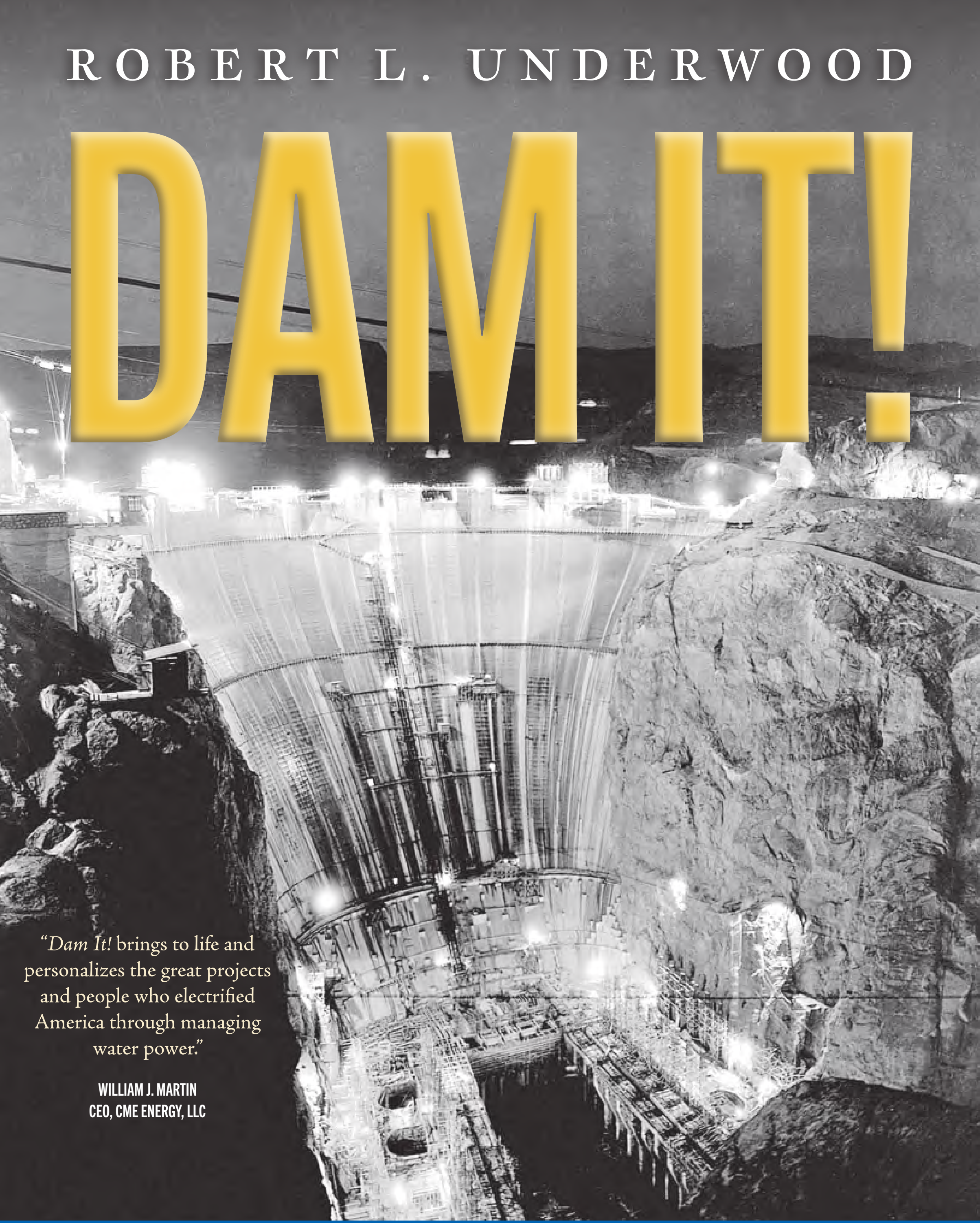
ROBERT L. UNDERWOOD

DAM IT!



