INDUSTRIALIZED NATURE

Brute Force Technology and the Transformation of the Natural World

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of the Stalinist plan for nature transformation. Seawater levels dropped in connection with all the new dams, river flow slowed, and spawning areas were destroyed. Scientists sought artificial propagation of sturgeon, Caspian inconnu, common carp, and bream. By 1959, sturgeon hatcheries at the Kura and Volga Rivers were in operation and, at peak, produced about 100 million fry annually. This was inadequate to prevent destruction of stocks, for sturgeon fishing was an industrial enterprise that earned the Soviet Union hard currency. Further, sturgeon are a slow-growing fish, reaching maturity after fifteen or twenty years, too long for planners impatient to harvest. The sturgeon is now so rare, with only about 100 fish caught annually, that it seems only a complete ban on fishing in the Caspian Sea can save it. However, economic pressures will make it difficult for the five countries bordering the sea to agree to a ban.

Although the scale and aesthetics of Stalinist nature transformation were unique in the twentieth century, the effort to transform was not. The Columbia River basin in the Pacific Northwest underwent similar radical transformation, with thirteen massive dams added between 1933 and 1973, complemented by huge irrigation systems and fish ladders that fundamentally altered the river's shape and flow. Often, construction moved ahead with explicit reference to Soviet hydropower efforts to demonstrate that the American way of life, its science, technology, and economic system, was better—more efficient and morally superior—than Soviet communism.

The Best Damn Capitalist Dams

The development of the Columbia River basin paralleled that of the Volga basin in temporal, ideological, and psychological senses. Planning, alteration, and construction began in the 1930s. Engineers and policy makers touted reconstruction of the basin as possible only in America, with the masses to benefit and the nation to become measurably more powerful. The rebuilt modern capitalist river would solve the problems of terrible floods and the economic crisis of the Great Depression. One of the last major floods, in May 1948, destroyed Vanport City, the second largest city in Oregon, and gave impetus to the construction of more dams for flood control even as the finishing touches were being

put on the exemplars of New Deal planning and ideology, Bonneville Dam and the Grand Coulee Dam.[47] And brute force technology with unrivaled grandeur was the tool for the river's transformation. In response to plans advanced decades earlier, the Army Corps of Engineers and Bureau of Reclamation turned earnestly to building dams on the Columbia River during the New Deal era. The dams would easily provide enough electricity for the entire Pacific Northwest and enough water to irrigate eastern Washington, Oregon, and Idaho. Like the Volga, the Columbia held significant historical and cultural meaning for local people, in this case Indians, but this fact was not taken seriously by settlers of European descent who were eager to overrun any obstacles to the generation of wealth in the Columbia's great drop and huge volume of flow.

The 1,250 mile long (2,012 m) Columbia has some 150 tributaries, many of them major rivers, that drain semi-arid land, areas of heavy rainfall, and mountains whose snowpack melts into the river in spring. The Snake River, one of the tributaries, is more than 1,000 miles long. The Columbia drops 2,400 feet (731.5 m) along its length, in some places charging through narrow canyons and over magnificent falls—Great Falls (Celilo), Long Narrows (The Dalles), and the Cascades—before spreading to a width of two and a half miles at its mouth. The river's flow fluctuates considerably, with its heaviest coming in late spring and early summer with snowmelt. Before the dams were built, the river rose 50 feet from low to high water at Celilo Falls, a traditional Indian fishing site several hundred miles from the Columbia's mouth but now under waters of The Dalles Dam.

When explorers Meriwether Lewis and William Clark traveled down the Columbia to the coast in the autumn of 1805, they encountered a wild river and many Indians who gave them food and assistance as they tried to negotiate the rapids, with their "swels and boils." Often the rapids tossed members of the expedition into the water, or they hit rocks, the canoes sank, and they lost "many things including shot and powder." There was no problem with provisions, however: deer, elk, sea otters, geese, grouse, ducks, and pheasants "as large as [turkeys]" were everywhere to be seen. But it was the salmon that astounded them the most. "The river is remarkably clear and crowded with salmon in maney places," they wrote. "The number is incredible to say—and at this season [the Indians] only have to collect the fish split them open and dry them on their scaffolds which they have great numbers."[48] The Indians had established hundreds of drying lodges the length of the river, Lewis and Clark discovered. Wherever they went, hundreds of Indians—notably the Cho-pun-nish, or Nez Percé—came to meet with them, to sit at fires all night to talk, smoke, and eat salmon.

The Indians caught salmon with weirs, harpoons, dip nets, and long nets of seine and gill-net type made of wild hemp, flax, or grass, and they trolled for the fish from canoes. They exercised close control over fishing sites in their area, trading fishing privileges and offering reciprocal rights to other groups. Before the white man invaded, the Indian population probably consumed one pound of salmon per person on a daily basis—for a total of perhaps 18 million pounds per year—more than is caught today by commercial and sport fishermen. This level of consumption did not destroy fish stocks, for the Indians did not overfish; perhaps they did not have the numbers to do so, but they certainly did not participate in commercial fisheries that inevitably led to pressure to overfish. Nor did they destroy spawning areas by building dams.[49] The effects on the salmon population of the incoming settlers, dams, and pollution were another matter.

The natural wealth of the Pacific Northwest attracted fortune seekers and settlers and drew them into early contact with the Indians, many of whom perished from smallpox and other epidemics. By the time Lewis and Clark traveled down the river, smallpox and malaria had already killed 90 percent of the Indian population on the lower Columbia. Many whites saw the destruction of the Indians as God's will, for they, unlike the Indians, intended to turn the land into productive gardens. To entrepreneurs such as John Jacob Astor, who established the American Fur Company in 1808, Indian suffering mattered little. Extensive missionary activities to convert or displace the Indians accompanied disease and economic exploitation. The newcomers' agricultural settlements—both crop- and cattle-based—spread rapidly through inland valleys after a brief gold rush in the 1850s. Soon, fences and cultivation moved along the Yakima, Walla Walla, and Grand Ronde River valleys. By 1870, settlers and developers had reached the upper Columbia in western Washington, where experimental wheat and barley fields on the high prairies attracted farmers. The harvest of Douglas fir, yellow pine,

and cedar facilitated the clearing of fields. The economic and cultural marginalization of the Indians was all but complete, and it remained only to introduce brute force technologies to transform the Columbia into what Richard White has called an "organic machine."[50]

As in Russia and other places, the railroad in the Pacific Northwest was a crucial ingredient in the pace of settlement. Rails came to the river floodplains in the 1860s and 1870s, and later tracks were laid over the mountains. Railroad owners first conceived of a Pacific Northwest route to join the two coasts. They secured financial backing in the 1880s and set about to build a roadbed, using dynamite to obliterate rock bluffs and tunneling through others. The first railroaders pushed ahead too quickly, building curves too sharp and roadbeds too weak, and much of the construction had to be rebuilt in later decades. The railroads were crucial for portage around the rapids at the Cascades and The Dalles and were important in their own right as an alternative to river transport. Reconstruction of the river itself through brute force technology, with dams and locks and canals, would complete a revolution in transportation.

