million gallons a day of raw sewage from Tijuana has flowed along a river channel and into the U.S. side of the border. Since the early 1980s, a two-mile stretch of San Diego beaches north of the border have been closed to use because of these runaway flows. The Tijuana estuary, designated a National Estuarine Area by NOAA, has also been contaminated.

In 1990, the United States and Mexico entered into a joint agreement to fund a sewage-treatment plant on the U.S. side to treat the cross-border flows. Mexico will require industries to pre-treat their flows before discharge into the bi-national plant, which will provide secondary treatment and disinfection prior to ocean-outfall disposal. Mexico will also upgrade a treatment facility on its side of the border that discharges into the surf zone. Tijuana's collection system is to be upgraded and expanded; half the city's residents live in unsewered areas.

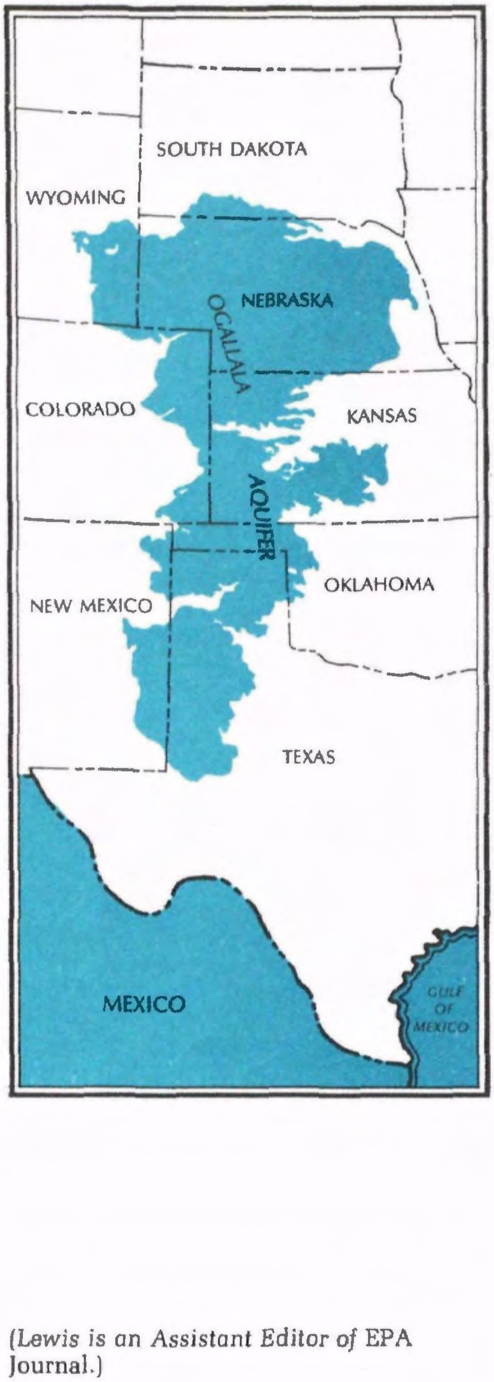
The Future is in Doubt

The emerging opportunities in water reuse, wetland restoration, energy conservation, and cross-border cooperation may provide this coastal region with expanded options in shaping its environmental future and protecting the resources of the bight. But population pressures and the risks of outstripping environmental safeguards will intensify.

By 2010, 2.6 million more people will reside in the coastal counties of Los Angeles, Orange, and San Diego, according to NOAA's Ocean Assessments Division. Orange Country's population alone will jump by 704,000. By then, fast-growing Tijuana could become the second largest city along this coast, exceeded only by Los Angeles. Amid such rapid development, the challenge of protecting the bight's natural resources will remain as formidable as ever. □

The Ogallala Aquifer: An Underground Sea

by Jack Lewis



(Lewis is an Assistant Editor of EPA Journal.)

One of America's greatest natural wonders is invisible to the naked eye: A king's ransom in fresh water lies buried under 170,000 square miles of sand and rock in the nation's once arid, now verdant Great Plains. Named the High Plains aquifer, this ground-water system is the largest in the United States, and one of the largest in the world. A vast, hidden, silent freshwater aquifer, it runs from South Dakota all the way to Texas, with part of its vast reserves extending under eastern Wyoming, Colorado, and New Mexico.

The High Plains aquifer system consists for the most part of the famous Ogallala Formation as well as connected parts of adjacent underground water deposits. The term "Ogallala Aquifer" was widely used in the past to refer to what is now technically known as the High Plains aquifer; the name "Ogallala" is still commonly used in areas where the Ogallala Formation comprises most of the High Plains system, as it does in most localities. ("Ogallala" in the language of the Sioux Indians means "scatter their own"—which is something the Sioux did to survive. The Ogallala Formation is named after the Nebraska town of Ogallala, located above the aquifer.)

In a sense, the High Plains ground-water system is America's sixth Great Lake. Its 3.3 billion acre feet* of fresh water would fill Lake Huron to the brim, with water left over to fill one-fifth of Lake Ontario. If pumped out over the United States, the High Plains aquifer would cover all 50 states with one and 1/2 feet of water.

Despite its richly deserved status as one of America's great bodies of water, the High Plains aquifer is virtually unknown outside its native region, even under its more traditional name, Ogallala. Symptomatic of its obscurity is the fact that neither the *Encyclopedia* Britannica nor the Encyclopedia *Americana* devotes even one word to this wonder of nature. Out of sight, as the adage goes, all too often means out of mind. Ground water, because of its invisibility, is mysterious, even awe-inspiring, but it lacks the charismatic glamour and the wide renown of a great above-ground tourist attraction.

Yet its beneficial effects—if workmanlike—are nothing short of spectacular. Thanks to Ogallala-tapped irrigation, the High Plains region of America's Great Plains has escaped its near-desert image of a century ago. Though precipitation is moderate in the High Plains (16 to 28 inches), it is insufficient to sustain intensive agricultural cultivation. The High Plains aquifer's bounty is directly responsible for $20 billion worth of High Plains food and fiber production in 1989 alone, with ancillary economic benefits estimated at $50 billion per annum.

But all is not well with the High Plains system. Seventy years of steadily increasing pumping have skimmed the top off the aquifer's reserves of water—reserves that took millions of years to build up through a slow dripping process not unlike the passage of water through a full coffee filter.

Experts now estimate that 11 percent of the aquifer has been pumped since the 1930s, and that 25 percent of its once vast reserves will be gone by the year 2020. With 170,000 wells sucking it dry—one for every square mile of the aquifer's area—it is almost a miracle that roughly 89 percent of the High Plains aquifer's freshwater treasure is still intact. Two-thirds of that reserve is under Nebraska, which is blessed with the thickest and most densely saturated of the vast system's underground formations. Other states, with ground-water reserves of shallower saturated thickness, have not been so fortunate; many wells in Colorado, Kansas, and Texas have already been pumped dry.

The pumping craze began in Texas shortly after World War I. A few dry-land farmers had a vision: They wanted to transform the Texas panhandle into a crazy quilt of huge, heavily irrigated cotton plantations. The 1930s Dust Bowl, which struck further north, brought a new wave of converts to irrigation, eager to tap into the transforming riches of the High Plains aquifer. However, it was not until after World War II that High

*An acre foot of ground water is enough to cover an acre of land with one foot of water. It is equivalent to nearly 326,000 gallons of water.

Corn being irrigated in southwestern Nebraska. Many farmers using water from the Ogallala aquifer are becoming more conservation-minded.

Tim McCabe photo. USDA.

Plains irrigation became entrenched up and down the region, even all the way up to South Dakota. From relatively humble beginnings in the late 1940s, these operations quickly intensified. For example, in 1948 Texas had 8,356 wells; a mere nine years later, that total had soared to 42,225. Southwest Nebraska had 111,600 acres irrigated in 1950, as opposed to a whopping 873,000 in 1983.

The popularity of irrigation was not hard to understand. Despite the expense of pumps and the fuel needed to power them, irrigation increased yields by 600 to 800 percent over those obtainable through dry farming. There was also a dangerous and pervasive myth that the waters of the High Plains system were inexhaustible, endlessly replenished by an underground river from the Rockies. In reality, almost all recharge to the High Plains aquifer originates from infiltration and downward percolation either of surface water or, more commonly, of precipitation.

For 30 years, from the late 1940s to the late 1970s, the rapid proliferation of privately owned wells continued virtually unabated. The result was the transformation of the once drought-ridden High Plains into a new fertile crescent, a "green belt" enormous in its dimensions and its productivity. Never before in human history had irrigation so drastically altered the physiognomy of so large an arid region. And it was all thanks to the High Plains aquifer, 7 million acre feet of which were pumped in 1950, as opposed to 21 million in 1980. Wes Robbins, a High Plains farmer, acknowledges the aquifer's pivotal role: "The High Plains is the largest land mass in the world with this kind of [irrigation-sustained] cropland."

By 1980, however, there were signs that the party was coming to an end. The state of Kansas discovered, to its dismay, that it had already pumped up to 38 percent of its High Plains system reserves. In parts of Texas, depletion was even worse, with water tables down 200 feet, and wells either running dry or ceasing to be profitable to pump. In Colorado, water tables were dropping up to five feet a year. Such drastic declines in ground-water levels were attributable to farmers pumping water at a rate faster than nature's ability to recharge the aquifer. The High Plains system was simply being overpumped.

In 1948 Texas had 8,356 wells; a mere nine years later, that total had soared to 42,225.

Then fuel prices shot up in the 1970s, and with them so did the once negligible cost of irrigation. Assisted by increased rainfall, farmers began to discover that higher profitability was often compatible with lower yields and curtailed irrigation. As a result, between 1980 and 1985, ground-water use dropped 19 percent in the High Plains region. Between 1980 and 1988, there was a most encouraging High Plains system water-level rise of 0.8 feet, representing an increase in available water of 13,400,000 acre feet.

During the 1980s, the Ogallala pumping that continued became more cost-effective and more conservation-minded. It must be conceded that economic pressures forced farmers to become water conservationists, but few would deny that that is what they have become. One success was achieved with LEPA, "low-energy proficiency application," which saved water by using a nozzle to squirt it directly into the soil rather than up into the air in a spray of quickly evaporating artificial rain. For many years, farmers had relied on artificial rain released in great wasteful sprays of water from so-called "pivots."

Other farmers experimented with the solar-powered surge valve, which automatically opened and closed irrigation valves around the clock. Still others built "run-off pits" to capture and recycle irrigation flows. The greatest savings in High Plains ground water came, however, not from any technological gadget or farming innovation, but simply from the discovery made by farmers that "less is more": Beyond a certain point, irrigation does not boost either profits or yield enough to warrant wholesale pillaging of an irreplaceable resource.

By the 1980s, the quantity of High Plains ground water was no longer the sole concern: Signs of its growing contamination were throwing a scare into farmers throughout the region. The problem was most acute in the very heart of the paradise created by ground water—namely, water-rich Nebraska. The aquifer is close to the surface in Nebraska and protected only by sandy soil. It was easy for pesticides and fertilizers to leach down into ground water and degrade what once was fresh and pure.

