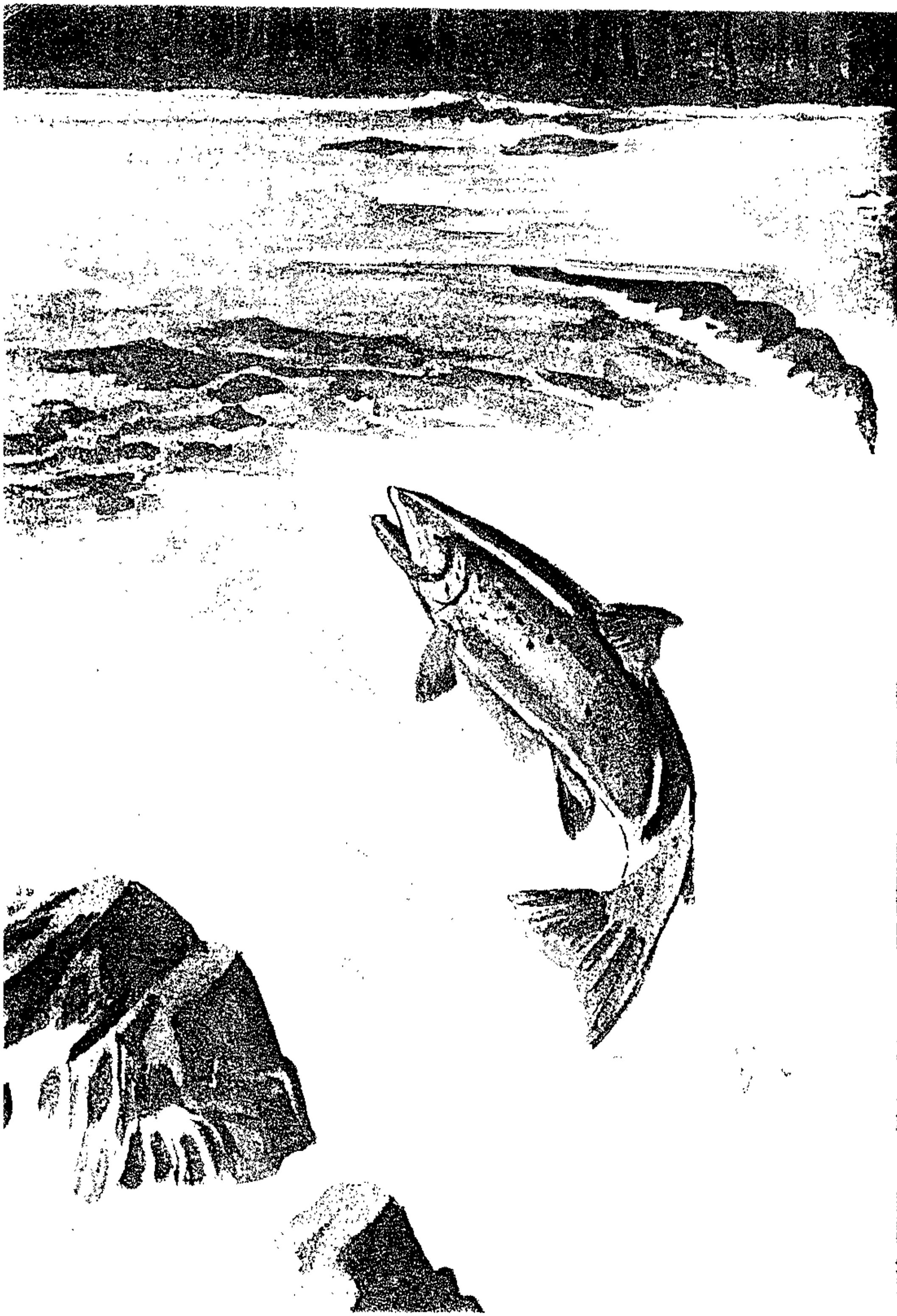

SEVEN

Outwater, Alice. WATER. 1996.

THE WATER OVER THE DAM

The intent of the Reclamation Act of 1902 was to use public funds to irrigate the otherwise unfarmable deserts of the West. In 1903, six major irrigation projects were approved, and the Reclamation Service, which had been established by the act, began construction on the Truckee-Carson Dam in Nevada, to irrigate an area that was virtually uninhabited. In 1905, work began on the Roosevelt Dam, on the Salt River near Phoenix, Arizona. The dam was built with rock hewn from the canyon walls by a crew of Apaches not twenty years removed from Geronimo's band, and a few Mexicans and hoboes recruited from ranches and freight trains. When completed in 1911 at a total cost of $10.5 million, the Roosevelt Dam was the tallest rock masonry dam in the world. A solid wall bowed upstream against the river's current, rising 280 feet above bedrock. The Reclamation Service's ingenuity and resourcefulness and the graceful design of its dam astounded the world. The grasslands of the Salt River Valley, now assured an ample, inexpensive supply of water, were soon farmed, and Phoenix was on its way to becoming a desert metropolis.