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"Drawing effectively on family connections to the dams that have electrified America, the lively prose and extensive illustrations of this book make it a valuable contribution to the history of dams and hydroelectricity."

-Christopher F. Jones, Author of
Routes of Power: Energy and Modern America

DAM IT!

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Electrifying America and Taming Her Waterways

ROBERT L. UNDERWOOD

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In loving memory of my grandfather, George P. Jessup:
"A dam engineer and proud of it."

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Introduction

We live in an electrified world—a world where electricity is a readily available commodity that we take for granted. Electricity powers our lives. We can plug in anywhere, anytime and know we will receive the power needed for our lights, our hair dryer, our phone, our television, and other daily necessities.

This wasn't always so. Scientists experimented with electricity as early as the 1700s, but it was Thomas Edison's demonstration of the first commercially viable electric light bulb in 1879 that liberated society from near-total dependence on daylight and spawned the use of electricity in almost every aspect of our lives today. In fact, the electric light usually is ranked among the innovations that most have changed history, right up there with the wheel, the printing press, and the steam engine.

Edison's discovery launched the race to electrify America. Electrification drove the American economy from 1900–30. Electric utilities and their suppliers utilized more capital than any other industry. By the early 1930s, seventy percent of homes in the United States had electricity.

Tapping the water in our rivers has been an integral part of generating the electric power that America needs. The mechanical power of falling water is an age-old tool. Dams had been used extensively to tame rivers for flood control, to create reservoirs to store drinking and irrigation water, and to generate mechanical power via water wheels. It was only natural that dammed water be used to generate electricity. And used it was as the electric power industry exploded.

Both the mechanical power of water and the other major energy source for electricity generation—steam produced by burning coal—converted their energy into electrical current by driving spinning turbines. Where rivers and streams could be tapped, waterpower was the cheaper energy source. By 1940, more than fifteen hundred hydroelectric facilities produced about one third of America's electrical energy.

The story of the evolution of hydroelectric power rivals that of any transformational technology we have seen arise from Silicon Valley. Eccentric inventors, financial wheeling and dealing, political intrigue, mind-boggling engineering and construction feats, inspiring personal stories … it's all here.

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Chapter Seven

A Dream Come True

Dreams really can come true. One did for the residents of Keokuk, Iowa, in 1913.

Keokuk is located on the Mississippi River at its junction with the Des Moines River, about 175 miles upriver from St. Louis. The Des Moines River forms the border between Iowa and Missouri there. The town is named for Chief Keokuk, noted leader of the Native American Sauk tribe.

The Mississippi River is America's premier river, flowing 2,300 miles from its headwaters in Minnesota above Minneapolis to the Gulf of Mexico below New Orleans. It was the country's western border until Jefferson's Louisiana Purchase in 1803. It always has been a vital transportation artery. An 11-mile stretch of rapids above Keokuk became a serious obstacle as commercial river traffic grew in the 1800s. The rapids disrupted travel and limited access to lead mined at Galena, Illinois, and lumber from northern forests. Loaded steamboats often were delayed, frequently were damaged, and sometimes sank when transiting the shallow waters and strong currents. Soon the practice of lightering began: cargo was moved from steamboats onto small boats for passage through the rapids.

In 1837, the Army Corps of Engineers dispatched young lieutenant Robert E. Lee to chart and tame the rapids. Lee and his crew spent the next three summers attempting to cut a channel through the rapids. The project then was cancelled due to budget cutbacks. He pointed out that the river's immense waterpower should be harnessed. The river fell 22 feet through the rapids. The falling water's mechanical power could power saw, grist, or textile mills.

By the mid-1800s, Keokuk had become a bustling steamboat port of nearly ten thousand people. It served as a gateway for settlers moving westward through Iowa and was a staging point for Union troops during the Civil War.

After the Civil War, the Corps began constructing a canal paralleling and bypassing the rapids on the Iowa side of the river. The canal, completed in 1877, created a 5-foot channel and included three locks. A drydock also was built in Keokuk adjacent to the lock at the canal's lower end.