Several Nebraska communities that had been relying on the High Plains system for drinking water had to pump new wells when nitrate levels exceeded the regulatory standard. The problem was less acute in Texas and Colorado, where High Plains ground water was deeper beneath the surface and shielded from surface activities by cap rock and low percolating soils. Even in those states, however, contaminants managed to seep down wellheads at the very site of pumping and to pollute depleted waters that were already becoming increasingly expensive to retrieve.

Concern over depletion and contamination of the High Plains system has prompted several states to take regulatory action. New Mexico is in the best position to act because its ground-water reserves have been in the public domain since 1931. To cite just one example, farmers in Yuma County, New Mexico, pump only one-quarter as much High Plains water as their neighbors in Gaines County, Texas, who regard the ground water under their land as private property. Texas passed a ground-water control law in 1949, and Colorado began requiring well permits in 1957. In 1968 Kansas created three water districts to monitor pumping.

In all three of these states, opposition to state regulation has been intense. For instance, a few years ago in Burlington, Colorado, state troopers had to be called out to quell opposition to proposed metering of irrigation pumps. Today the same farmers are more likely to acquiesce in what they once resisted—or at least to shun direct confrontation in favor of hiring high-priced lawyers.

The threat of litigation also hovers over Greeley County in western Kansas. Keith Lebbin, the water manager in Scott City, has condemned the tokenism implicit in recent efforts:


D. A. Spencer photo. U. S. Fish and Wildlife Service.

People once thought that water and the prairie would last forever, despite drains on the aquifer and other impacts of human activities. But nature's bounty is not inexhaustible.

"The horse has already left the barn . . . . A new proposal would limit 12 areas in Greeley County to 641 acre feet of [irrigation] water. But permits are already in existence for 8,191 acre feet. What do you do: sue everyone to take away their property rights? What's the cost of that?"

Water-rich Nebraska, with High Plains reserves predicted to last 400 years, is determined to preserve its advantage. The Cornhusker state is in the forefront of ground-water regulation. In 1975 the state legislature divided Nebraska into Natural Resources Districts (NRDs), to be headed by elected officials, mainly farmers. In 1978, the Upper Republican River NRD had to go to court to defend its right to meter wells. Ten years later, the same NRD set the first pumping limit in the state—75 inches per acre over the next five years—and met with astonishingly little resistance.

What does the future hold? Some visionaries have suggested using surface water to compensate for depleted ground-water reserves. At the cost of billions of dollars, these prophets recommend constructing a huge canal west to Texas from the Mississippi, and another south to Kansas and Colorado from the Yukon, Susitana, and Tanana Rivers in Canada. Predictably, officials in the Mississippi River valley and Canada have turned a deaf ear to these bold, outrageously expensive, and possibly ecologically damaging proposals.

In turn, a few people have suggested that Nebraska begin exporting some of its over-abundant High Plains reserves, but these suggestions have met with an even greater storm of protest. Critics of the idea note that interlopers from Kansas, Colorado, and Texas are already buying up large parcels of Cornhusker real estate.

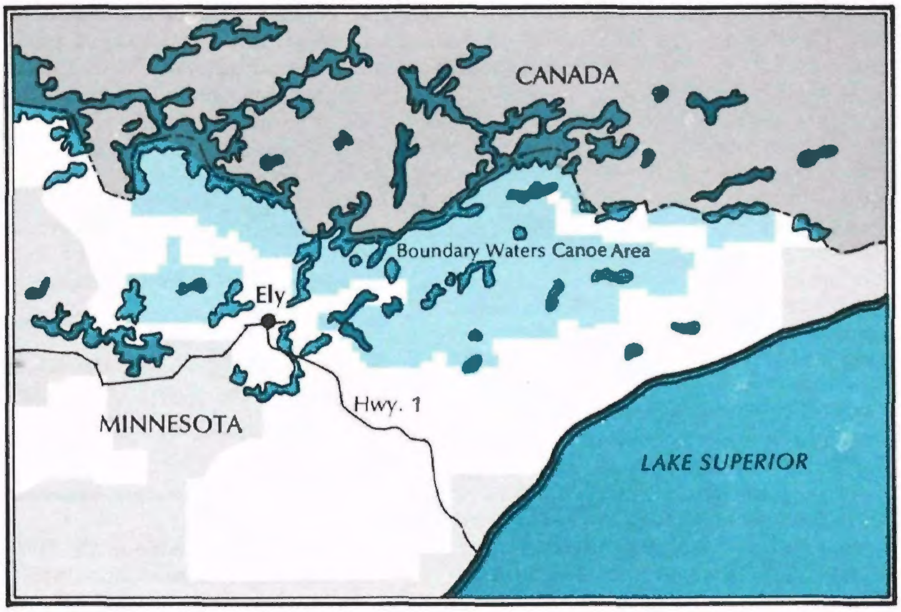
Is it any wonder that some water-crazed High Plains farmers are hiring rainmakers to attempt with magic what logic and science have been unable to accomplish: the saving of the High Plains aquifer. Professional rainmakers, using a blend of high-tech savvy and good old-fashioned hocus pocus, have taken credit in some areas for the recent increases in High Plains rainfall. Unfortunately, rainfall restores only 10 percent of the ground water in the High Plains aquifer that pumping at present rates depletes. Given the basic aridity of the High Plains region, it would take hundreds of years of heavier than normal rainfall to replenish what 70 years of undisciplined pumping have depleted: reserves of ground water accumulated drip by drip over millions of years.

It will take more than a rainmaker but probably less than a canal to right the wrongs of the High Plains system's past. Already the sheer cost of irrigation—$40 per acre foot in some places—is teaching farmers valuable lessons of self-restraint; others are learning new behavior from state regulators, once despised but now regarded as harbingers of the future. Part of this shift in attitude can be explained by the growing popularity of the concept of "sustainable" development: the idea that present-day farmers and other businessmen must save nonrenewable resources for future generations. So pervasive has this new attitude become that the farmers of the High Plains region would be universally castigated if their single legacy was a bone-dry aquifer, especially one formerly so mighty.

How sad it would be, almost everyone now realizes, if residents of some new High Plains desert could only read of what their forefathers once squandered: the legendary but only seemingly inexhaustible riches of the High Plains ground-water system . . . otherwise known in more traditional and more romantic terms simply as the great Ogallala.□

The Quetico-Superior Lakes: Tainted by Surprise

by Dean Rebuffoni



Historically, the myriad lakes along the Minnesota-Ontario boundary have exemplified good water quality—clear, clean, cold, and sheltered within a vast coniferous forest.

This is the land of the Boundary Waters Canoe Area (BWCA) Wilderness, the largest federal wilderness area east of the Rockies, and the adjoining Quetico Provincial Park of Ontario. Each covers more than 1 million acres, and together they have more than 2,000 interconnected lakes. Not only do these lakes comprise one of the finest freshwater systems anywhere, but this is North America's premier canoeing region.

There are no year-round residents in either the BWCA or Quetico Park, logging and mining are prohibited, and there are no point sources of pollution within either wilderness sanctuary. And while more than 250,000 canoeists paddle across the lakes each year, they leave little trace of their visits.

And yet, a toxic substance—mercury—has contaminated fish in the BWCA, Quetico Park, and the surrounding region, including Voyageurs National Park and the Superior National Forest. That has prompted Minnesota and Ontario health officials to issue fish-consumption advisories, and environmentalists are calling for prompt action to halt the contamination.

Until recently, neither the source of that mercury nor the extent of the problem was known. Some observers suggested that the contamination was a natural phenomenon; others thought that it resulted from old gold-mining activities in the region.

But such conjectures were before completion of a two-year study, made public last January, by scientists at EPA's Environmental Research Laboratory in Duluth, the Minnesota Pollution Control Agency (MPCA), and the University of Minnesota. The study concludes that air pollution is the primary source of the mercury. It also estimates that the rate of mercury deposition in the region's lakes is increasing at 3 to 5 percent annually.

Although more research is needed to determine the specific sources of the contaminant, the study calculates that perhaps 86 percent of the mercury comes from atmospheric deposition. That phenomenon occurs when potential sources—the MPCA cites coal-burning power plants and garbage incinerators—emit mercury high into the atmosphere and the contaminant then falls onto the surface of the lakes in snow or rain or as dry deposition.

Federal and state researchers said the contaminant could be blown into the region from outside sources after being carried long distances on the wind. They emphasized that research on acid rain, another form of air pollution, has shown that about 90 percent of the acid-forming air pollutants in Minnesota come from other states.

Another potential source of the mercury is mercury additives in latex paint used on building exteriors to

(Rebuffoni is the environmental reporter for the Star Tribune in Minneapolis.)

retard the growth of mildew on the paint; mercury additives in the paint may be entering the atmosphere via this source.

The remaining 20 percent of the mercury in the boundary-lakes region apparently comes from other sources in the lakes' watersheds. That could include mercury that falls onto land within those watersheds, then is washed into the lakes.

The study calculates that perhaps 86 percent of the mercury comes from atmospheric deposition.

Based on figures contained in the state-federal study, an estimated 300 to 600 pounds of mercury falls on the BWCA and Quetico Park each year through precipitation; the amount entering from dry deposition is not known.

Although the study focused on 80 lakes in the BWCA, the Superior National Forest, and elsewhere in northeastern Minnesota, there's little doubt that the mercury known to be tainting fish in Quetico Park also is the result of atmospheric deposition, said Gary Glass, a research scientist at the EPA's Duluth Laboratory. "The problem of mercury deposition in the BWCA and Quetico is indicative of the kinds of atmospheric inputs to all freshwater bodies that are within the impact zone of such airborne toxins," he said.

Glass and George Rapo Jr., a professor of geology and chemistry at the University of Minnesota's Duluth campus, directed the survey of the 80 lakes to pinpoint mercury concentrations in water, sediment, and zooplankton (plankton animal life). They also gathered data on mercury concentrations in the region's air and precipitation.

"We found that the mercury in precipitation comes from airborne sources, some of which are within the region and some outside," Glass said. "Some mercury enters Minnesota much the same way that acid rain comes into the state." He noted that the burning of fossil fuels results in airborne emissions which contain not only acidic pollutants, but mercury and other toxic metals.

Minnesota environmentalists have suggested that some of the mercury might be emitted from waste-to-energy incinerators in the state. Fourteen major, publicly owned incinerators are operating, under construction, or being planned in Minnesota. If, as planned, all those plants are fully operating in the next several years, they will burn at least half of the state's municipal garbage. Minnesota then will have a heavier per-capita reliance on garbage incineration then any other state, the MPCA has said. No definitive studies, however, have been conducted to determine how much mercury might be falling on northeastern lakes from incinerators in Minnesota, or elsewhere.