After the Roosevelt Dam on the Salt River came the Arrowrock Dam on the Boise, which was even taller, the Elephant Butte Dam on the Rio Grande, and the Gunnison tunnel, dug through granite and shale to divert Colorado's Gunnison River into the Uncompahgre Valley. By 1919, twenty-six separate reclamation projects were in various stage of completion.

The newly irrigated lands were generally planted in alfalfa, wheat, cotton, or hay—all low-value crops that were cheaper to raise in nonirrigated regions. Except for California lettuce and oranges, crops grown in the desert did not make the farmers rich. The overhead was high, and it was more difficult to make a living growing irrigated crops in the short-grass prairie than nonirrigated crops in the tallgrass prairie. In the good year of 1917, for example, a Department of Agriculture study showed that the Corn Belt farmers in Illinois cleared an average of $870; in Chester County, Pennsylvania, the farmers made $789; but on the irrigated land of Utah's Salt Lake Valley, farmers made only $417.

Nonetheless, the concept of reclaiming a desert was a potent lure, and in the first decades of the twentieth century, some of the best engineering graduates in the country gravitated toward the Bureau of Reclamation (as it was renamed in 1923). Projects were financed by a fund initially made up of revenues generated by the sale of public land in the West, and construction costs were meant to be paid back gradually, through the sale of water to farmers.

As the size of the projects increased, so did the cost of the engineering and construction. But the farmers made too little money to pay much for water, and it was soon clear that the cost of building a dam was unlikely to be recouped through water fees. The difference between the farmers' payments and the actual cost of the Bureau's forty-year Columbia River project, for example, amounted to a 96.7 percent public subsidy by 1980. Dams were not built as moneymakers, though: they were built to bring farmers and civilization to unpopulated land. As a good landscape was one that lay plowed, planted, and stocked, so a good river was one that was dammed, channeled, and leveed. From an engineering standpoint, dams were wonderfully multipurpose construction projects, useful for hydroelectric power, flood control, and water supply as well as irrigation. Every canyon was a hole that was waiting to be filled, and water that ran to the sea without being used was considered wasted.

The dams generally had modest effects on the waterways until the 1930's. Floods were regulated and sediment was trapped, but the dammed rivers retained some of their natural character. Seasonal flow variation was less pronounced but nonetheless apparent; reservoirs were relatively small and affected the stream channel only for a limited distance. But in the 1930s the construction of large dams and the grouping of multipurpose projects within entire river basins became symbols of American engineering mastery over the landscape. The Tennessee Valley was the first fully integrated basin development in the country, and others soon followed. In 1936, the Bureau blocked the Colorado River with the Hoover Dam, which, like the Great Wall of China, is said to be visible from the moon with the naked eye. In Washington State, the Bureau concentrated on the Columbia River Basin. Eight dams had already been built on tributaries to the Columbia when, in the

1930s, the Bureau decided to dam the Columbia itself, on a glacial outwash known as the Grand Coulee. The Grand Coulee Dam was completed in 1942; ambitious projects were under way in the Central Valley of California; and before the century was half over, the American West had more and bigger dams on its waterways than any other region on the planet—and still the building continued.

Between government and private enterprise, roughly fifty thousand dams have been built in this country. Of these, a thousand or so are what engineers refer to as "major works"—truly gigantic constructions holding back rivers that were once thought to be untamable: the Colorado, the Columbia, the Snake, the Tennessee. There are sixty dams on the Missouri River and its major tributaries, and twenty-five dams on the Tennessee. Why on earth did we build so many?

With the adoption of river-basin planning in the 1930s, a single project typically included dams, canals, and irrigation works from headwaters to river mouth, across 1,000 miles of terrain. During the Roosevelt and Truman administrations, several omnibus river bills authorized dozens of dams and irrigation projects at a single stroke. Economics mattered little, for while the irrigation projects might never pay off, the hydroelectric dams within the same river basin could generate the revenues to cover the losses.