By the turn of the century, commerce with paper and wood mills stimulated further improvements in railroads and in the river channels and contributed to the creation of a steam shipbuilding industry in the years leading to the Great War. Congressional delegations and businessmen from the region were persistent and successful lobbyists in getting federal funds. They secured funds for a highway at an extravagant (for that time) $48,000 per mile, but the new highway enabled a new industry, tourism, to feed the prosperity of the region. Fifteen thousand automobiles used the highway the first day it opened. Today, the ecology of the region has changed so much that tourists visiting the dams outnumber the fish they come to see swimming upstream to spawn.[51]

The farming, logging, mining, and other activities had a negative effect on the fisheries long before the great dams were erected. As the leading ethnographer of salmon, Anthony Netboy, describes it, these activities changed habitat for fish overnight. Clearing and plowing led to erosion and increased silt loads in rivers and streams. Irrigation in arid areas reduced flows of some streams below levels necessary to support fish. Grazing reduced ground cover. Lumbering activities destroyed land, and frequent and devastating forest fires added to the silt in streams. Sawmills, plywood mills, and pulp and paper mills dumped their waste into streams. Logjams stopped fish migrations. Dredging removed "vital transition zones" for the fish. Road and railroad construction both contributed to erosion and caused the loss of spawning areas as sand and gravel operators removed vast quantities from the rivers.[52]

For businessmen, adventurers, and many settlers, the transformation of the Pacific Northwest into a utopia of economic growth and American democratic ideals was an unavoidable process tied to technological advance. Progressive changes in transportation, from canoe to bateau, flatboat, sailing vessel, and steamboat and thence to railroad and automobile, left no doubt about the promise of the region's future productive capacity. The construction of canals and locks, the removal of rock and reefs, the deepening and straightening of channels, and the engineering of rapids would make the Columbia a major thoroughfare of local, national, and international commerce. Those who were eager to transform the river into a tool amenable to human activities justified their actions as part of the human compunction to improve on nature and engage in economic activities. They insisted that worries about destruction of nature through canals, locks, railroads, and highways were unfounded. In 1917, William Lyman, a biographer of the Columbia River, acknowledged that there might be "an inrush of population with its common place conveniences and contrivances, but it is only just that the world enjoy these scenes, and we have faith that not even civilization can spoil them," for this was a land "abounding in resources and filled to the brim with hope and enthusiasm."[53]

As in Soviet Russia, advocates of progress became convinced that electricity, more than the railroad, was the key to further economic development of the region. Engineers opined that the electric potential of the Columbia River was nearly limitless, and by the 1920s they had proposed nearly 100 sites for dams. Almost no bend in the Columbia River or its tributaries lacked that potential. One such engineer, Carl Edward Magnusson, proposed in 1925 building massive reservoirs "in order that the stream flow may be made more nearly uniform than the monthly precipitation." He called for study throughout the basin to ensure a scientific foundation for site selection. A patriot of his state, Magnusson anticipated the day when Washington would assume its rightful place as the country's leading producer of hydroelectricity. Unlike his Soviet colleagues who ignored transmission lines in their capital cost calculations to keep estimates down, Magnusson acknowledged them as a crucial cost,[54] but this did not dampen his enthusiasm.

Washington engineers, like their Soviet counterparts, spoke about the huge dams in unbounded metaphor. In the new "power age," they wrote, electric energy "serves most of our needs. . . . It brings the radiance of sunshine to our hours of darkness; it gives motion to our machines, waters our deserts, fertilizes our fields and transforms our crops." It would create a new economy that tamed natural resources "on the basis of almost unlimited supply of electrical energy." Products drawn from the earth's core, such as aluminum and cadmium; the farms; space heating; regulated river flow; and a host of other things meant "a new civilization of mankind" based on electricity.[55]

The Columbia, like the Siberian rivers, the Amazon, and the Volga, was indeed a river of superlatives. Its flow was twice that of the Missouri River and ten times that of the Colorado—at least before water interests turned the latter into a trickle by siphoning off much of its flow for agriculture, desert lawns, and industry in Arizona and California. American hydrologists calculated that one-fifth of the world's hydroelectric potential was to be found in North America and one-third of that in the Columbia basin. Before 1933, there was not a single dam on the main stem of the Columbia River, but in the ensuing forty years, thirteen of the world's largest concrete structures would be put up in its path. By 1957, Bonneville, Shasta, McNary, Chief Joseph, Grand Coulee, and The Dalles Dams were on-line. The Pacific Northwest had 28 percent of the country's total hydroelectric capacity, with 115 plants in the Columbia River basin at a capacity of 6 million kW, or 82 percent of the Pacific Northwest total.

The federal government was the only institution in the United States capable of running the gauntlet of landownership, regulation, and capital investment challenges to build massive dams. Progressive Era thinking about the need for national stewardship of forest and water resources provided the context, although progress itself on hydroelectricity was slow. The first federal installation was the Theodore Roosevelt Dam and power plant on the Salt River in Arizona, begun in 1906; in 1920 the total federal capacity nationwide was still only 54,000 kW. By 1930, that had grown to 1.8 million kW, and by 1940, to 6.5 million kW; in the 1950s, 5.5 million kW was added, with another 5.5 million kW under construction. Hydroelectricity, as in the USSR, was therefore large scale state technology.[56] Interestingly, growth rates in hydroelectric capacity in the United States and the USSR mirrored that in the rest of the world. Total world capacity doubled between 1920 and 1930, growing from 18 million kW to 36 million kW, and it had increased by another 50 percent by the eve of World War II.[57]

To build these dams, federal authorities required more than potential and more than the justification of flood control. The crisis of the Great Depression supplied the final push. New Deal enthusiasm, "emergency" economic action through the Public Works Administration and the National Industrial Recovery Act, feasibility studies by the Army

Total Hydroelectric Capacity and Generation in the United States by River Basin, 1957

Drainage Area	Capacity (10^6 kW)	Average Annual Generation (1,000 kWh)
Total United States	26.5	132.5 million
Ohio River basin (includes the Tennessee River)	4.2	18.8 million
Pacific Northwest (includes the Columbia River basin)	7.4	47.6 million
Columbia River basin (includes the following)	6.1	41.9 million
Columbia River (main stem)	4 million	30.8 million
Lewis River	199,000	720,000
Willamette River	393,604	1.5 million
Sandy River	21,000	93,000
John Day River	1,100	3,600
Snake River	434,105	2.8 million
Yakima River	23,130	103,600
Chelan River	48,000	400,000
Spokane River	147,260	1.05 million
Clark Fork River	805,038	4.03 million

Source: Federal Power Commission, *Hydroelectric Power Resources of the United States* (Washington, D.C.: Federal Power Commission, 1957), 1–17.

Corps of Engineers, recognition that grandiose projects had cultural significance in addition to whatever practical value they had, and an ideological contest with the USSR were now all in place. Marc Reisner wrote: "In a slip of time, the mantle of achievement passed from private enterprise to public works. The dams announced that America could still do remarkable things; they also said that the country would never be the same."[58]

In the American East, the Tennessee Valley Authority (TVA), a government-owned utility, was instrumental in advancing public works efforts to improve on nature. One of the most ambitious projects of the New Deal in its overall conception, and one of President Franklin Delano Roosevelt's favorites, TVA built a series of dams to promote flood control, conservation, and agriculture and to bring electricity to thousands of people—especially poor people of Appalachia—at an affordable price. Roosevelt supported federal entry into the utility business, reversing the veto of his predecessor, Herbert Hoover, who opposed efforts to create public utilities such as the Tennessee Valley Authority. On February 2, 1933, the newly elected president announced the formation of the Tennessee Valley Authority to create 200,000 jobs, overriding concerns about "socialism" in the Tennessee River basin. TVA also aided the national defense by establishing government facilities to manufacture nitrate and phosphorus at Muscle Shoals and, later, by providing power for uranium separation plants at Oak Ridge. According to its charter, TVA had the mandate to improve "the economic and social well-being of the people living in said river basin."