Most of the 80 lakes studied by Glass and Rapo are in the BWCA or elsewhere in the Superior National Forest, which sprawls across 3 million acres of northeastern Minnesota. The U.S. Forest Service is responsible for maintaining the BWCA's wilderness values and protecting air quality throughout the Superior Forest. But the forest supervisor, Dave Filius, stressed that his agency lacks the power to deal with air pollution from outside sources. "We've got a problem in the BWCA and adjacent areas that can't be controlled by the local ranger," he said.

Filius emphasized that while the Forest Service is concerned about mercury contamination, it doesn't want to frighten people who eat fish from northeastern Minnesota lakes. "We do, however, want to inform them in order to build support for more effective controls on the emissions that cause this problem," he said. "We are charged by federal law to maintain a pure, natural environment. Fish that are too toxic for some people to eat aren't what I would call 'natural.'"

Minnesota officials have known for more than 20 years that mercury has contaminated fish from certain state waters. But the recent state-federal study pointed out that the problem is growing. In 1977, only one lake in Minnesota (at the edge of the BWCA) was covered by a fish-consumption advisory issued by the state Health Department. Advisories now cover 260 lakes and 26 streams, many of them in the state's northeastern quarter. Although many of the advisories are based on mercury contamination of fish, others result from contamination by chemicals such as polychlorinated biphenyls (PCBs).

"It's clearly a problem that we have to deal with or we lose the battle," EPA's Glass said.

The advisories include the Health Department's recommendation that women of child-bearing age and children under 12 not eat large walleye or northern pike from more than half of 99 lakes tested within the BWCA and elsewhere in the Superior National Forest.

"It's clearly a problem that we have to deal with or we lose the battle," EPA's Glass said. "The fish in the boundary waters are not being affected directly: They still have good reproduction, for example. But enough mercury is entering those lakes through atmospheric deposition that the flesh of fish is being tainted to the point where someday they could be unsafe for anyone to eat.

Duluth News-Tribune *photo.*

Although the Boundary Waters Canoe Area wilderness appears pristine, airborne mercury is contaminating lakes in the area.

"Now 11 percent of the 80 lakes we studied have advisories restricting fish consumption to one meal per month," he said. "Unless we act, in 20 to 30 years about 80 percent of those lakes will be covered by the same restriction."

The MPCA (Minnesota Pollution Control Agency) stressed that the concentration of mercury in fish depends not only on the availability of mercury, but on each lake's water chemistry, which varies greatly across Minnesota. Before mercury can enter the food chain, it must be converted to methylmercury, a complex process researchers say is not completely understood. The MPCA and the EPA's Duluth laboratory are continuing research on how mercury finds its way into the flesh of fish.

And the problem is not restricted to fish, said Marvin Hora, who heads the MPCA's water-quality toxics assessment unit and helped coordinate the mercury study. He noted that the contaminant can harm certain wildlife species which highly depend on fish for food, such as eagles, otters, loons, and mink.

"Everybody seems to agree that the mercury in remote lakes is the result of an atmospheric problem," Hora said. "We have to shut off the source of that mercury, and in Minnesota we're looking strongly at the idea of pollution *prevention* rather than pollution *control*. We have to make sure that the mercury is never released into the environment."

The MPCA and Minnesota environmentalists recently supported a proposed amendment to the federal Clean Air Act that would have restricted emissions of mercury and other air toxins from coal-fired power plants and factories. But congressional sources said that the electric-utility industry was instrumental in persuading federal lawmakers to drop that amendment, arguing that more studies are needed on the issue. As part of its recent reauthorization of the Clean Air Act, Congress directed EPA to undertake such studies, then propose standards to cut toxic emissions.

The MPCA seeks a national mercury-control program similar to Minnesota's 8-year-old program that has cut emissions of sulfur dioxide from power plants in the state. That state program, one of the first in the nation, is intended to reduce Minnesota's contribution to the national acid-rain problem. Like acid rain, airborne mercury does not respect state boundaries, and the MPCA emphasizes that only a national effort will effectively curb both forms of pollution.

Despite the concern about mercury contamination in the boundary-waters region, there is hope that the problem can be alleviated.

Glass noted that some of the region's larger, deeper lakes require more than 100 years to renew their water and flush out some contaminants. "But that applies to certain other classes of toxins than mercury," he said. "Mercury appears to have a much shorter lifetime in a lake's water column. If the input of mercury is halted, it might be only a few weeks or months before mercury is removed from the water column and absorbed into sediment or plankton and other biota (all of an area's living material).

"That would allow the fish to grow with decreasing body burdens of mercury, and within a short period of time they would be safer to eat." □

Managing Nature in the Everglades

by James Webb

Once, North America's greatest wetland system gathered waters from the center of Florida's peninsula and deposited them in Lake Okeechobee, purified through winding rivers and grassy swamps. Overflows of the lake moved slowly southward in a wide sheet, picking up abundant rainfall along the way, and drained into the innumerable estuaries of the coast.

Over thousands of years, waters sweeping the peninsula's limestone shelf produced tree islands and pinewood flats in the slightly higher elevations and, a few inches below, created a vast, interwoven system of swamps and sloughs. The Everglades was born, and beneath its waters dying plants formed a deep accumulation of peat soils.

Reaching into the climate of the Caribbean, the varied landscapes of the "'glades" became home to a unique mixture of plants and animals from tropical and temperate zones and provided generously for them all. An intricate pattern of life adapted to the seasonal procession of Everglades waters and to years of drought and deluge, flood and fire.

That adaptation was so successful that Europeans making their timid early entries into the province found the continent's richest hoard of wetland life. Clouds of egrets and ibis rolled from sprawling, noisy rookeries. Waters teemed with fish, amphibians, and alligators. The nighttime scream of the panther and the dawn sweep of spoonbills bespoke a magic realm. But the real magic of the Everglades lay invisible, unheard, and unknown.

The real magic was that the Everglades was one thing—an organic whole, an ecosystem. From the microbial chemistry of its muck soils to its soaring eagles, from sunfish in its crystal headwaters to infant shrimp in Florida Bay, the parts worked because the whole ecosystem worked.

The Western spirit of conquest being what it was, however, most pioneers saw the Everglades only as a set of engineering, economic, and political problems. Bloody suppression of the Seminole Indians could lead to peaceful occupancy by "civilized" people. A shipping shortcut from the Atlantic to the Gulf could be made by dredging the Caloosahatchee and building a canal from Lake Okeechobee to the Indian River. Plumes from millions of slaughtered egrets, perched on millions of fashionable *chapeaux*, could add millions of dollars to private accounts. Drained and diked, the Everglades' rich soils could produce rich farms.

Despite setbacks from flood, fraud, and folly, efforts to subdue the 'glades inched forward for a hundred years, supported by various forms and degrees of public grants and public corruption. Highways and drainage districts, farms and towns, gnawed at its parts. The invasion took a toll on nature and on the intruding humans as well. Hundreds died when the weakly diked Lake Okeechobee broke loose in a hurricane of the mid-1920s, and great storms of the 1940s damaged the swelling economy of the region. Such events—and the growing technical prowess of the nation—spurred the impulse to bring the Everglades under comprehensive human control.

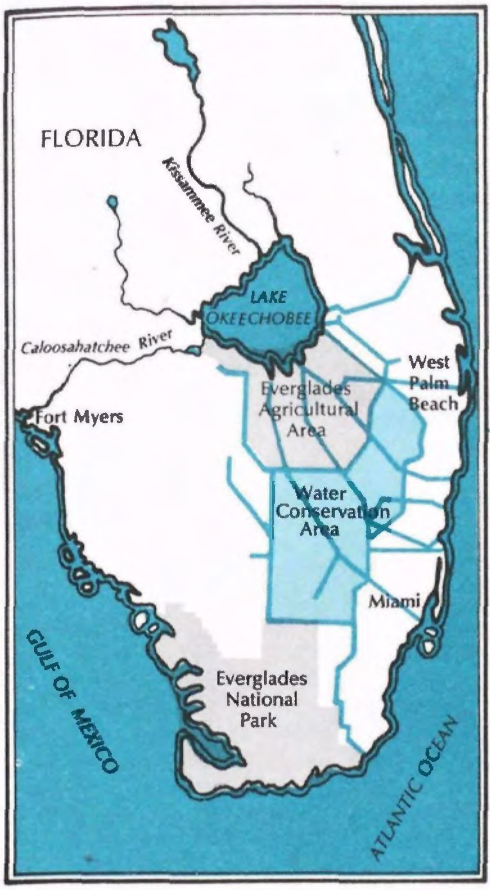
In 1947, Army engineers, modern heirs of the conquistador spirit, issued a plan for management of the Everglades' waters that entailed gigantic changes to their natural condition. Built to the direction of Congress, the Central and Southern Florida Project joined and expanded the faltering drainage systems then in place, created the Everglades Agricultural Area (about 700,000 acres of arable land south of Lake Okeechobee), and laid the base for the vast urban agglomeration that now occupies Florida's southeast coast.

Almost simultaneously, Congress established Everglades National Park at the downstream end of the system, thereby placing over a million acres

(Webb is Regional Director of The Wilderness Society in Florida.)

George Grant photo, National Park Service.

Some areas of the Everglades remain relatively undisturbed, like this lagoon with trees festooned with Spanish moss.



Waterways and Canals

under the highest standards of natural protection that our society offers. This was the first great expression of a national purpose to preserve the Everglades and its natural life.

That the Central and Southern Florida Project and the Everglades National Park were born at roughly the same time is almost ironic. The tension between the respective goals of those two initiatives illustrates the enduring problems of "saving the Everglades."

Considering the era, the Army's project was potent and sophisticated, with capable structures and well-integrated goals for regional flood control and water supply. Again considering the era, the absence of strong plans to accommodate and protect natural processes is no surprise.

From the time the project's main elements were built, and their operation turned over to a state agency—now the South Florida Water Management District—human decisions rather than natural forces became the most influential factor in the watery ecosystem. The fate of Everglades National Park and of every natural element of the region was tied to human intention—and human inadvertence. When we humans take over management of an ecosystem, our best efforts are clumsier than God's most casual, and we align our purposes awkwardly to His.

The project compartmentalized the Everglades, so that its waters could be used for irrigation when farmlands were dry—and could be drained away when the lands were wet. Thus the native flux of the system was lost, and so was wildlife that could not adapt to an unnatural pond here, an unnatural prairie there, or the disruption of age-old cycles of inundation and drying.

Half the historic Everglades is now farms, groves, pastures, and cities. What's left functions so poorly that plant and animal life, accustomed to millennial patterns of water and food supplies, suffer as those supplies are diminished, distorted, and dirtied.

Over the last 50 years, we have lost 90 percent of the Everglades' wading bird populations, and the trend continues downward. Now appended to the Everglades system is the nation's longest, saddest list of endangered species.