Over a period of eighty-six years—from 1905 to 1991—the Bureau of Reclamation and its predecessor built 339 reservoirs, 154 diversion dams, 7,670 miles of irrigation canals, 1,170 miles of pipelines, 270 miles of tunnels, 267 pumping plants, and 52 hydroelectric power plants. With the help of $18 billion in capital outlays, over 14,000 square miles of farmland received water, and the West bloomed and prospered. Water made much of this land intensely productive, and advocates of reclamation saw public irrigation as a miraculous font of free riches. There were, however, great costs.

* * *

Mammoth dams are able to exert total control over the downstream river. The waterways are manipulated for power, flood control, and water supply, and the result is a truly engineered river system, whose out-of-season high flows don't correlate with seasonal rains. Natural extremes of flow, water temperature, and sediment transport are eliminated. Instead, unnaturally rapid flow fluctuations or sudden periodic flow changes are often superimposed on a constant background discharge: the low flows are higher, the high flows are lower, and the cleansing and nutrient-filled annual flood pulse is eliminated.

When the Hoover Dam went up, fish that had evolved to survive in the widely fluctuating and muddy flows of the Colorado lost their competitive advantage. The muscled humps of the humpback and bonytail chubs, designed to allow these fish to hold position or make progress against currents that swept most fish away, were suddenly superfluous. Eight dams on the lower Colorado and an aggressive dredging program to redirect the riverbed have contributed to the extinction or threatened status of eight species of fish native to the Colorado. As a kind of compensation, channel catfish and rainbow trout were introduced, and have prospered.

Water takes much longer to move through a dammed river system, and nearly all the sediment and organic matter carried along by the water is permanently stored in the reservoirs. There is less organic matter in the water to fuel the aquatic ecosystem; worse, since natural river channels are maintained by a dynamic equilibrium of sediment deposition and erosion, water without sediment can trigger major riverbed erosion. When dams retain silt, erosion is accelerated for dozens of miles downstream. Below the Hoover Dam on the lower Colorado, for example, millions of cubic yards of sediment were scoured from the channel for 100 miles, and the channel slope was noticeably reduced. It took about twenty years after construc-

of fat totaling up to a third of their body weight, and swim thousands of miles to the deep of the Sargasso Sea, which lies south of Bermuda. There they lay their eggs, and die soon after. The young females return to fresh water; the males stay in salt or brackish water all their life.

Striped bass 5 feet long and weighing as much as 100 pounds once entered the streams of the mid-Atlantic states in great abundance, along with the shad, the alewives, and the Atlantic salmon; and the sturgeon were once so regular in their inland expeditions that the full moon of August was called the sturgeon moon. The largest of all freshwater fish, some sturgeon live for two hundred years, measure 20 feet long, and weigh close to a ton. (The sturgeon of Russia's Lake Baikal are said to reach 2,200 pounds and an age of three hundred years—estimated from annual growth rings on their eardrums—although it seems highly unlikely to me that a fish could survive from the reign of Peter the Great to the present.) Some species of anadromous fish die after a single spawning, but the sturgeon returns to the sea and makes forays inland to spawn every few years. Sturgeon eggs are nice as caviar, and their swim bladders were once used to make isinglass windows (that roll right down, in case there's a change in the weather).

The sturgeon of the Great Lakes were so large that the spawning runs were easily obliterated by commercial fishermen at the turn of the century. As early as the late 1700s, overfishing began wiping out the Atlantic salmon as well. The survivors are much smaller today than they were two hundred years ago. An early writer reported that 40-pound Atlantic salmon were occasionally taken on the Grand Codroy River in Canada. In this generation, the average salmon caught there tips the scale at 4 pounds, with the largest fish, year after year, weighing in at less than 25 pounds. But the anadromous species that commercial fishing didn't take care of, dams did. The rivers of the East powered the early Industrial Revolution, with dams built by entrepreneurs running mills of all sorts. Dams proliferated on the smaller streams, and in the first half of the 1800s industrialists commandeered the larger streams, while lumbermen dammed the rivers to create high flows for enormous log drives. The New England states passed laws to protect the salmon to no avail, since the fish could not swim past the dams. By the 1870s, the Atlantic salmon had virtually disappeared, while there were 433 laws on the Maine books to control and preserve the fisheries.

In 1890, perhaps haunted by the recent disappearance of the Atlantic salmon, Washington State's first legislature passed a law requiring that fish-passage devices, such as fish ladders, be built on dams "wherever food fish are wont to ascend." Federal fisheries laws were also passed in the last two decades of the century, and these also required that dams permit some way for migrating fish to pass. Nonetheless, by 1940 eight unladdered dams had been built on the Yakima River in Washington's Columbia Basin, and they had decreased the annual salmon run from six million to nine thousand fish. The Grand Coulee Dam effectively closed more than 1,000 miles of spawning streams in the upper Columbia Basin, destroying the legendary "June hog" King salmon run in that region.