Fears of socialism, of state ownership of the means of production, and of Soviet-style communism had delayed the passage of bills and allocation of funds for projects in the Tennessee and Columbia River basins in the 1930s. Many objections were based on free-market, anti–New Deal concerns that downplayed the federal government's potentially positive role in stimulating regional economic development, in distributing income and services more fairly, and in taking on costly or risky ventures the private sector could not or would not. Free-market critics of TVA and the Bonneville Power Administration (BPA) claimed that these projects prevented greater or equal amounts of goods and services from being produced in the private sector by siphoning taxpayers' money—hundreds of millions of dollars—away from factories and jobs, denying Americans "more work and more happiness." They attacked the inherent centralization of the projects for abrogating common law and states' rights.[59] But supporters easily pointed to the contributions of federal hydroelectric projects to navigation, fertilizer, electricity, and flood control purposes, to job creation, to pest control, and to wildlife and fish culture, as well as the recreational, scientific, and training functions of the dams. In fact, as it turned out, the similarities between the Grand Coulee Dam and the Kuibyshev dam were greater than either subsequent defenders or detractors of New Deal public works projects cared to admit. Both promised salvation for agriculture based on rational planning and scientific study; both supported burgeoning war industries; both inundated areas of historical and cultural importance; and both had significant deleterious environmental effects on ecosystems, habitat, flora, fauna, and people.

Kuibyshev Meets Grand Coulee

Modern hydropower stations were not only symbols of America's might. They were above all else the culmination of the vision of engineers and businesspeople to transform nature into an orderly, well-oiled machine. The Army Corps of Engineers reported to Congress as early as 1927 that twenty-one dams might be built on the Columbia River for flood control, electricity, navigation, and, especially, irrigation. Projects to build dams in any number gained impetus from the convergence of meteorological, economic, and political factors. A huge dust storm in April 1931 at Big Bend, Washington, not far from the farming community of Richland, provided the Corps the opportunity to report to the Bureau of Reclamation and the Federal Power Commission that a dam powering a regional irrigation effort would prevent any future dust storm. Many local agricultural, energy, forestry, and other interests opposed the dam, however, fearing higher taxes, loss of land, and little market for the excess electricity produced. The severity of the Great Depression largely derailed opposition, enabling President Roosevelt to gain congressional approval to establish the BPA in order to tame the Columbia. In December 1935, workers poured the first concrete for the Grand Coulee Dam, the flagship of the project, eighty miles west of Spokane, Washington.[60]

When he visited the Grand Coulee construction site two years later, on October 2, 1937, President Roosevelt emphasized that it was jobs and farming as much as electricity and flood control that lay behind the provision of federal money for the project: "There are thousands of families in this country who are not making good because they are trying to farm on poor land, and I look forward to the day when the valley is dammed up to give the first opportunity to these American families who need some good farm land in place of their present farms. They are a splendid class of people, and it is up to us as a Nation to help them to live better than they are living now. So, in a very correct sense, it is a national undertaking and doing a national good."[61]

The Grand Coulee Dam was the Kuibyshev dam, the Tsimliansk reservoir, and the lower Volga irrigation project wrapped into one. According to reclamation engineers, it would irrigate a vast tract of rich desert and dry-farming land in central Washington by spreading water from the reservoir through a series of canals and irrigation channels that covered an area sixty miles east to west and eighty-five miles north to south, bringing "life-giving waters" to more than 1.2 million acres, or 485,600 ha. Mean annual precipitation in the region was roughly eight inches, or about twenty centimeters, with less than half of that falling in the growing season. Soil and climate were suited to temperate zone crops; the Grand Coulee would provide the water. When the Bureau commenced the Grand Coulee irrigation projects, there were hundreds of abandoned farm buildings scattered over the area, "mute reminders of farm families that settled on the land years ago, when a succession of wet years made the area appear to be adapted to dry farming." Settlers, the Bureau assured them, "will benefit from the most comprehensive planning investigations ever undertaken for an irrigation project." The Bureau, the Corps, the U.S. Department of Agriculture, University of Washington agricultural experiment stations, and the state highway and conservation departments all participated in planning studies. The studies determined how many acres a competent farmer needed to earn a suitable living for an average family, what type of farm economy he should embrace, how to develop the land and maintain its productivity, how to transport and market his produce, how much water to use, what kind of financial assistance was available, and so on.[62] The studies provided assurances that American vision and American technology would enable irrigation farming and at the same time support the small family farmer.

In the eastern part and some of the northern parts of the Columbia basin project, livestock fed on alfalfa and other forage crops seemed promising for land use, with perhaps 20 percent of land to be used for cereals and 5 percent for other crops. In regions with lighter soils, 50 percent would be for forage crops, 25 percent for cereals, and 25 percent for fruits, nuts, beets, and potatoes. The studies, the Bureau warned, could not do away with risk, hardship, or long hours of work: the land must be leveled and cleared, and buildings, fences, and irrigation ditches would have to be constructed. But Americans do work hard. The Bureau expected that 50,000 acres would be developed annually in the first few years after the land was opened to irrigation in the late 1930s, and by 1965 or 1970 all the land, millions of acres of it, would be irrigated.[63] The government sought to promote individual small farmers, not corporate farming or speculation. Congress stipulated a maximum number of family-size farm units at noninflated prices and limited the amount of water to which one owner was entitled to that needed for a family-size tract. In the end, by the 1960s, agribusinesses dominated anyway,[64] for over time, laws changed and corporations learned how to manipulate them, and the corporations had the wherewithal to acquire the farms as they came up for sale.

Among its various benefits, the Grand Coulee created the perfect French fry potato. Beginning in the 1950s, low-cost publicly subsidized irrigation water and energy provided by the Bureau of Reclamation (some of the lowest kilowatt-hour rates in the country) enabled rich, arid soil to turn out the highest potato yields in the world. The region's soil and climate are perfect for growing the Burbank russet and similar potato varieties. But this productivity is achieved at no small cost. A few major potato processors located on Washington, Oregon, and Idaho lands irrigated largely with Columbia River water account for 80 percent of frozen potato products in the United States; they use millions of gallons of water a day; and their profligate use of pesticides and fertilizers has contributed to dangerously high nitrate levels in alluvial aquifers.[65] Approximately 8 million acres are under irrigation for all agricultural purposes in the Pacific Northwest (including 1.6 million acres in Washington, 1.9 million in Oregon, and 3.6 million in Idaho). Some 35 million acre-feet of surface water are pumped out for agriculture, and less than 2 percent of total water consumption is for nonagricultural uses. Most farms in the region are large: in Washington, a potato farm averages 227 acres. Fertilizers account for more than 50 percent of potato production costs. Much of the potato itself is wasted; the large processors seeking to produce plain stick French fries throw away, or use as fertilizer or cattle feed, as much as 40 percent of the potato.[66]

Before the farms began production, before the irrigation canals filled with water, the engineers, workers, and government officials gathered to build the Grand Coulee Dam. Grand Coulee technology was simple, if massive.[67] As with other brute force projects, Grand Coulee encompassed not one single technology but scores of them, from the dam itself to turbogenerators, pumps, pipes, canals, electric substations, power lines, and so on. It consisted of construction firms, engineering organizations, universities, and government bureaucracies. By the summer of 1937, as the base of the dam neared completion, more than 7,000 people were at work at Grand Coulee, from engineers to the construction workers themselves. To reach this stage, they had to construct a thirty-mile railroad from the Northern Pacific Railway line at Odair and a thirty-mile power transmission line from the Washington Water Power Company lines near Coulee City, relocate and hard-surface highways, erect a 950 foot steel highway bridge, hang telephone and telegraph systems, and raise two towns for the workers.