Water that once flowed through the heart of the system, taking perhaps a year to get from Okeechobee to the tides, is now rushed to sea, and lost forever to the 'glades. As a result, the Everglades—think of it as a huge sponge—is generally drier, and the effects of flood and drought have grown more volatile. To the Everglades, our water management practices now bring discharge spikes, too-rapid recession, wild swings in estuarine salinity, degraded water quality, extended drought, and the threat of early death. Property tax assessments for water management force most citizens to subsidize operations that damage their own natural capital.

Everglades water goes underground to supply the Biscayne Aquifer, the source of every drop from every faucet in every house, business, and industry of the coastal metropolis. Whereas ships once took on fresh water from the aquifer's upwellings in Biscayne Bay, water managers now struggle to keep salt water out of municipal wellfields.

While billions of gallons of water are diverted to tide, authorities plan expensive, energy-hungry desalting plants to meet urban water demands.

Areas along the eastern margin of the Everglades, critical to movement of its waters underground, are now drained and paved for development, adding to demands on the aquifer instead of supplying strength to it. Draining the upstream Everglades Agricultural Area (EAA) caused its soils to subside, so the whole system is managed at lower water levels to keep the EAA sufficiently dry, further denying water to the Everglades and the aquifer.

One reason for the subsidence of those soils is that they are oxidized when exposed to air and bacterial action. Nitrogen and phosphorus, once chemically bound in subaqueous muck, are released to flow downstream with drainage water. The typical sawgrass marsh of the Everglades is adapted to extremely low levels of those elements. Modest increases in their concentrations convert the marsh to dense growths of cattail and other pollution-tolerant plants. Thousands of acres of public wetlands, including parts of Loxahatchee National Wildlife Refuge, have been so altered. Their oxygen-depleted waters now support some topminnows and polychaete worms, where the whole volume and variety of Everglades life once flourished.

The EAA continues to pour nitrogen and phosphorus into the system, a tremendous slug of pollutants is already in train, and the integrity of the Everglades—*all* of the Everglades—is imperiled.

Unplanned, unintended, and damaging results of the Central and Southern Florida Project are more evident daily, as growing demand strains its operating capacities, sharpens competition for its benefits, and generally incurs higher costs to the ecosystem and the society. Against those effects, we now freight the project with purposes not comprehended in its original aims, such as protection of endangered species and water quality. The latter reflect a legal and moral direction to protect nature in the Everglades, restore what we can of its lost values, and provide for a

U.S. Fish and Wildlife Service photo

Drainage of portions of the Everglades has disrupted the ecosystem as a whole. It is now much more vulnerable to flood and drought.

burgeoning human population and for a vigorous, urban economy.

Ungodlike as their powers remain, scientists, policymakers, and ordinary people have learned a lot in the half-century of the project about what the Everglades needs, what the Everglades does for us, and what happens when 4 million people move into the neighborhood. The political lesson is this: Living with the Everglades system, and restoring its liveliness, presents a hard, permanent, and vital challenge to our institutions.

Throughout the United States, issues of constitutional federalism are increasingly about water. Serving private and public water needs through the interlaced methods, aims, and authorities of state and nation is nowhere more demanding than in the Everglades.

The law establishing Everglades National Park calls on the Department of Interior to protect the objects and processes of its natural life, forever. In fact, the park's "forever" lies more with the South Florida Water Management District than with federal authority. The fate of the natural system is influenced more by Florida's choices in growth management than by the United Nations' designation of the park as a World Heritage Site.

Increasingly, laboriously, in a maze of enactments, lawsuits, studies, and management plans, state and federal authorities have come to recognize the systematic problems of the Everglades and take common aim at better solutions.

That recognition illuminates fundamental errors in the management of the Everglades' waters and awful barriers to needed change—the kind of change that will support the most productive economic uses of those waters and also protect the ecosystem on which such uses finally depend. Such recognition also reveals some steps along the True Path: some things we've done right, some ideas that deserve wider embodiment.

The system's great public reserves give both motive and hope for the accommodation of man and nature in the Everglades; they preserve not just land and water, but choices. A current example of action broadening the Everglades' prospects is the 1989 addition of 108,000 acres to Everglades National Park's eastern boundaries. Enacted with firm support by the state, the East Everglades expansion brings the park's central supply of overland waters, Shark River Slough, into public control.

Half the historic Everglades is now farms, groves, pastures, and cities.

The expansion area is now mostly divided into small lots, distinguished only on paper, and their owners are mostly victims of unscrupulous swamp peddlers. As a result of withholding water flow from the otherwise unprotected, never-to-be-developed private holdings, the western, park-owned half of the slough is subject to excessive discharges from project control structures, and the wetlands life of the eastern portion is decimated.

In addition to its acquisition program for the eastern lands, the park expansion measure directed changes to project works that will let managers replicate more natural water patterns in the slough. The district developed a computer model, based on regional rainfall, that attempts to show how the slough's waters would move under unimpaired conditions. That model, refined as necessary by actual operating experience, will guide future deliveries to the park. More broadly, it suggests the kind of knowledge and application needed to restore abundance and diversity in the whole ecosystem.

The most powerful data from the most powerful computers leave us far short of understanding a complex system like the Everglades, but they sufficiently reveal gross error and important choices. Many prior choices, imbedded in the concrete of the Central and Southern Florida Project, are sapping resources—water, money, and options—needed to save the Everglades. Those choices—and the project itself—must now be remade, as growing knowledge shows us systematic impairment that demands systematic corrections.

Before we began to alter the Everglades, it survived 5,000 years of drought, hurricane, and fire, perennially healing the fabric of its life. We have cut and ruptured that fabric in ways that will never be repaired; still it remains one of the world's natural glories.

The Everglades is now our ward. We are obliged, for the Everglades and ourselves, to bind energy, intelligence, and the knowledge of the heart to its protection and revival. Only if we guard and cultivate the seeds of renewal, and redress each of our errors, however deeply rooted, will a bounteous nature respond.

There is no adequate precedent, in the nation or the world, for conscious restoration of an ecosystem so invaded by man. The job in the Everglades is to set the precedent and to do so quickly and well. Nesting success, whether for storks, alligators, or people, depends on it. □

The Eco-Invaders

by David Yount

Zebra Mussels. LePage photo. ASci Corp.

Ruffe fish. LePage photo. ASci Corp.

Spiny Water Flea. Tietge photo. ASci Corp.

(Dr. Yount is an aquatic ecologist at EPA's Environmental Research Laboratory in Duluth, Minnesota.)

Around 250 million years ago, all of the Earth's land mass was contained in one gigantic continent which geologists today call Pangaea. About 200 million years ago, this gigantic continent began to break apart, and the pieces began to drift toward their present locations.

While Pangaea existed, many species were widely found because they could move about and disperse relatively freely. As the pieces of Pangaea separated, however, the organisms that inhabited them became isolated from their relatives on other continents and islands. Over time, these species evolved in diverse ways and produced varieties that might not have survived had they needed to compete with their close or distant relatives. Consequently, the diversity of species on Earth increased.

About 500 years ago, the human species began, in effect, to reconnect the pieces of Pangaea through worldwide shipping. More recently, rail and air travel and faster and larger sea-going vessels have brought together species previously separated by oceans, deserts, mountains, and other barriers. Historically, such breakdowns of barriers between species occurred gradually, over millions of years; now the descendants of the species that once inhabited Pangaea are being reunited in the course of a few centuries, even decades. (This graphic picture of species exchanges was painted recently by Alfred Crosby in a book called *Ecological Imperialism* (New York: Cambridge University Press, 1987).

More than 30 years ago, Charles Elton wrote in *The Ecology of Invasions by Animals and Plants* (London: Chapman & Hall, 1958) of so-called "ecological explosions": enormous increases in the numbers of some kinds of introduced organisms. Ecological explosions, he observed, differ from other kinds of explosions in that they do not make loud noises and do not happen instantaneously—although they often make "quite a loud noise in the press." Elton wondered whether our awareness of these events was due merely to a more efficient news service or whether they really were becoming more common. He concluded that ecological explosions were in fact becoming more common. "We need to understand what is causing them," he wrote, "and try to arrive at some general viewpoint about the whole business."

According to estimates, zebra mussels currently filter all the water in Lake St. Clair several times daily.

Within the last two years, many articles have appeared about an "introduced species" called the zebra mussel. The enormous feeding and reproductive capacities of this invading species have led to its epidemic spread throughout the Great Lakes, where in some areas it reportedly has reached population densities greater than 30,000 individuals per square meter. The mussel's spread to other freshwater systems throughout North America is likely.

The mussels have immediate economic impacts because they clog water-intake pipes. In addition, for the longer term, there is also considerable concern that the species may cause catastrophic changes in the ecology of North American fresh waters. Consider the example of Lake St. Clair—a small

LePage photo. ASci Corp

Shippers and boaters are incurring extra expenses to have zebra mussels scraped off their hulls. The mussels also attach themselves in quantity to buoys and navigational aids. Managing the zebra mussel and other exotic species will cost millions of dollars.

connecting lake located between Lake Erie and Lake Huron—which is heavily infested with zebra mussels. According to estimates, zebra mussels currently filter *all* the water in Lake St. Clair several times daily. Zebra mussels can out-compete many native bottom organisms, and in Lake St. Clair and western Lake Erie, the mussels have dramatically shunted the energy flow away from fish in the aquatic food web. The spread of this mussel would mean severe and dramatic consequences for the ecological integrity of surface waters as it causes major shifts in food-web interactions and in the movement of nutrients and toxic materials, and reduces the diversity of species.

How did this situation come about? At a recent EPA workshop in Saginaw, Michigan, on introduced species, Edward Mills reported on a study of species invasions in the Great Lakes which he and his colleagues had conducted. The results indicated that exotic species have been successfully invading the Great Lakes since the early 1800s; no fewer than 115 different species were identified as having succeeded in establishing reproducing populations.

Although these invasions have been occurring for at least two centuries, 46 percent of them took place after the opening of the St. Lawrence Seaway in 1959. Thirty-five percent of the exotic species in the Great Lakes entered through ship activities. Of this group of 40 species, 28 arrived in the ballast water that unloaded ships carry for stability when crossing the ocean to pick up cargo.

Ed Mills and his colleagues reported that these 115 non-native species (which have had both positive and negative impacts) include the alewife, sea lamprey, purple loosestrife (a wetland plant), chinook salmon, the spiny water flea, and the ruffe, as well as the zebra mussel. Of these species, the latter three were brought into the Great Lakes through ballast water.

The zebra mussel was present throughout its native Europe before the last glacial era, when it found refuge in the Black and Caspian seas. From these strongholds, it has recolonized Europe not only by natural dispersion, but with the help of merchant vessels and inland waterways. Complete recolonization of Europe occurred about 160 years ago. Thanks to their natural predators and parasites, zebra mussels generally have not been a serious problem in Europe, except in new or disturbed habitats such as reservoirs. In any case, modern industry in Europe developed over the years in the mussels' presence, thus giving industry an opportunity to accommodate gradually by building infiltration and control systems.