Salmon, the most studied of the anadromous fish, are beautiful swimmers, who glide effortlessly on unseen currents and can accelerate faster than a car for short distances. The Chinook, or King salmon, is the largest of the Pacific salmon, and will occasionally weigh in at 125 pounds, with a 5-foot-long body; the other four species range down to 20 pounds packed into a 2-foot torpedo. And they used to be numerous. The Columbia River once had annual runs of an estimated sixteen million salmon.

Young salmon live in the ocean, feeding on zooplankton, small fishes, and squid. They follow the prevailing North Pacific currents in sweeps of 1,000 miles, traveling regularly each year in migratory patterns that depend upon the currents, the climate, the contours of the ocean bed, and possibly even the sun and stars. Salmon have good eyesight and can also detect pressure waves, using currents to navigate; they may even navigate using the earth's magnetic field. Fish migration is now believed to be based on exploration and learning, and as new habitats arise, the fish rapidly exploit them.

When a salmon is about four or five years old and has traveled 10,000 miles or more in its circuits of the great oceanic grazing grounds, it puts on weight and heads inland to spawn. Some salmon spawn in the spring, others in the fall; some swim as far as 2,000 miles inland to reach their natal stream. Salmon, like many fish, follow their noses. They distinguish between species and sex of other salmon by scent, and use olfactory landmarks to determine their location. They remember the smell of the vegetation and aquatic residents of the stream they grew up in, and smell their way back to breeding territory.

Although the salmon's life path was never easy, it has become unspeakably difficult to be anadromous today. If a salmon needs to ascend (for example) the Columbia to find its natal stream, it has to start with the Bonneville Dam. Fish mill about at the bottom of the dam waiting their turn at the fish ladders, bottlenecked in the odd-quality water straight from the reservoir. At the top of the Bonneville ladder, they are confronted with 40 miles of warm, placid water, very different from the cool, oxygen-filled waters of the rapids and river currents it replaced. After the Bonneville Dam comes the Dalles and then the John Day and the McNary—each a major barrier to fish migration and each a major lake to swim through. Next come the Priest Rapids Dam, the Beverly Dam, and the Rock Island Dam, for the Columbia is no longer a river but a series of slackwater lakes.

Every dam that went up inundated a stretch of spawning stream on one side and eroded the gravel on the other. When too many dams are built on a river and too many downstream miles of riverbed are scoured, there are too few miles of gravel beds left for riverine fish to make nests in. The salmon, having made the journey, will dig their redds one on top of the other if necessary, each fish laying and fertilizing perhaps five thousand eggs.

Salmon hatch after two months of incubation in their gravel nests. The hatchlings live in the gravel until the yolk sacs attached to their bellies are consumed, after which they are recognizable as little fish. The fingerlings hide behind logs and under ledges, grab their food quickly, and retreat for cover. They swim near the bottom of the stream, where the current is weakest, traveling alone and conserving energy by resting in eddies. They come to know the stream's hiding places and its predators, and when the water runs low the young salmon will dive into the gravel rather than swimming unprotected into the current. They are surprisingly skillful at making their way through the gravel substrata, and have been known to follow underground watercourses into wells and springs, making it seem as though salmon fell from the sky. The fingerlings live in their river for as long as a year before becoming smolts, a silvery transformation that allows them to survive in salt water and immediately precedes their swim to the sea. Which is when things get extremely dicey.

A highly stratified reservoir can have surface temperatures that are lethal to juvenile salmon, while the cooler subsurface water is usually low in oxygen. Reservoirs are fine homes for lake fish, but they can become impassable barriers for juvenile salmon. Once the smolts get through the reservoir, they must pass through the hydroelectric turbines, which can be a bruising experience. In low-flow years, they may have to go through the turbines of seven or eight dams before they reach the ocean, and as many as 95 percent of the smolts will be macerated en route.

In high-flow years, the juveniles may be able to avoid the turbines, but the water that goes over the dam's spillway captures air and plunges it to substantial depths, mixing too much nitrogen into the water. A young salmon swimming in water supersaturated with nitrogen can die of the fish equivalent of a massive attack of the bends. Nitrogen bubbles form under their skin, their eyes bleed, sometimes their internal organs explode. In 1970, when the nitrogen levels in the water of the Columbia and Snake Rivers reached 143 percent of air saturation, the National Marine Fisheries Service estimated that 70 percent of downstream migrant salmon and steelhead trout were killed by nitrogen supersaturation before they reached the ocean.