At the site itself, the builders poured nearly 12 million cubic yards ($yd.^3$) of concrete, or about 48,000 boxcar loads. The cement was produced at five modern cement plants with electric controls for blending the mix, shipped in bulk in boxcars, unloaded through hoses and pipelines by pumps, and stored in eleven steel silos with a capacity of 55,000 barrels. During construction of the base of the dam, the cement pipeline crossed the river on a suspension bridge, which also carried a conveyor belt supplying sand and gravel to a mixing plant. The engineers transferred the concrete to four-yard bottom-dumping buckets. Diesel-electric locomotives weighing ten tons hauled the buckets to huge cranes with a reach of 115 feet.[68]

The Grand Coulee Dam was also a series of settlements. On the eastern side of the river, the contractors built Mason City, a temporary city with a large mess hall, office buildings, a hospital, a hotel, a laundry, churches and schools, 280 residences, and sixty bunkhouses to accommodate more than 1,200 workers. The government village, known locally as Engineers' Town, separated the workers from their masters, the engineers and managers. The engineers, government employees, and senior contractors were blessed with indoor plumbing and shade trees. They lived in mass-produced but very pleasant houses designated by letter grades that indicated their—and their inhabitants'—stature. "Dry laws" kept the engineers sober. The "working stiffs" lived in Grand Coulee, a town that had all the features of Hollywood's Wild West: gambling, prostitution, murder, and syphilis. The workers lived in boarding houses, tents, cars, caves, and the boxes in which supplies for the project—including pianos for the managers and engineers—were shipped.[69] The government paid Woody Guthrie $3,200 to write and perform serenades to the dam. For thirty days, he and his government chauffeur drove up and down the river between Grand Coulee and Bonneville while he wrote lyrics for twenty-six songs, none of them referring to syphilis.

On its completion in 1942, the Grand Coulee Dam, at a height of 550 feet and a length of 4,173 feet, was, the Bureau of Reclamation proclaimed, "the largest man-made structure in the world." Power plant capacity was 1,890,000 kW, with Westinghouse generators rated at 117,000 kW. Maximum annual output was 8.3 billion kWh, with another 2.3 billion kWh for irrigation. Until the Kuibyshev dam was built, it had the highest electric energy capacity in the world. At each side of the 1,650 foot centrally located spillway section was a powerhouse and abutment section, each more than 1,000 feet long. The Grand Coulee Dam is a straight-gravity type dam, depending entirely on the weight of the structure to resist the pressure of water behind it. It transforms water into electricity through sixty 8.5 foot gate-controlled outlet tunnels with a combined length of 2.5 miles, carrying 253,000 cubic feet (ft.^{3}) per second. The average annual rate of flow of the Columbia River would fill the reservoir in about two months, but the flow in June or July would fill it in less than one month. Silt from the Columbia is extremely fine, and practically all of it is carried in permanent suspension, so engineers expected the silt to have no detrimental effect on the reservoir, and they have been correct in this estimation. The dam's base is 500 feet wide, covering thirty acres, and 30 feet wide at the crest, covered with a highway. Jackhammers and dynamite moved a million yards of rock to make a firm, clean footing for the dam. In all, workers excavated 19 million yd.^{3} of earth for the dam and 25 yd.^{3} of sand and gravel for the concrete.

The Grand Coulee's reservoir is fifty-one miles long and averages 4,000 feet in width, with a maximum depth of 375 feet, and extends up the Columbia River toward the Canadian border. It has a total area of 128 square miles and a capacity of 10 million acre-feet of water. The dam eliminated 1,100 linear miles of salmon spawning grounds, mostly in British Columbia, by flooding and stilling the waters.[70] No one questioned whether land was more valuable than salmon, for there were too many superlatives associated with the dam.

In addition to Grand Coulee and the eleven other major Columbia River structures, there are scores of other dams in the Columbia River basin. They do provide cheap electricity year-round, turn desert into farmland, regulate floods, and create jobs in the aluminum, logging, and nuclear industries. The calculations the government made about the river itself—about its volume flow, turbidity, silt, and temperature, on the basis of which they built the dam—were quite close to the mark.

But the river, any river, is more than water molecules. In altering the river on such a scale, the engineers altered human culture and history and flora and fauna, underestimating or ignoring their value, for history and culture cannot be quantified. They did not calculate the cost of destruction of local history, geophysical monuments, and fish. Dams displaced thousands of people along the Columbia. Eleven towns large enough to have post offices disappeared under reservoir water. The dams destroyed the Indians' burial grounds and their chinook salmon runs at Kettle Falls, which had been protected by treaty. Kettle Falls and its rapids also vanished so that no water would be "wasted." There were no more obstacles to navigation or farming, nor to progress and democracy. Salmon have no right to vote, and the question is whether new home appliances, plutonium, and potatoes are worth destruction of river ecology.

Nuclear Salmon

On the eve of the New Deal dam construction projects, several observers noted the human influence on the coveted salmon population. Once there had been "hordes" of chinook (king), sockeye (red), silver (coho), dog, and humpback (pink) salmon fighting their way upriver past natural and human-made obstacles. The Indians had speared and netted them. Later, sportsmen shot them with rifles and pistols, beat them with clubs, hooked them with gaffs, even dynamited them, and trapped them for canneries. People learned the species' spawning and life cycles in order to maximize, but in no way to moderate, their rapacious harvest. When settlers first reached the upper Columbia River, they observed that royal chinook salmon ascended as far as Windermere Lake in British Columbia. By the 1920s, they were rarely seen above Kettle Falls, 100 miles downstream.