The spiny water flea (also known as *Bythotrephes cederstroemii*, or BC) probably entered the Great Lakes in ballast water from ships frequenting European ports with low-salinity harbors. According to Craig Sandgren at the EPA-sponsored workshop on introduced species, BC is native to lakes in Europe, where it is typically a minor component of the planktonic community and therefore has been little studied. It was first reported in southern Lake Huron in 1984. It spread east to Lakes Erie and Ontario in 1985, into Lake Michigan in 1986, and into Lake Superior in 1987.

Each Great Lake has responded to BC in a different manner, probably as a result of their different plankton-eating fish communities. Whereas the zebra mussel has caused economic impacts that are easily measured, an assessment of the impact of BC must wait until fisheries or other ecosystems respond to the food-web alterations BC produces.

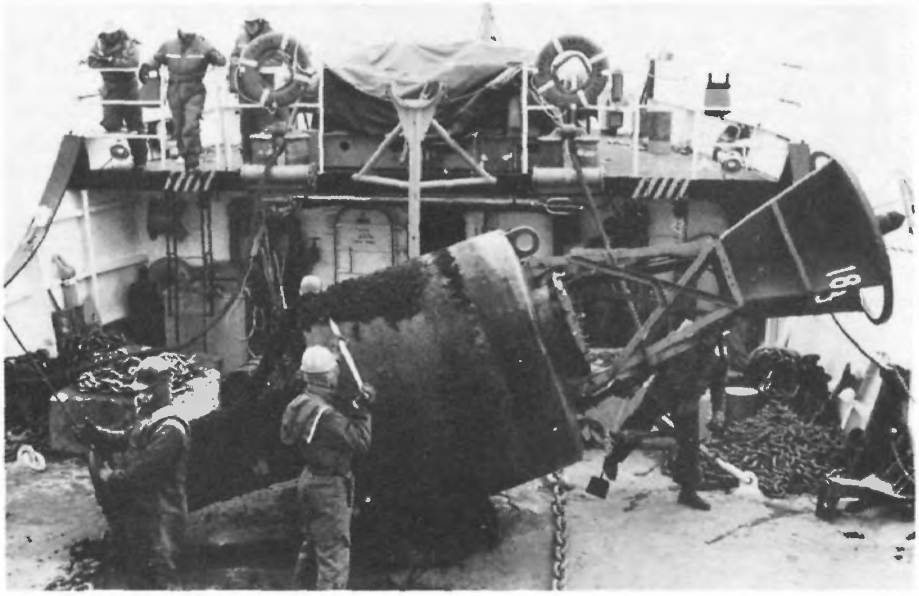
The ruffe, a small member of the perch family, is found in lakes, slow-flowing rivers, and canals throughout Europe and across central and northern Asia. It has been recently introduced to North America in ballast water. At this time, it has been reported only from the western end of Lake Superior, where it is becoming one of the more abundant species. The ruffe has little sport or commercial value in its native habitat, where it preys on the eggs of whitefish. Because it is very prolific, the ruffe can rapidly dominate other fish populations.

With the possible exception of the zebra mussel, the most serious introduced-species problem in the Great Lakes to date has been with the sea lamprey. This species migrated through the St. Lawrence Seaway into Lake Ontario and became common there in the 1800s. Niagara Falls blocked its migration to the other Great Lakes until the Welland Canal bypassed the falls in 1829. By the late 1930s, sea lampreys had spread throughout the lakes and quickly devastated the lake trout populations in Lakes Michigan and Huron and much of Lake Superior. An intensive control program, using a compound (TFM) which selectively kills sea lamprey larvae with minimal effect on other organisms, has reduced the lamprey populations to about 5 percent of their previous levels. However, continuous expensive and labor-intensive effort is required to keep the sea lamprey under control.

Three of these examples—the zebra

J. Howard McCormick, an aquatic biologist with EPA's Environmental Research Lab in Duluth, samples mussels on a recent Lake Erie trip made on the Coast Guard cutter *Mariposa*. Zebra mussels winter well and appear to have few natural predators in the Great Lakes.

To maintain stability, ships without cargo take on water from various ports for ballast. When picking up cargo at Great Lakes or other ports, they drain the ballast water, as shown here. Many exotic species are believed to have arrived from overseas in the Great Lakes this way.



LePage photo. ASci Corp.

LePage photo ASci Corp

mussel, the spiny water flea, and the ruffe—involve the transfer of species between major pieces of the former supercontinent Pangaea; the fourth example, the sea lamprey, concerns the removal of a natural barrier to dispersion. All four cases illustrate the range of problems that can arise when species which have evolved in separate parts of the world are brought together. Other examples, such as the purposeful introduction of rainbow trout or coho salmon, although considered beneficial by some fishermen, are looked upon with suspicion by those who are concerned about the natural integrity of ecosystems.

So what is the answer? Should we accelerate the reuniting of Pangaea and simply let the best competitors survive? Most thoughtful people say no. Apart from the problems involved, the world would certainly be a much less interesting place to live if that were to happen. Or should restrictions be placed on the controllable routes of introduction?

A recent report by the International Joint Commission and the Great Lakes Fishery Commission (Exotic Species and the Shipping Industry, September 1990) concluded that "the discharge of ballast water in the Great Lakes and connected ... waters must become a privilege granted only to those ships that have taken reasonable and acceptable precautions to prevent ballast-borne introductions." Toward this end, the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 requires that first voluntary guidelines, then regulations be issued to prevent the introduction and spread of aquatic-nuisance species into the Great Lakes through discharges of ballast water. The act also includes provisions for further research concerning introduced species.

This new law should slow the mixing of species among the pieces of Pangaea while promoting scientific understanding and minimizing the impact of those invading species that have already become established. □

An Independent Perspective

by William M. Eichbaum

Since the passage of the Federal Water Pollution Control Act Amendments in 1972, substantial progress has been made in addressing the water pollution problems of the nation. Rivers have been brought back from degradation. Billions of gallons of human sewage which received little treatment are now rendered almost harmless to man by massive treatment plants. Industrial discharges of metals and organics have been reduced by as much as 90 percent.

Yet there is growing concern, as evidenced by the recent report of EPA's Science Advisory Board entitled "Reducing Risk," that the ecological integrity of few of the nation's great water systems has been restored. The Chesapeake Bay continues to experience declines in oysters and rockfish. Waterfowl of the Great Lakes show substantial contamination by organic chemicals. The great water aquifers of the midwest, such as the Ogallala, become less productive each year. Lakes in the Rocky Mountains have increasing levels of acidification. Irrigation practices in California contaminate local ecological systems and degrade the San Francisco Bay.

The nation's effort, over the past 20 years, to protect the ecological integrity of our hydrologic regimes has produced benefits, yet the natural resiliency of these aquatic systems, upon which our long-range well-being depends, continues to decline. Where have we gone wrong? Or, more significantly, what do we need to do in the future if we are truly to protect the water resources of the United States?

Too often, efforts to reverse the degradation of water resources focus only on the most obvious symptom rather than responding to the complex problems of an entire ecological system. As a consequence, often there are several points of failure: Water quality improvements are limited, scarce resources are spent inefficiently, or, while quality improves, the abundance of flora and fauna does not. This fragmentary approach must be replaced by an integrated management system for water quality. Such a system would consist of several elements.

The first of these is *pollution abatement*. Efforts to reduce pollution need to go beyond controlling pipes. There is no question that point sources, such as industrial discharges and sewage-treatment plants, need to be effectively regulated. And, in large part, these sources have been well controlled through expensive treatment facilities. While there remain arguments about ultimate levels of treatment and about degrees of compliance at these plants, today the most significant uncontrolled source of pollutants appears to be nonpoint sources, such as runoff from agriculture and developed land. In fact, current estimates suggest that these sources of pollution are actually more important in degrading most water bodies than are point sources.

Too often, efforts to reverse the degradation of water resources focus only on the most obvious symptom . . . .

Unfortunately, there are few remedial mechanisms which are demonstrably effective for controlling these diffuse sources. Accordingly, pollution prevention will be increasingly important for controlling nonpoint-source pollution.

For example, management practices such as grass filter strips and small ponds appear to be largely ineffective in reducing the runoff of nutrients from farm fields. This means that pollution must be prevented by allowing no more nutrients to be applied to farm fields than will be utilized by the crops being grown. Fortunately, even for point sources, preventing the discharge of pollutants to treatment facilities, such as through a ban on phosphates in detergents, is highly cost effective.

A second element of an integrated management system would be *land management*. The land-development process is perhaps the single most important activity which degrades water quality and related ecological values. As the construction of housing and commercial and industrial facilities destroys forests, covers the land with impermeable surfaces, and converts wetlands, we lose an enormously rich natural habitat which depends on interaction between land and water for its biologic functioning. In addition, this transformation of the land fundamentally alters water quality and rates of flow, which results in the degradation of both surface and ground water. For example, the polluting impact of runoff from housing subdivisions can be many times that from forests.

If our society is to preserve the richness of aquatic habitats, we need to better manage our terrestrial activities which are critical to their viability. Controlling the location and nature of development must be a central strategy in protecting water regimes. Land disturbance and concentrated development of new communities should be prevented at the water's edge since their destructive impacts cannot be completely controlled with structural or engineered techniques. New development should be largely confined to areas where the existing infrastructure has the capacity to minimize environmental harm. Such strategies have been adopted by several states for their coastal zones and are now urged upon the states under the recently reauthorized federal Coastal Zone Management Act.

The third element of our management system would be *protection of living resources*. Too often we assume that achieving compliance with traditional water quality standards will be adequate to protect the flora and fauna of the aquatic environment. This is clearly false. Overharvesting and subtle changes in the aquatic or terrestrial habitat can result in the demise of especially important species almost

(Eichbaum is Vice-President of World Wildlife Fund and The Conservation Foundation.)


Bob Walker photo.

What happens on the land is a major factor affecting what happens in the water of many of the nation's great bays, rivers, and lakes. Heavy development is common near many great water bodies, including San Francisco Bay. Pictured is the East Bay shoreline, from Richmond to Oakland, California.

without a regretful glance to the past.

Careful plans must be laid for the survival of species as part of an environmental restoration strategy. Many species are important to humans for particular economic, cultural, or other reasons and should be the subject of protection programs. The states' management of freshwater trout fisheries is a pervasive example of such protection. Other species are of less obvious value, yet they play a role, often subtle, in the maintenance of natural processes necessary for the well-being of ecological systems. For example, in the Chesapeake Bay, it has been found that submerged aquatic grasses are critical to the long-term well-being of the bay because of their nutrient-control functions. Thus, nutrient-control programs which will protect submerged grasses are emerging as one of the most important living-resource protection strategies.

Lastly, *institution building* is necessary for filling out our management system. No natural system can long survive or be the subject of intensive human efforts at restoration unless there is a significant effort at building the institutions necessary for managing the human interaction with the system. Institutions of governance are built on political commitment, but if they are to function successfully, they require a wide range of inputs. They must be adequately staffed, and financial resources must be available. There must be strong mechanisms for public information and pathways for the public to influence government. Educating the public about the complex requirements for protecting ecological systems is necessary.