The Pacific salmon's habitat has also been degraded by deforestation. Streams in deforested land are warmer, and the quiet pattern of pools and riffles created by fallen logs disappears, reducing food sources for the fingerlings. The salmon coevolved with the beaver, and until John Jacob Astor made his fortune in beaver skins from the Columbia River Basin, beaver ponds were part of the salmon's early life and part of its success as well. It is not surprising—fish ladders and legislation aside—that the salmon population started to fall off rapidly as the Pacific Northwest was dammed.

The solution to this complex environmental problem was technical: build hatcheries. The first salmon hatchery in the United States was built in 1871 on the Columbia, and between 1900 and 1930 the number of fry annually released by the state increased from twenty-five million to ninety million. So great was the government's faith in hatcheries that when a dam was built on the Olympic Peninsula's Elwha River in 1915, the Elwha hatchery was opened in lieu of emplacement of fish ladders, and in the next few years seven more hatcheries were built to compensate for the fish runs lost to dam construction on the White Salmon, Chehalis, and Elwha Rivers. Initially, two million eggs were collected annually to hatch in tanks, but within a few years the pool below the Elwha dam was empty of fish. The Washington Department of Fisheries abandoned the Elwha hatchery in 1922.

In the 1930s, Canadian fisheries biologists showed that substantial releases of hatchery sockeye increased neither the commercial catch nor the number of fish spawning in the wild. Canada closed all of its Pacific salmon hatcheries, and a number of American hatcheries on the West Coast were closed. But the Washington Department of Fisheries expanded its network. In 1958, the first of twenty-five Washington fish farms was built. By 1966, the program, which used natural lakes to raise large numbers of confined fish, was abandoned, because almost no farm fish were coming back to spawn. But to prepare the selected areas for the farmed salmon, all the native fish had been poisoned, so the failed fish farms, in addition to costing millions of dollars, removed dozens of wild salmon runs.

Hatcheries continue to release many millions of salmon every year, and the salmon returns have continued to decline. In 1992, a study conducted by Terry DiVietti, a Central Washington University psychology professor, provided an explanation. When fish are raised in a hatchery, they learn far less than the tiny fingerlings that grow up in the riverbed. Hatchery fish in concrete tanks have no threats in their life; they flock to the surface for food, and swim in packs the rest of the time. By contrast, fish that grow up in a stream learn to survive dozens of predators, and will hide, dart out, and zip back under cover to eat. They swim alone. They know how to use rocks and logs to conserve energy, having honed their swimming technique in the variable, complex flows of a stream. Hatchery fish learn none of these lessons in their tank. Releasing hatchery fish to the wild may be the piscine equivalent of sending a well-fed adolescent who has watched a lot of television into the woods to survive on his wits.

The other problem with hatchery fish is genetic. In the last few decades, it has been found that stream fish are much more genetically dynamic than anyone had ever imagined. There once were roughly 1,000 breeding stocks of salmon, of which 106 are now extinct and 314 are threatened or endangered. A human being offers up a few genetic carriers to the world; a salmon offers up thousands of genetically unique offspring, and the few that make it through to adulthood are likely among the very best of the lot. Therefore, salmon species adapt relatively quickly to local conditions. Genetically speaking, each stretch of river is home to its own strain, and every adult that returns is the pick of a very large litter. Hatcheries provide the protection that salmon are designed to do without, so hatchery-raised fish are genetically unculled. Releasing millions of hatchery fish plays havoc with the wild salmon, for both compete for the same food sources. Hatchery fish are much less likely than wild salmon to survive to adulthood, but they do apply pressure on the surviving wild stocks.

Thanks to dams, habitat degradation, overfishing, and hatcheries, the Pacific salmon has now disappeared from over 40 percent of its former range in Washington, Oregon, Idaho, and Montana. In 1994, despite a billion-dollar salmon recovery program, only about two and a half million salmon returned to spawn in the Columbia and its tributaries (two million hatchery fish, half a million wild), and the numbers continue to fall.

When anadromous fish swim up rivers to spawn, they provide an input of nutrients gathered at sea which are enjoyed by the entire food chain. Anadromous fish are consumed by carnivores, like wolverines and eagles, and omnivores, like bears and people; and the plants benefit as well, because fish concentrate phosphorus, one of the critical nutrients for plant growth, in their bones. The fish-laden feces of larger animals and the offal and bones left on land once delivered a nutrient element that present-day inland soils are often short of. When the spawning runs of fish declined, there was less flesh to sustain the meat eaters, and the green plants at the bottom of the food chain had less phosphorus to grow on, so the deer and elk had fewer new shoots to nibble on. No catastrophe, mind you, but it's harder to be fat and happy when the fish don't run.