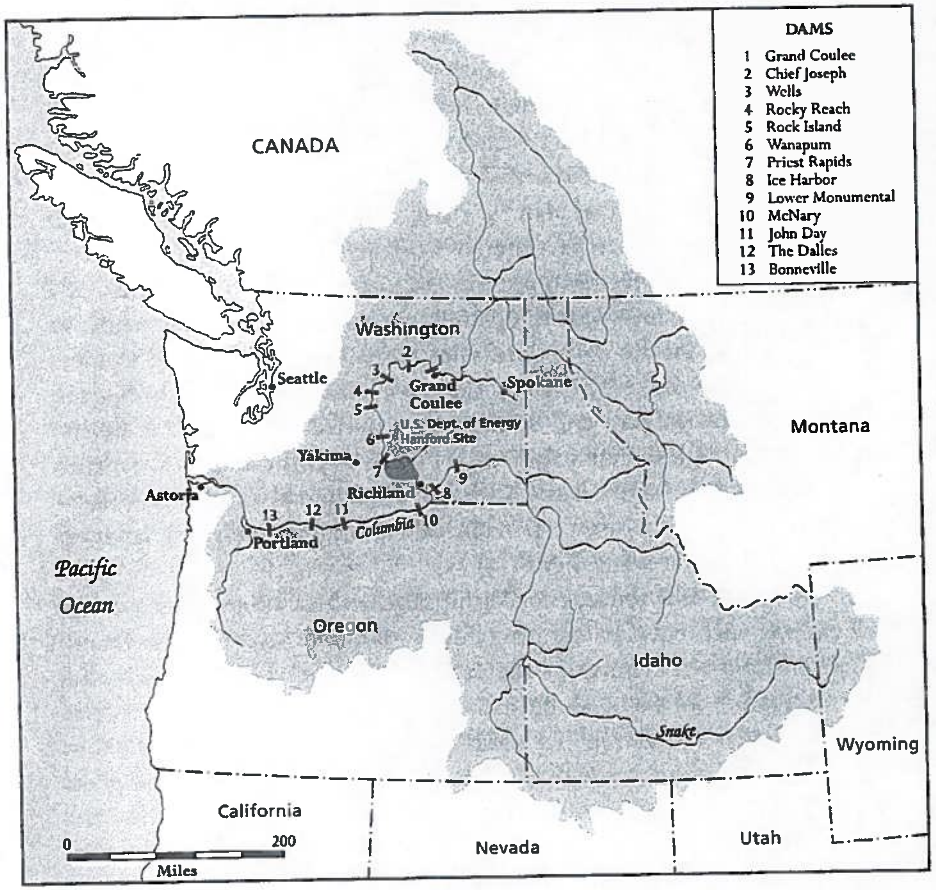
Even before the building of the great dams, technological change had given the fish little chance: steam engines had replaced oars and sails in fleets, mechanized seiners had supplemented gillnetters, internal combustion engines had replaced steam engines, and mechanized canneries had replaced manual ones. First, more efficient harvesting technology took a toll. The fisheries took salmon when they were still "fresh and unmarred," at the start of the upstream migration, before they had weakened or had been bruised and discolored, but also before they had spawned. The first businesses used fish wheels, erected on shores or on movable scows, with wire mesh arms that revolved with the current, intercepting the fish and scooping them onto platforms. A single large fish wheel might harvest eight tons in one day. These so decimated the fish population that they were outlawed in the 1930s. Fish traps and gill nets, which were pulled ashore by horses, augmented the wheels. By midcentury, a huge canning, packing, and shipping industry had developed. In 1873, there were eight canneries on the Columbia. By 1883, there were fifty-five canneries at Astoria, some as far upstream as The Dalles, that packed 630,000 cases, roughly 43 million pounds, mostly of chinook. The "mechanical chink," a racist reference to a new canning device that replaced Asian laborers to fill, seal, and label cans automatically, put additional pressure on the fisheries.[71] Gasoline boats that used drift gill nets and seines took to trolling in the open sea with hook and line techniques. Commercial fishing was without limit, and by World War I, many runs were "showing signs of exhaustion."[72] Only twenty-one canneries remained on the Columbia, mostly in Astoria, in 1921. To prevent complete annihilation of the fish stock, the states began to regulate the fisheries in various ways: postponing the time of the catch,

controlling the methods and equipment, and limiting the amount. But the agencies responsible for regulation rarely had the personnel or budgets to enforce laws, and they had to watch the catch decline as the fish did.[73]

In the concrete visions of the Army Corps of Engineers, the salmon had little importance. The original design of the Grand Coulee Dam in fact had no provisions for anadromous fish (those that migrate upstream to spawn). Only after public consternation on the part of ichthyologists and local fishing interests were fish ladders, locks, elevators, and bypass canals included in the final plan for the dam. At first, the salmon largely figured out how to move past the coffer dams to spawning areas, with 1 million salmon and steelhead passing upstream in 1938. Once construction of the big dams was completed, fewer and fewer fish made it upstream. By 1942, the number of salmon making it past Grand Coulee had dwindled to 625,000. Clearly, there was sizable mortality of fingerlings going downstream and adults going upstream. But the numbers were good enough for the engineers who asked, If the ladders work this well, why not build more dams? By 1947, dams and associated construction had destroyed about 40 percent of the original spawning areas of the Columbia River watershed.

In the 1950s and 1960s, the Washington and Oregon congressional delegations succeeded in securing funds to build several more dams, which ensured the demise of the salmon. The power, industrial, and river navigation interests, along with local chambers of commerce, lobbied with their delegations for more dams. General Claude H. Chorpening, chief of the Army Corps of Engineers, testified before Congress that, judging by the success of Bonneville Dam, there would be no difficulty in getting fish beyond other dams the Corps intended to build, even though there were losses of at least 15 percent at Bonneville. But how could salmon climb 88 feet at The Dalles, 132 feet at John Day, 100 feet at McNary (finished in 1953), 100 feet at Ice Harbor (1961), 93 feet at Lower Monumental (1969), 100 feet at Little Goose, and 82 feet at Lower Granite (1973)?[74]

Fishways had been around for nearly 300 years when scientists set to moving the salmon beyond Bonneville, and the scientists hesitated to admit that they poorly understood how to build them. A fish ladder, the most common type of fishway, is merely a series of concrete steps over



which dam water flows. Elevators and locks have also been used. But construction in and around river basins occurred so rapidly during eighteenth- and nineteenth-century settlement and industrialization that fishways were often an afterthought—in many cases after industrial development had already interfered with or destroyed large populations of migrating fish. Specialists remained convinced that fishways based on scientific research and management would help preserve and even increase species that had survived, especially since creation of the legal framework to ensure obstruction-free passage or to require fishways for migrating fish had become standard in many countries by the mid-twentieth century. Shockingly, by 1940 there appears to have been only one study that considered the actual performance of fish in relation to a number of different fishways, and this study was limited to fish that were native to streams of Iowa.[75]

Engineers designed dams with fishways, but a Canadian fisheries specialist acknowledged that their approach to developing them was "haphazard" and that "progress was slow." On Bonneville Dam in 1937–1938, he noted that "perhaps for the first time, sufficiently large numbers of salmon were involved to warrant large expenditures on designs incorporating the latest ideas of experienced engineers and fisheries biologists." The design employed such new principles as large quantities of pouring water ("attraction water") to attract the fish to upstream entrances away from spillways and powerhouse effluent. Bonneville Dam also incorporated fish locks. The U.S. Fish and Wildlife Service reported that the effort was not entirely successful, with only one-sixth of the annual run making it past the dam in 1948.[76]