Especially in the increasingly difficult world of integrated environmental management, the problem of practicing good science and assuring that it is wisely used by managers and policy makers deserves serious attention. The science of ecological management is a great deal more uncertain than the simple problem of engineering a treatment facility to produce an effluent to meet a set of water quality standards. This uncertainty places a premium on good communication between scientists and managers and upon well-directed research programs. These efforts need to reach beyond the physical, chemical, and biological sciences into economics, sociology, and related fields. Finally, a system of monitoring must be established to measure success, or the lack thereof, and allow for program evolution and political accountability.

Successful design of a program based on these elements of an integrated management system will require that we give up thinking of water pollution problems in isolation. The causes of water degradation are not accounted for simply by the discharge of pollutants directly to the water from either point or nonpoint sources. Pollutants come from a complex set of sources, including such unlikely culprits as auto emissions transported through the air or changes in hydrologic regimes resulting from forest destruction or suburbanization.

Thus, the nature of the water, land, and air throughout the entire watershed, and even beyond, determines the quality of water and the well-being of associated flora and fauna in a particular body. Understanding and protecting the ecological connectedness of these complex interrelationships in an integrated fashion is crucial. Not only must our management efforts be oriented to the complexities of the four elements which have been outlined, but these elements must be applied throughout the often extensive geographic area of a watershed. The crucial role of the watershed—its hydrologic as well as terrestrial and atmospheric components—quickly leads to the recognition that the use of the land throughout the watershed is perhaps the single most important determinant of water quality in the receiving aquatic system will be.

Political will lies at the heart of a strategic aquatic restoration and protection program that is based on managing an entire watershed. The multiple challenges of complex decisions, participation by many sectors of society, and requirements for substantial resources can be successfully met only when there is powerful leadership. Manifestation of such political will is altogether too rare. Consequently, many of the nation's great water bodies are facing a long tortured process of decline. The few exceptions suggest several factors which drive such leadership in the environmental context: dramatic illustrations of the problem, like the die-off of a species; a big event, such as completion of a study; an emotional appeal, such as a popular book or song; adverse economic consequences, like the loss of a fishery; and, perhaps most important, growing public demands.

Pollution prevention will be increasingly important for controlling nonpoint-source pollution.

The nation's great water systems remain threatened. Isolated "hot spots" have been corrected, but the central function of our aquatic regimes as a vital source of the environmental stability and well-being of our society seems to be poorly understood, and fundamental protection remains absent. Fragmentary approaches will no longer work. The future of water quality protection in the United States must be based on a holistic system derived from good science and implemented through a comprehensive system of protective strategies. □

Chris Ayres photo.

Cold water doesn't deter beachgoers from recreation at Popham Beach on the Gulf of Maine. Growing public demand for clean recreational water across the United States may help force a comprehensive system of protective strategies.

Measuring Environmental Success

by Steve Glomb


Mike Brisson photo.

People want direct answers to questions as to whether water is safe for recreation and other uses. EPA is working on improved methods for measuring changes in water quality.

How healthy are the nation's great water bodies? The question suggests the story of the blind men who were asked to describe an elephant. One touched the elephant's leg and said it was like the trunk of a tree. Another said it was like a wall, after touching its side. Those who could only touch the trunk or the tail believed the elephant to be a hose or a rope. Everything depends on perspective.

Likewise, answers to questions about the health of our nation's water bodies often are based on different perspectives and sometimes fail to paint a complete picture. In the past, many of our reports to Congress and the public on the health of our waters have revolved around numerical accounting—"bean-counting," to use the common parlance. Such accounting measures are administrative surrogates for true environmental measurements and describe only part of the elephant. As a result, EPA and the states can readily tell the world how much money we've spent on various programs, how many permits or grants we've cranked out, how often we've taken bad guys to court, and how many water-quality criteria and standards we've written and reviewed.

In several areas we have made real progress, moving beyond administrative beans to measure the amounts and kinds of pollutants entering the water. We can now estimate pollution loads coming into the Great Lakes or other coastal areas; for many water bodies, we can estimate the local proportions coming from pipes, from nonpoint sources, and from rainfall. For example, phosphate loadings into the Chesapeake Bay and the Great Lakes have been cut dramatically due to improvements in sewage-treatment plants and new programs to control nonpoint sources. EPA's new Toxic Release Inventory gives us a benchmark against which we may be able to gauge future loadings.

But how can we describe the real environmental effects of decreased pollutant loads? Can I swim there? Can

(Glomb is a biologist in EPA's Office of Marine and Estuarine Protection.)

I eat the fish? Are the oysters safe to eat? These are the questions the public asks. Ecologists go a step further and ask about biodiversity, or biological community structure, or habitat quality. In addition, the public is asking how effective are all the program expenditures, the standards, and the permits if people can't eat the fish. Before finding answers, we need to agree on the questions.

EPA is now asking itself many of the same critical questions. Consensus is growing in scientific and regulatory communities that administrative and pollution-loading measures are not enough—that often they don't tell us beans, so to speak, about what's really happening in the environment.

The Science Advisory Board recently called for greater ecological focus in EPA's programs. Administrator Reilly and Deputy Administrator Habicht are also pressing for better long-term strategic planning that would reflect a stronger emphasis on measuring and reporting environmental results of Agency programs, not just administrative milestones.

The framework for the Office of Water's strategic plan reflects these big issues now in the mind of both the public and EPA. The plan lays out several long-term ecological goals for the nation's water resources. Among the goals for the Great Lakes and our estuaries are:

- To increase the number of shellfish beds open for harvest
- To decrease the number of fishing bans and health advisories
- To decrease the extent of low-oxygen "dead zones"
- To maintain, and increase if feasible, the extent and productivity of critical habitats, especially wetlands
- To maintain the biotic integrity of invertebrate and fish communities.

Not surprisingly, progress toward some of these goals is harder to measure than others. Counting the number or measuring the area of open or closed shellfish beds is relatively easy. State and local governments regularly measure bacteria concentration in water near shellfish beds, then classify the beds as being open for harvest or restricted, based on standard national guidelines. The National Oceanic and Atmospheric Administration (NOAA) summarizes these harvest classifications in the National Shellfish Register, published every five years.

Although measuring may be easy, understanding what the changes in numbers mean is not. While the standards are uniform, monitoring efforts vary widely from state to state. NOAA and EPA are working to improve monitoring methods and reduce some of the monitoring variability.

Similarly, bans and advisories concerning fisheries are easy to quantify. But interpreting what changes in those numbers mean is difficult. A greater management emphasis on decreasing the health risks from eating fish would likely result in a short-term rise in the number of fish advisories. (It is a truism that any time you look hard for problems, you can usually find some.) But continuing emphasis on fish advisories over the long term should eventually lead to a decrease in toxics loadings, lower levels of toxic contamination in fish, and a downturn in the number of bans and advisories. Knowing when to look for results, combined with a sense of what results to expect, is important when evaluating information on environmental health.

Before finding answers, we need to agree on the questions.

Measuring oxygen or defining "dead zones" also is relatively simple, but the choice of assessment methods depends on geographic scale. Using a probe that continually measures oxygen concentration can be very helpful to someone assessing the local influence of a suspected pollution source, but no one can afford to put such probes everywhere. On a bay-wide or a regional scale, reports of massive fish die-offs may be the most useful indicator. On a national scale, satellite data may provide environmental managers with the best picture.

Satellite data and aerial photography also have proved useful in measuring the amount of wetlands and other critical habitats lost over the past few decades. For example, using these resources, Louisiana estimates that its coastal wetlands have been disappearing at the rate of 35 square miles per year. The health of the remaining critical habitats, including created habitats built to mitigate losses, is much more difficult to measure. By 1996, research by EPA, the U.S. Fish and Wildlife Service, and states should lead to development of methods for evaluating the health of habitats. (Species diversity and productivity are two of the most promising research topics.)

Biological community interactions are probably the most difficult goals to measure. Many scientists, however, think that these interactions are the most important factor to assess. Especially important are the invertebrates that live in the mud at the bottom of our coastal waters. Because they don't move much, they can be used as an indication of problems over time. Measuring fish communities can be confusing because of their migration patterns. A fish may get contaminated in one estuary, then move along the coast and eventually become part of a sample in a clean estuary. Commercial fish harvests and sport fishing also confound analyses of the fish communities.

Even among scientists, there is debate about what index to measure in particular instances and how to measure it. For fresh water, EPA has developed a set of community bioassessment protocols. These protocols comprise a set of methods that assess richness or diversity, dominance, ratios of pollution-tolerant to pollution-sensitive organisms, and comparative ratios of organisms with different feeding strategies. These factors, when examined together, paint a much more complete picture of ecological health than any single factor.

As an illustration, consider each of two stream sites with very similar physical characteristics and a sample of 100 critters from each. The first stream site has critters from 10 families, 10 organisms each. The second also has individual organisms from 10 families, but what if 50 are from one family with the rest split fairly evenly between the other nine families? Both streams have the same richness (10 families), but are the sites equally healthy? Generally, a community like the one at the second site, dominated by relatively few families, indicates environmental stress. Further examination of the proportions of filter-feeding organisms, organisms that scrape or scavenge for food, and those that shred leaves would give

Because mud-dwelling invertebrates don't move around much, they make useful indicators of conditions at the bottom of our coastal waters. Drawing depicts a healthy community living beneath intertidal flats.

further insight into the types of stresses present.

This type of approach has been readily accepted by many states and incorporated as an integral piece of water-quality protection programs. The Agency is now beginning to examine various approaches for assessing communities in estuarine and coastal waters. After discussions this winter to narrow the list of potential methods, EPA should begin field validation tests in the spring, perhaps leading to results in three to four years.

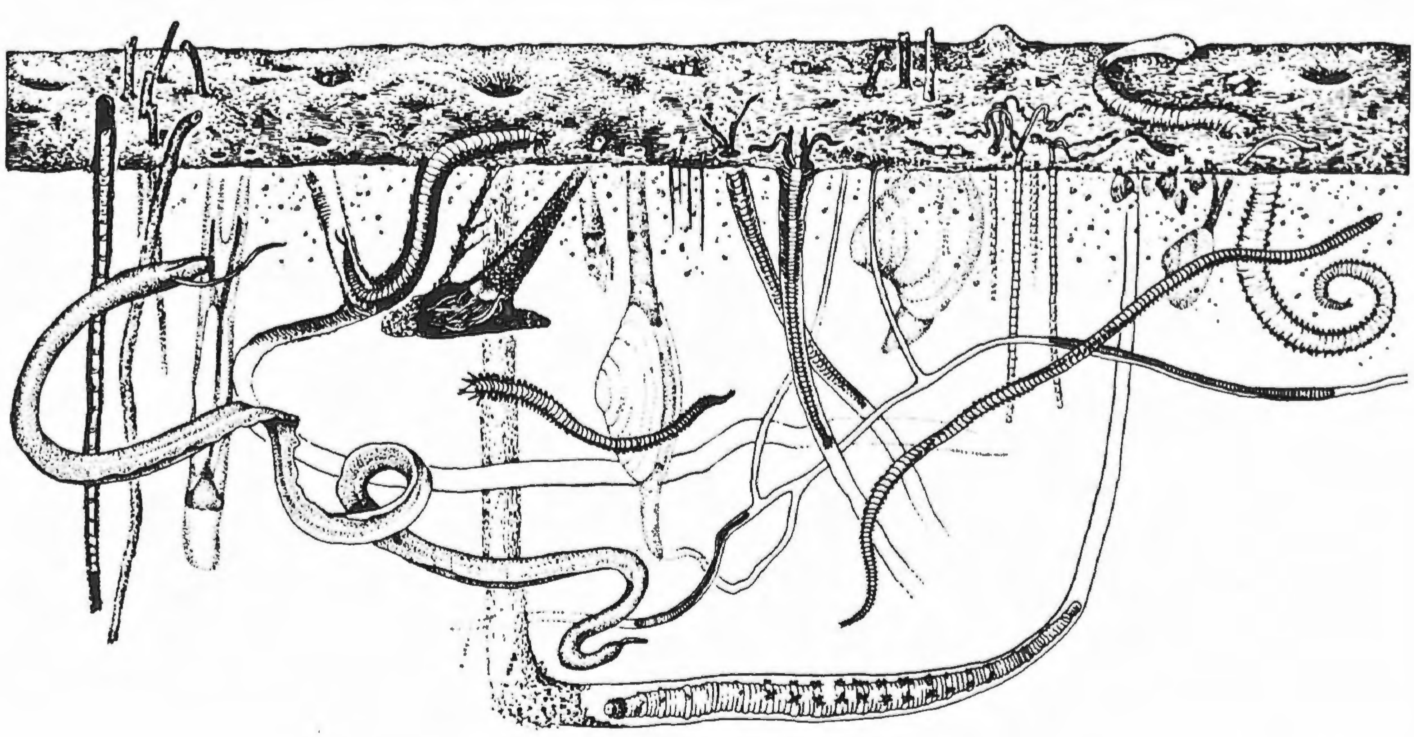
Until coastal ecological interactions are well understood and integrated assessments are fully developed and tested, we probably will need to rely on studies of individual species. Usually the species used as indicators are either extremely sensitive organisms or commercially important ones. They are the coastal equivalent of a canary in a coal mine: Changes in these species can signal changes in the overall environment. For example, declines in underwater plants in Chesapeake Bay over several decades was one of the key changes that helped state and federal legislators focus on the need to protect the bay. Increases in the number of fish with lesions and fin rot led the Puget Sound estuary program to concentrate on controlling sources of toxic pollutants to its urban bays.

Researchers at EPA laboratories in Gulf Breeze, Florida, and Narragansett, Rhode Island, are examining early-warning signals, "biomarkers," in individual species. Biomarkers reflect the effect of pollutant stress on the chemistry and physiology of the individual organism. Pollution-induced changes in the blood chemistry, enzyme production, or other internal systems can affect the organism's ability to grow, respire, or reproduce. Such responses are akin to changes in human physiology. Doctors call for blood tests to examine sick patients; they don't wait until an entire community is infected before determining there's a problem. These changes in aquatic individuals may also help in detecting early responses to improvements in the environment. But more research is needed to link such changes to an entire population.

Even knowing what to assess, and how and when to measure it, may not be enough. Many other factors can figure into EPA's interpretations of data. One is the ever-increasing population near the Great Lakes and other coastal waters. Maintaining the status quo despite the increased pollution potential from the higher population may be a big programmatic success, even though there may be no marked improvement in the critters. Natural variability and fluctuations over time are difficult factors to understand. The influence of a couple of very hot seasons, or extremely heavy rains, could mask *bona fide* progress made in protective efforts. Understanding such natural variability is one of the goals of our current efforts.

In order to paint a comprehensive national picture, two differing approaches will be used to measure ecological health and progress. The Ecological Monitoring and Assessment Program (EMAP) currently being developed should prove useful in presenting a broad, nationwide assessment. At the same time, information compiled from monitoring studies by various state and National Estuary Program environmental managers will help fill in details of the national picture.

A marriage of the EMAP's broad, top-down national picture with the more detailed, bottom-up view described above will produce a composite portrait that will give the Agency a much clearer picture of the health of the nation's waters than either approach alone. Combining both approaches will also enable the Agency to better focus its money and people and more effectively target the most important problems and geographic areas. In doing so, we should be able to avoid the predicament of the blind men and the elephant. □

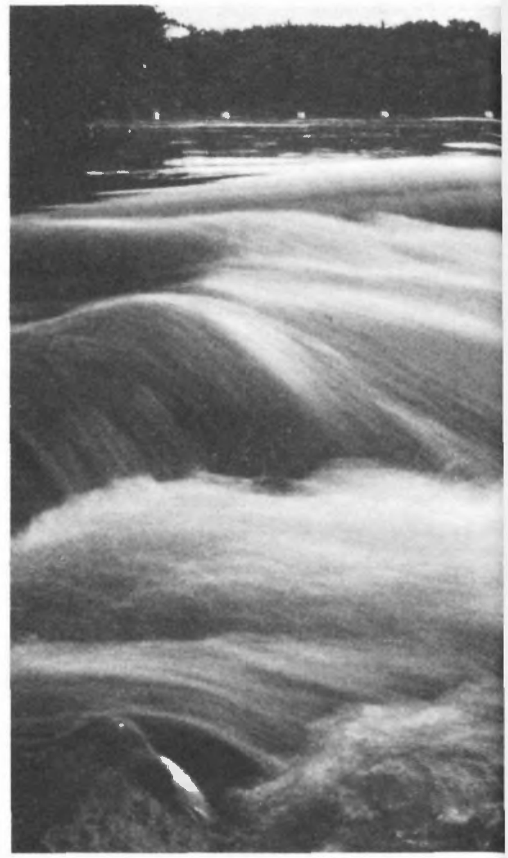


Drawing adapted from an illustration by Alice Jane Lippson.

Looking Forward in the Office of Water

by LaJuana S. Wilcher

"If you have built castles in the air, your work need not be lost; that is where they should be. Now put the foundations under them."
—*Henry David Thoreau, Walden*



Water—a living resource. Protect it, and benefit from it.

We all want pure, clean water. The farmer, the factory worker, the family on the beach. Pure water to drink, healthy aquatic ecosystems to nurture fish and wildlife, uncontaminated water to grow our crops, sustain our livestock, and support our industries.

EPA has been working diligently toward these goals for the last 20 years. With the passage of the Clean Water Act in 1972, we began to address water quality problems comprehensively. In 1970, when the Agency was created, we were faced with immense quantities of pollution from industry and municipal sewage treatment plants. Although we had little in the way of sophisticated scientific evidence at the time, many of the problems were obvious enough: untreated sewage in the Potomac River and Boston Harbor, toxic industrial waste in the Mississippi, Ohio, and Cuyahoga rivers, massive red and green tides (algae blooms) in Lake Erie, and quickly declining fish and shellfish populations in the Chesapeake Bay. At that time, all we really had to do was look; the problems were evident to our eyes and noses.

(Wilcher is EPA's Assistant Administrator for Water.)

Through the municipal wastewater construction grants program, the federal government contributed $48 billion and large amounts of technical assistance to help states and municipalities stop the dreadful practice of using our rivers, lakes, and coastal waters as open sewers. The number of people in the United States served by secondary or higher levels of sewage treatment rose from 85 million in 1972 to 176 million in 1988. Significant unmet needs still exist, especially the need to upgrade and replace wastewater-treatment facilities. Because this program's focus is changing, we are in the process of moving toward state-run loan programs.

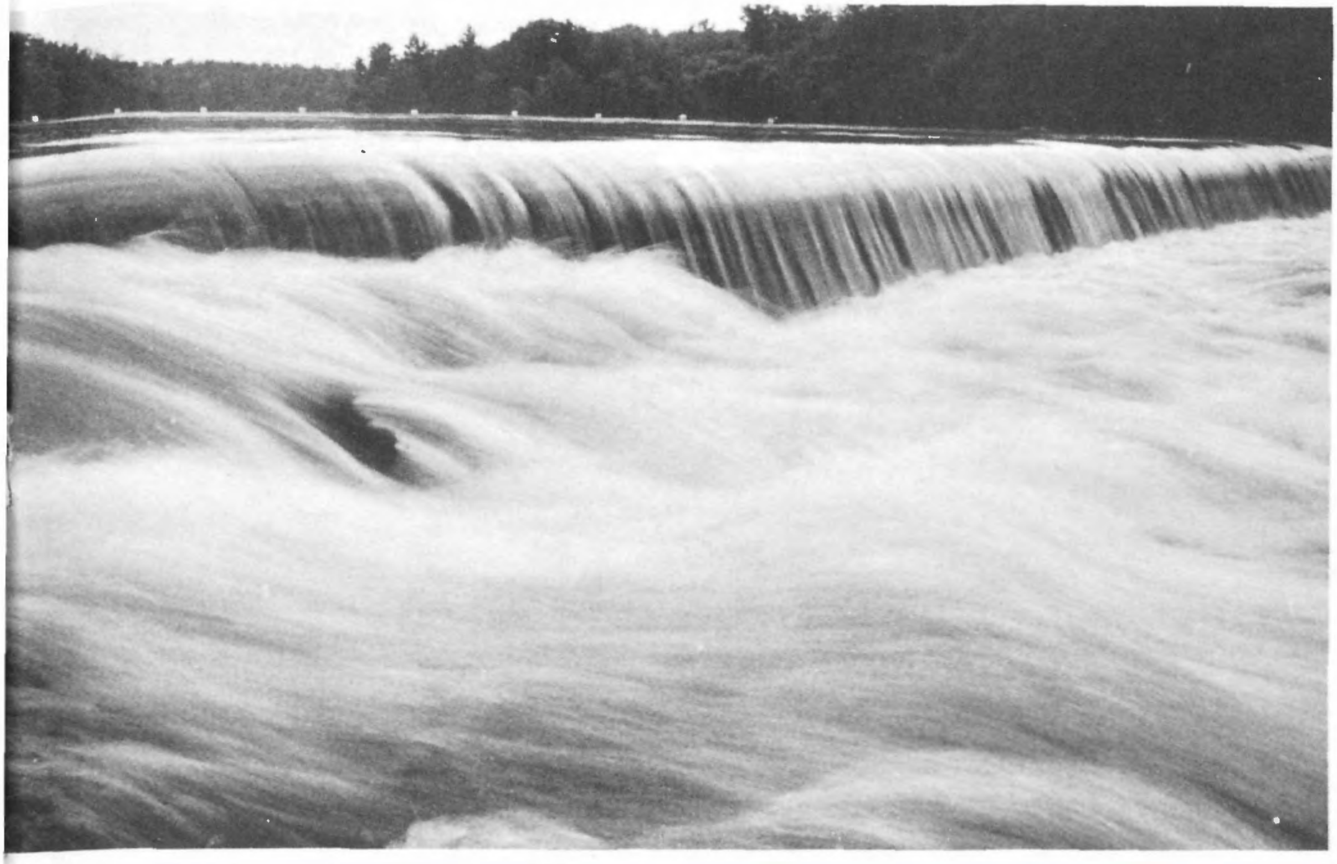
EPA recently has given another $12 billion to states to capitalize a new State Revolving Fund Program for municipal wastewater-treatment facilities and other water quality improvements. To control industrial discharges, EPA has promulgated technology-based effluent guidelines (limits) for a variety of industrial categories and implemented a water-quality standards program with the states.