Experience at Bonneville Dam led to increasing awareness of the complex nature of fish passage problems and eventually to basic research on the problem of downstream passage over dams as well as the efficiency of facilities for moving fish upstream. Only then did scientists ask certain basic questions: What are the hydraulics of fishways? What are the mechanics of swimming fish? How must spillways be designed and their flow regulated to encourage fish to enter fishways? What influence do eddies, boils, and upwellings have on migration? They recognized that careful study was not enough. Provision of fishways did not "insure the continued existence at their original level of abundance of the migratory fish for which the facilities were designed." This was because dams changed the physical characteristics of the river: water temperatures, normal patterns of seasonal flow, settling of silt above the dam, levels of oxygen and nitrogen. So a fishway is only a partial solution to one of many problems created by dam technology. No matter the effort, design flaws seemed to be the rule, for, the specialist concluded, "actual counts in the Bonneville fishways failed to reach the totals assumed."[77]

Belatedly, it became clear that fish passage facilities did not ensure the livelihood of the fish. With changes they caused in water temperature, oxygen and nitrogen loads, and seasonal flow patterns, the dams effectively prevented natural behavior, and humans were incapable of overcoming human-made problems. In the 1960s and especially in the 1970s, after passage of the National Environmental Policy Act of 1969, those same fans of dams, now pushed and harassed by environmentalists, fish scientists, and various Indian nations, asked for funds for fishery development, including artificial propagation; removal of stream obstructions such as logjams, waterfalls, and small, abandoned dams; construction of fishways; and establishment of fish refuges. The fish ladders at these facilities cost approximately $0.5 billion, but this did not prevent an estimated $6.5 billion loss of fish between 1960 and 1980. To keep the fish from passing through turbines downstream, dam operators have covered the intakes with plastic screen to shunt the fish to a juvenile collection, a holding and transportation facility, and a system of pipes, tanks, and vats to enable anadromous behavior, leading to expensive and surreal carting by truck, barge, or airplane. Of the fish that manage to pass through turbines, few survive. For example, those that get beyond Ice Harbor Dam on the Snake River, ten miles before its confluence with the Columbia River, are so disoriented or exhausted that they are easy prey for birds and other fish. Moving through water that is placid and warmer than normal by as much as 4 degrees Fahrenheit (2.2 degrees Celsius), salmon prematurely begin their transformation to saltwater physiology or, once again, fall prey to predators. The water also carries more nitrogen and less oxygen. Gone is the Columbia, gone are the rapids, gone are the netsmen and the Indians; gone, essentially, are the salmon.[78]

The effect of expanded hatchery facilities that raise and then release upstream from the dams millions of fingerlings and smolts has been minimal. Scientists at the Idaho National Engineering and Environmental Laboratory, those same folks who developed reactors for electric energy production and nuclear airplanes, apparently wanted to contribute more than nuclear technology to society. They came up with the idea for a flexible 350 mile Kevlar fish tube eight feet in diameter, with a estimated cost of $1.4 billion, to bypass the dams entirely. But this project, abandoned as too costly, would have been a losing battle. Because of changes in water chemistry, speed, and other characteristics, Idaho rivers will not support salmon in spite of "enormous hatchery releases." For example, in 1983, 3 million smolts were introduced, but only 2,000 adults returned to spawn. To figure out what is going on in such a situation, fish managers inject the smolts with a passive integrated transponder, a computer chip the size of a rice grain that lodges in the salmon's belly and enables high-tech tracking, sorting, and study. The Army Corps of Engineers produces millions of salmon annually in its hatcheries. Today's salmon travel in style, but transponder or not, the number of fish getting upstream declines almost every year.[79]

Another plight of the salmon is in fact connected with nuclear scientists working at another brute force technology along the Columbia River, the Hanford Atomic Reservation. Cheap, plentiful hydroelectricity, as in the Amazon and Siberia, copious amounts of water, and the seclusion of the desert made the region of the Columbia River near Richland, Washington, appropriate for Hanford. Just as with the dams themselves, the nuclear enterprise developed on the foundation of scientific uncertainty even as the engineers assured the public that their activities were safe, effective, and predictable.

In December 1942, Lieutenant Colonel Franklin Matthias scouted eastern Washington for an area suitable for construction of plutonium production reactors. His requirements were secrecy, space, and water. His superior, the head of the atomic bomb's Manhattan Project, General Leslie R. Groves, had first considered the Argonne Forest, just outside Chicago, and Oak Ridge, Tennessee, as locations. Since physicists were not yet clear about the risks of plutonium production, the former location was eliminated because it was so close to a major metropolitan area; the latter's weak point was that the TVA dams near Oak Ridge produced electricity that was largely spoken for in uranium separation, aluminum production, and other purposes. When Matthias flew over Hanford, an area of 0.5 million acres and only about 2,000 people, he knew he had found the right spot. The Columbia River provided all the water needed, and the Grand Coulee Dam supplied the electricity through 20,000 kilovolt (kV) lines. There were few roads and no railroad to bring curiosity seekers.[80]

When the Army Corps of Engineers selected Hanford for the production of plutonium, the agency gave thirty days' notice to local fruit growers and farmers to get out. The Corps bought up 600 square miles of land and sealed it off behind barbed wire and armed guards. Over the years, the Hanford facility produced the plutonium for thousands of nuclear weapons, including Fat Man, the bomb used on Nagasaki, Japan, in August 1945. Hanford accepts scrapped submarine reactors, barged up the Columbia from Puget Sound Naval Shipyard, a disposal process far superior to the Soviet practice of dumping reactor carcasses in the Arctic Ocean. That is small consolation to living things. The radioactive waste began to leach within a few years, not the 180 years the engineers had assured everyone it would take.

How would the river and salmon fare? The Army Corps of Engineers and contractors built Hanford in record time during the war; they believed they had to do so to beat German physicists to the bomb. True, they worried about some aspects of safety. The reactors and separation facilities had extensive shielding to protect the workers from radioactivity. But they designed some of the reactors to take cooling water directly from the Columbia and then send it, warmer and with some radioactive additions, back into the river (a "single pass" process). The U.S. government closed the last single pass reactor only in 1971. To deal with the heightened levels of radioactivity in the water, the engineers decided to dilute it and hold it temporarily in ponds, to allow the radionuclides with short half-lives to decay, and then release the water back into the Columbia. The releases were premature, however, for the levels of radiation remained high. Compounding the problem, they buried the highly radioactive waste, it turns out, haphazardly. This included billions of gallons of contaminated radioactive sludge stored in sandy soil, some of it only 100 yards from the Columbia River. General Groves claims that army personnel told him Hanford would not harm a single salmon, and he was convinced this was the case. Yet almost immediately after it was built, officials testing the river downstream from Hanford found water—and the fish in it—carrying high levels of radioactivity. Some of

the very same water was used to irrigate fields of alfalfa, lima beans, potatoes, and corn. There have been cancers and birth defects among the Washington residents who live downwind and downstream at rates significantly higher than those for the rest of the population. The government never issued a public health warning, and only recently has the Department of Energy declassified data indicating the extent of this severe public health problem. In any event, the cooling water effluent raised the temperature of the Columbia River by 2 degrees Fahrenheit, giving the salmon another obstacle with which to contend.[81]