Our efforts to issue permits and firmly to enforce infractions of the law have led to partial recovery of several severely degraded waters, including the Potomac River and Lake Erie. Only 36 percent of the waters states assessed in 1972 met their designated uses; the most recent data reported by the states in 1988 showed 70 percent of the assessed waters met their designated use requirements.

Today, significant pollution problems come from literally millions of "diffuse" or "nonpoint" sources. Rain water and snow-melt runoff from urban and suburban areas, farms, mining operations and industrial sites are often laced with pesticides, heavy metals, and excess nutrients. Toxic pollutants are still a major concern, especially those that do not biodegrade. These toxics become trapped in the bottom sediments of rivers, lakes, and coastal waters or accumulate in the flesh of fish, shellfish, other wildlife, and, ultimately, in humans.

Clearly we have more work to do, and we need new approaches to do it. No longer can we use just an end-of-the-pipe approach. No longer can we look only to industry and municipalities as sources of our waters' contamination. No longer can we limit our efforts to cleaning up our great water bodies after we have fouled them. No longer can we relegate protection of our ecosystems to the bottom of our agenda. No longer can we operate our water programs in isolation from each other and other EPA programs.

As the famous conservationist Aldo Leopold wrote almost 50 years ago, "Instead of learning more and more



Mike Brisson photo.

EPA Documerica photo. National Archives

Significant improvements in water quality have been made since the Clean Water Act was passed in 1972, when detergent foam on the nation's rivers was a common sight. Step by step, the clean-up effort is gaining new understanding and framing new strategies to meet today's pollution challenges.

about less and less, we must learn more and more about the whole biotic landscape." We must look broadly and comprehensively to identify our water quality problems and act boldly to prevent pollution and habitat destruction.

The foundations for achieving our water-quality goals rest upon several new approaches.

Ecological Protection

First, we must place the protection of ecosystems on the same footing as human health. Last September, the Science Advisory Board (SAB) issued a thought-provoking document entitled *Reducing Risk: Setting Priorities and Strategies for Environmental Protection.* The report says, "EPA's response to human health risks as compared to ecological risks is inappropriate, because, in the real world, there is little distinction between the two. Over the long term, ecological degradation either directly or indirectly degrades human health and the economy."

The Clean Water Act has long been the most ecologically focused of our major environmental statutes. Since the 1987 Amendments to the Clean Water Act, water programs have emphasized controlling chemical impacts in response to public concerns about toxics. Physical impacts, including

Tim McCabe photo USDA Soil Conservation Service.

Nonpoint-source pollution control. By planting alternating strips of corn and small grain, this Maryland farmer helps prevent erosion and runoff into nearby streams which flow into the Chesapeake Bay.

habitat destruction from urbanization, farming, dam construction, diversion, irrigation, stream channelization, and intense recreation have garnered little attention until recently.

The SAB report has served as a catalyst for our thinking about our programs and how we view our mission. The Clean Water Act instructs us to protect the chemical, *biological, and physical* integrity of our nation's water resources (emphasis added). We need to view the integrity of the water environment holistically—the sum total of the complex chemical, biological, and physical dynamics necessary to sustain the ecological integrity of healthy aquatic ecosystems.

As Indian Chief Seattle said in 1854, "All things are connected like the blood which unites one family. All things are connected." We are beginning to develop the scientific tools necessary to protect ecological systems on a holistic basis. No longer is it enough for us to concentrate on water chemistry; we must move beyond the stream banks to consider the interrelationships between all parts of the ecosystem.

Geographic Targeting

In order to accomplish this broader goal of protecting all aspects of the nation's waters, we believe geographically targeting some of our resources to those areas most at risk is vital to accomplishing our task.

In the past, our systems for controlling pollution were focused on national standards for industries and sewage-treatment facilities. In order to fully address ecosystem integrity, and in order to get the most "bang-for-the-buck," we must turn our attention to individual watersheds and ecosystems. In addressing the gross pollution problems of the past (which were common to virtually all our waters), we have uncovered a range of problems which tend to be unique to individual watersheds. For instance, the current problems of the Chesapeake Bay (primarily extensive dead zones caused by excess nutrients) are far different from those of the Great Lakes (primarily toxic hot spots, and toxic pollutants in fish and other wildlife). Because of the potentially high costs, complexity, and difficulty of the measures which are necessary to achieve ecological protection, we must target our efforts to those watersheds that are most at risk, most threatened, and most valuable—in ecological terms—to the country.

William C. Franz photo.

Even on a dry summer day, this storm sewer outlet oozes its outflow across a Staten Island beach and into the ocean. Control of urban stormwater runoff is one of the clean-up tasks society faces.

Restructuring for the Future

To better reflect the changes in our approach to protecting water resources, we are proposing to reorganize our Headquarters office to reflect our focus on better science, ecological protection, and geographic targeting. To this end, we are contemplating a structure that will help integrate all of our functions to focus on addressing the unique problems of individual water resources, and to strengthen our emphasis on scientific and technical support of regional, state and local decisionmakers. We are now considering many suggestions from EPA staff and managers as we prepare to send this ambitious proposal into formal Agency review.

The Clean Water Act Reauthorization

As we approach 1992, we must consider how to approach the reauthorization of the Clean Water Act. We have designed a three-phased process to gain the best thinking from all relevant sectors of society. In Phase 1, we are holding informal meetings with a broad spectrum of individuals and groups, including state and local water quality managers, agricultural interests, environmental groups, industry representatives, natural resource economists, and others. Phase 2 is devoted to culling the best ideas and options from these conversations and other sources and presenting them in background papers. In Phase 3, we will hold a series of symposia with experts on four aspects of clean water:

- "The Risks to Clean Water" (relative remaining risks to water resources)
- "The Cost of Clean Water" (economic incentives, funding issues)
- "The Structure of Clean Water" (necessary changes to the Clean Water Act)
- "The Feasibility of Clean Water" (economic and political realities).

These symposia will be open to the public and will encourage their participation. Our goal is to gather information from a wide range of interests to better prepare us for the reauthorization process.

Foundations for the Future

As we move toward the 21st century, federal, state, and local water programs must be prepared to address the most pressing water resource problems. If we are ever to do more than just keep pace with growing threats, we must be willing to change our programs to best fit the most significant remaining risks. We must be prepared to go beyond our present chemical focus to protect the full range of values that make up chemical, physical, and biological integrity.

Additionally, we must improve our ability to target our efforts to the most serious risks or threats to our most valuable water resources. Clearly these are lofty goals, but ones we can achieve. We have a solid foundation of programs and people to build toward our dreams of safe water for all, whether fish, fowl, or people, throughout our country. □

Appointments

Tobin

Rasmussen

Schilling

Gagliardi

Patrick M. Tobin is the new Deputy Regional Administrator for Region 4, which is headquartered in Atlanta, Georgia.

Tobin is a charter member of EPA. He joined the Agency as a Sanitary Engineer for the Office of Research and Monitoring in 1970. Since that time, he has worked in the Office of Water as Deputy Director and Director of the Criteria and Standards Division in the Office of Drinking Water. Since 1986, he has served as the Director of the Waste Management Division in Atlanta.

He has been a member of many of EPA's National Committees and Task Forces, has testified for the Agency before Congress, and has represented EPA internationally in Japan, India, the Netherlands, and Australia.

Tobin earned a bachelor's degree in civil engineering at the University of Maryland in 1962. Following a tour as an officer in the Air Force, he earned a master's degree in environmental engineering at the University of Maryland in 1968.

The new Regional Administrator for Region 10 in Seattle, Washington, is **Dana Rasmussen.**

Rasmussen was Assistant Vice President and Chief Counsel of Federal Relations for U.S. West, a telecommunications firm which she joined in 1985. She was a General Attorney for Pacific Northwest Bell Telephone Company in Portland, Oregon, from 1979 to 1985.

A Portland native, Rasmussen received a bachelor's degree in psychology from Stanford University in 1968. In 1977 she earned her law degree from the University of Oregon School of Law. She also is a graduate of Stanford Business School's Executive Program.

She was an Administrative Law Section Chair of the Ratemaking Committee for the American Bar Association from 1989 to 1990, and is involved in numerous outside community and public service activities.

Albert H. Schilling has been named the new Associate Assistant Administrator for the Office of Policy, Planning, and Evaluation. Schilling joined the Agency in 1985 as a Special Assistant for Legislative Development after working in the private sector for 14 years. In his five years with the Agency, Schilling has also served as Supervisory Attorney Advisor and Director of the Office of Legislative Analysis.

Schilling received his bachelor's degree in economics from Harvard in 1967 and his master's in history from Princeton in 1971. He earned a law degree from Rutgers Law School in 1974.

He received the Special Act or Service Award in 1983 and an EPA Bronze medal in 1986.

The new Deputy Associate Administrator for the Office of Communications and Public Affairs is **Carl S. Gagliardi.** Gagliardi worked for EPA from 1983 to 1986 as a Press Officer and Deputy Director of the Press Division before transferring to the Department of the Interior, where he served as a Special Assistant in the Secretary's office, and subsequently as Director of Public Affairs for the Bureau of Reclamation. He left the government to work with a Washington-based public relations firm before returning to EPA as Special Assistant and Director of Communications Strategy in 1989.

Gagliardi graduated from the University of Maryland at College Park with a bachelor's degree in government and politics in 1975.

Several other appointments recently have been made in the Office of Communications and Public Affairs, including **Charles Osolin** as Director of Publications; **John Kasper** as Press Director; **Hank Roden** as Director of Special Projects; **Helga Butler** as Director of the Communications Strategy Staff; **Nanci Martin** as Deputy Press Director; and **Chris Rice** as Special Assistant to the Associate Administrator. □

The nation's great water bodies—a treasure for all seasons. Photo of Lake Michigan from Door County, Wisconsin, by Mike Brisson.

Back Cover: San Francisco Bay, a major West Coast estuary. See article on page 20. Photo by Jerry Derbyshire.