Salmon and other living creatures in the area ran up against perhaps the most dangerous, most highly polluting human activity, the production of nuclear weapons. It requires separation of various radioactive isotopes and the use of acids to remove metal cladding from fuel rods. It creates millions of gallons and tens of thousands of tons of low- and high-level radioactive waste that remains lethal for tens of thousands of years. At Hanford, the PUREX (plutonium uranium extraction) facility is the major culprit. Hanford engineers built huge concrete canyons at PUREX for the acid baths and isotope separation. To produce 1 kilogram of plutonium, they generated 2.5 million gallons of wastewater for evaporation ponds, 55,000 gallons of low- to mid-level waste for dirt trenches, and 340 gallons of high-level waste destined for underground steel tanks, some of which almost immediately sprang considerable leaks. A PUREX accident in September 1963 released four to five times more iodine 131 than did the partial meltdown at the Three Mile Island facility. Only in 1990 were data about exposures declassified to enable studies of illness and death rates. According to one estimate, 200 workers have died or will die from cancer as a result of exposure to low levels of radiation.[82]

Documents from the Atomic Energy Commission, E. I. du Pont de Nemours and Company, and General Electric reveal that officials had worried since the 1950s about the release of radionuclides in the Columbia River. Local residents—eventually called "downwinders," like their compatriots downwind of the Nevada nuclear weapons test site—were exposed to radiation in water, fruit, vegetables, and fish. Over time, some residents noticed that more and more of their number seemed disproportionately afflicted with various diseases, including cancer. Then they learned that late in 1949 the Hanford managers had intentionally released radioactivity into the atmosphere in the so-called green run. The purpose of the release was to provide a baseline for analyzing traces of radioactive isotopes from Soviet facilities picked up in atmospheric samples. The samples would enable scientists to gauge the direction of the USSR's weapons programs. Because of the weather patterns during the green-run release, the radioactivity spread much farther than managers had anticipated, exposing tens of thousands of Americans downwind of Hanford. But to them it seemed a small cost to pay for national security, and they convinced themselves the exposures were at safe levels.[83]

When exposure hit home—the engineers themselves rather than the fish or downwinders—there was higher concern. An engineer at Hanford was accidentally exposed to a relatively large radiation release. A married man, he wished to know the consequences for his reproductive choices. The Atomic Energy Commission enlisted prisoners at Oregon and Washington State penitentiaries in a study of the effects of testicular radiation on spermatogenesis. Doctors took multiple biopsies of testicular tissue and then vasectomized the subjects. The results showed that reproduction would be possible for the engineer, but not so for the vasectomized prisoners. These experiments, carried out over eight years, eventually led enlightened medical personnel to conclude that prisoners ipso facto cannot give informed consent for their participation in such studies, for they are already coerced by their incarceration.[84]

Recent studies indicate that salmon and people exposed to radiation in less dramatic fashion also suffer serious health consequences. In the 1990s, after the cold war ended, the federal government finally supported studies of the amount and types of radiation to which people were exposed during the four decades when Hanford produced plutonium. Indians may have eaten more fish than others living in the area, and they prepared it in such a way that their radiation exposure was increased. Initial studies assumed that Indians ate about 90 pounds of fish annually. In fact, as Lewis and Clark had discovered, the amount was much higher, perhaps 1.5 pounds daily.[85] Hanford and Grand Coulee will continue to affect Indians for decades to come.

For the salmon, worst of all were not so much the radiation effects but the dams and irrigation systems. Many of these were the smaller dams put up by private utility companies without ladders or other fishways. Dams built by the Army Corps of Engineers put an end to the fisheries as the salmon knew them. Anthony Netboy has described in disturbing detail the effects of the "megalithic dams" on the salmon migrations; the initial hesitance of designers to include fish ladders, so as not to be "nursemaids" to the fish; the challenges of building ladders that induced salmon to go upstream beyond the Bonneville Dam, which required them to climb 70 feet; the use of locks and elevators to lift salmon, shad, and sturgeon; and the dangers to the fingerlings going downstream of the crushing spillway waters or through the turbine blades. When it came to Grand Coulee, at 550 feet, the salmon could no longer reach their spawning grounds. So biologists tried catching salmon and relocating them to holding ponds and incubators at three new hatcheries. The program was not successful. Studies showing the dams' destructive effect on salmon populations, however, did not diminish the enthusiasm of the builders or the certainty of many fish scientists that they might somehow keep the fisheries going as before the dams.[86]

The Legacy of Hydropower Envy

When asked to think about state-sponsored big science of the 1950s and 1960s, most people envision space and nuclear technologies. But the postwar decades were also an era of hydropower projects larger than those imagined only fifteen years earlier, when the first wave of giant dams were built in the United States and the USSR. In the United States, construction accelerated on the Columbia River in the 1950s and continued in the Tennessee River basin. In the USSR, on the Siberian rivers Ob, Lena, Angara, and Enisei, engineers commenced design and construction of what would become the world's largest stations; in Gamal Abdel Nasser's Egypt, the Aswan High Dam was built. Only later did the project engineers recognize that the dams had colossal negative effects and that their understanding of hydrology, ichthyology, and geology was incomplete at best. From the start, local organizations and citizens fought hydropower, from the Tennessee River valley to the Angara River in Siberia and from the Alta River in Norway to the forests of Brazil, but they were powerless against the forces of industry and defense and the ideology of modernization and progress.[87]

Like their Soviet counterparts, American engineers and politicians recognized the symbolic meaning of large scale technologies, especially in competition with the USSR for supremacy in ideological jousting. Franklin D. Roosevelt pushed the Grand Coulee Dam to remind the public of America's great economic and scientific potential, not just to put thousands of people back to work. There was no difference between getting Woody Guthrie to pen songs about the Columbia and getting writers in the USSR such as Maksim Gorky to glorify water projects through their prose. Employees of the Bureau of Reclamation at the Grand Coulee visitors' center have long touted American engineering authority when describing the dam's majesty, size, and power, with numbing numerical chapter and verse.[88]

Like their American counterparts, Soviet planners and engineers justified their transformationist visions by pointing to dedicated workers toiling for socialism and to nature channeled to operate according to plan. Similar to U.S. efforts on the Columbia, the Stalinist plan for nature transformation involved geological engineering to maximize productive capabilities on a scale never before imagined. Visionaries proposed turning nature itself, its lakes, ponds, rivers, forests, and plains, into a giant factory. Stalin insisted that all natural "aberrations" from the planned norms be eliminated. A centrally managed, unitary system would cover the socialist countryside. One Soviet scholar asserted that complete mastery of nature was simply impossible under capitalism. A socialist order was required to ensure "complex rational utilization of resources." The anarchic distribution of property and monopolies under capitalism, he explained, interfered with large scale transformation of nature.[89]

Soviet engineers and planners embraced universal practices in industrial design intended to minimize risk, economize on materials, and maximize the immediate utility of natural resources. These practices resulted in proletarian aesthetics. Put simply, Soviet engineers developed a technological style noteworthy for bland, functional designs in which safety and comfort played a secondary role and in which environmental issues were only belatedly a concern. Soviet engineers, perhaps like many engineers throughout the world, had come to believe that what they designed was inherently safe or perfectible. They viewed public involvement in decisions about whether to proceed with the diffusion of a new technology as at best a necessary evil; as for the environment, it

was simply something to be managed. Almost without exception, hydrologists, limnologists, geophysicists, and others—so-called engineers of nature—who studied virtually every aspect of Soviet natural resources read conservation as "intensive utilization."[90]

Proletarian aesthetics reflected the primacy of state programs for resource development over local, historical, and ecological concerns. The United States was not immune to proletarian aesthetics—the spirit of each dam remains the same even when the architecture is different. The essential sameness of the Columbia River dams—the way they were built, the speed with which they were built, the joy of the engineers over how much concrete they poured, the uniformity of their negative effects on the environment, and the typical addition of fishways as an afterthought—reflects the primacy of the interests of engineering organizations and big businesses over the long-term concerns of salmon, Indians, downwinders, and indeed all of us. The Army Corps of Engineers, the Bureau of Reclamation, and the contractors and utilities who worked with them in the Columbia River basin strove to put standardized technologies in use as early as practicable. They also viewed nature in mechanistic terms, perhaps as an "organic machine," when they applied their knowledge to the control of nature.[91] And before environmental impact statements were required, they built dams and canals rapidly; seemingly no obstacle other than the occasional shortage of capital stood in the way of dam construction on the Columbia.

Soviet plans never lacked enthusiasm for the belief that engineers could improve on nature's gifts. They assumed they could take advantage of the unanticipated payoffs of their hubris. But though unbounded designs on nature had their birth under Stalin, they grew to epic proportions after Stalin's death and the rebirth of constructivist visions for the communist future under Khrushchev and Brezhnev. In the absence of market forces, which might have damned fiscally and environmentally expensive projects, and vocal public opposition, which might have drawn attention to those costs, the engineering organizations responsible for water melioration projects in the USSR seemed only to gain in hubris. In each year of Soviet power, the quantity of manipulated water increased, from 70 billion m^3 in 1937 to 125 billion in 1957 and to 450 billion by 1967. Said one Soviet writer, "To possess such great volume of controlled water means to be able to eliminate desert, decisively change climate just like that, and forever be done with poor harvests."[92]

The technologies of the Army Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration have national mystique. Rarely did opposition to these projects materialize, and once the projects commenced, opposition, especially at the local level, was powerless. The language of Corps directors and publicists demonstrated the agency's omnipotence. There would be "no slackening," and there ought to be "optimum development" of "basin wide" and "project oriented" goals.[93] The dams were symbols of the New Deal rebuilding of America. Through the Rural Electrification Administration, they would bring electricity to the poor, enabling them to purchase modern conveniences, including illumination. Cheap electricity, it was said, demonstrated that democracy worked well, for the common man and woman had indeed secured a path out of the Great Depression.

The large scale approach to large scale problems requires large scale surveying, engineering, and construction organizations. In the United States, a series of fortuitous political and economic factors came together in the twentieth century to give the Army Corps of Engineers and Bureau of Reclamation seemingly unlimited power in their efforts to build canals, dams, and irrigation systems across the American West. The Central Valley Project in California (to replace groundwater "pumped relentlessly" out of the Sacramento and San Joaquin River valleys with river water brought in by canal), the proposed Klamath Diversion (wherein engineers imagined reversing the flow of the Klamath River, the second largest river in California, in order to get the water to Los Angeles, hundreds of miles away), and the damming of the Columbia required billions of dollars, hundreds of thousands of workers, and tens of thousands of managers. Melded together by a belief that humans ought to improve on nature, these organizations brooked no obstacles and searched out new projects as older ones neared completion.[94]

Similarly, the large scale, centrally planned projects that were paradigmatic for the USSR were characterized by technological momentum. They grew from Stalin-era efforts to force the pace of industrialization, carried out by construction and industrial trusts with a relatively narrow profile, into megaprojects that left, literally, no stone unturned. The experience at DneproGES, Magnitogorsk, and the Moscow metro foreshadowed the technological momentum the Volga basin development projects would acquire. For example, crews totaling 70,000 workers and 5,000 engineers from Dneprostroi, Magnitostroi, and the Kuzbass coal combine joined together to build the Moscow subway. Bratskgesstroi, formed in 1954 to tame the Angara River in central Siberia, had 6,000 employees by 1955 and 35,000 by 1961, by which time the town where most of its workers lived had grown to 51,000. Hundreds of Soviet organizations responsible for the scientific, design, and construction activities surrounding transformationist projects acquired technological momentum seemingly greater than that of, say, the Army Corps of Engineers or the Tennessee Valley Authority in the United States.[95]

The Soviet system gave impetus to questionable projects through the need to keep workers who were employed by construction trusts somehow occupied in the towns built to house them for the initial project. In part, this led Soviet engineers of the late 1950s to calculate the potential energy of the 1,500 largest rivers of the USSR at an impressive 300,000 MW. Engineering organizations thus proposed building another 1,800 hydroelectric stations, with perhaps another 20,000 small hydropower stations for electrification of agriculture. Under Khrushchev and Brezhnev, they turned to the Siberian rivers with a vengeance.

Was the American system any better? Did it consider the social costs of brute force technology? Planners of the Columbia River projects either assumed the workers would migrate to jobs elsewhere or conveniently ignored relocation costs, including those of social displacement. What happened to the crews of the Grand Coulee Dam after construction ceased? And what of the town of Grand Coulee, the headquarters for construction activities, Electric City, and Coulee Dam, towns of several thousand people? There had been a boom in these towns for eighteen years, until 1950, and then a 50 percent decline in population over three years. The trade and service outlets were twice what the towns' purchasing power could justify. Carrying out economic rehabilitation through federal aid would have been the just thing to do, but demolishing the towns or selling them off to the private sector, letting the workers fend for themselves in search of uncertain jobs, was the American way. The Bureau of Reclamation had failed to answer its assigned question: What was the "rational, long-range" economic basis to which investment values and population could reasonably adjust so that "institutions of local government and property ownership" would fall "into patterns more nearly harmonic with the values of American life"? Nature improvement, not environmental study or social costs, was its concern. The Bureau's final recommendations were to make the towns self-governing municipalities, transfer all private use buildings and land to private ownership, give title to highways to the state of Washington, and provide some funds to utilities and municipal facilities but not to individuals for permanent housing.[96] Let the workers and salmon look out for themselves.

The cascades of hydropower stations and irrigation systems on the Volga and Columbia Rivers required extensive capital investment, unbounded organizational reach, and scientific certainty. They required a vision of nature that was at once utopian and utilitarian. The former came from the belief that nature ought to be controlled—indeed, could be controlled—through the melding of scientific study, large scale technology, and appropriate government structures. The utilitarian aspect grew out of colu war competition between the United States and the Soviet Union to build eternal artifacts of capitalist and socialist culture. They also came from a deeply ingrained belief among specialists in both countries that water had an obligation to humanity, indeed a moral duty, to fulfill many missions before it flowed wastefully into the sea. A stream, a brook, a river all had a "duty"—a strictly quantifiable term—to irrigate the land and to produce electricity.[97] Vision, power, and funding hence enabled the transformation of nature, but at great human and environmental costs.

In *Farewell to Matyora*, Siberian writer Valentin Rasputin describes an island town in the middle of a turbulent river whose residents must pack up and move away. The waters beyond a newly completed hydropower station will soon cover the island, obliterating their homes, land, businesses, churches, schools, and memories. They must move to mass-produced prefabricated boxes—apartments—typical of the Soviet era. Matyora is fictional, but the dams and rivers are not. *Farewell to Matyora* could describe the human consequences of the Grand Coulee Dam just as well as those of the Kuibyshev and later stations. How much longer must we say farewell to nature itself?