In 1893, leading citizens of Keokuk experienced the breathtaking electrical display at the Columbian Exposition in Chicago. The development of hydroelectric power at Niagara Falls starting two years later sparked their imagination: If Niagara Falls could be harnessed and spur economic development in the Buffalo area, why couldn't the mighty Mississippi River be harnessed to attract new manufacturing businesses to Keokuk? Why couldn't Keokuk grow and overtake St. Louis as a gateway to the West?

In April 1900, business leaders of Keokuk and its Illinois-side neighbor Hamilton formed the Keokuk and Hamilton Power

Company to make plans to dam the river and generate hydroelectric power. KHPC was enthusiastically supported by the residents of both Keokuk and Hamilton, and both towns appropriated public money to assist in KHPC's promotional efforts.[1]

KHPC engaged the prominent Chicago-based hydraulic engineer Lyman Cooley to confirm the possibilities for a dam.[2] The concept that emerged called for submerging the existing canal and locks and moving stretches of railroad tracks. Since navigation on the river had to be maintained, KHPC sought and eventually obtained Corps of Engineers endorsement of the proposed project. It would give the Corps a new lock and drydock at Keokuk, eliminate two upstream locks, and significantly improve navigation.

On February 9, 1905, President Theodore Roosevelt signed a law granting KHPC rights to construct and indefinitely maintain a dam across the Mississippi River at Keokuk.[3] The legislation required KHPC to construct, at its expense, a lock and drydock in conjunction with the dam. Ownership of the lock and drydock was to transfer to the Corps upon completion. The Act further required War Department approval of all construction plans and that construction commence within five years and be completed within ten years. KHPC had sent a delegation to Washington to lobby extensively for passage of the legislation.

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1 KHPC's organizers cobbled together $2,500 for its initial funding (about $80,000 in today's dollars), and Keokuk and Hamilton subsequently appropriated an additional $5,400. These funds were fully repaid by the dam's developer in 1908.

2 He was best known for engineering the Chicago Sanitary and Ship Canal to reverse the flow of the Chicago River so that it would flow out of rather than into Lake Michigan.

3 Fifty-eighth Congress, Session III, Chap. 566, 1905.

When news that Roosevelt had signed the bill reached Keokuk, fire bells rang and factory sirens blew as the town celebrated. KHPC said it was confident that dam construction could be completed within four years and that the region within 75 miles would soon become the most highly developed industrial area of the Midwest.[4]

Armed with project rights, KHPC needed a competent engineer or organization to undertake the project and the capital necessary to proceed. KHPC widely circulated a project proposal, or prospectus, to engineers and financial interests around the world. Only one expression of interest was received. It was from Hugh L. Cooper, who had supervised the just-completed construction of the Toronto Power Generating Station at Niagara Falls.

Cooper was a capable, self-taught civil engineer. Born in Minnesota in 1865, he began working as a laborer on bridge construction projects after graduating from high school. He was determined to become an engineer. As he later said, "I have had no college education. … What I know has been gathered by night study and day practice."[5] By 1889, he was assistant chief engineer of the Chicago Bridge and Iron Company. He soon switched his focus to the nascent field of hydroelectricity and to designing and building hydroelectric plants in the United States and abroad. In 1905, he opened his own firm in New York City as the Toronto Power Niagara Falls project was winding down. He immediately was hired to design and build a major dam across the lower Susquehanna River at McCalls Ferry to supply pow-

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[4] *Washington Times,* February 12, 1905, p. 9.

[5] Statement of Hugh L. Cooper, Hearings before the Senate Committee on Agriculture and Forestry on S. 3420, 67th Congress, Second Session, May 22, 1922, Washington, DC: US Government Printing Office, 1922, p. 707.

er to Baltimore. His involvement there ended In October 1907, when the project's development company filed for bankruptcy.[6]

A KHPC committee traveled to Niagara Falls to meet with Cooper in early September 1905. He quickly convinced them that he could manage the development of the Keokuk project and that the financial syndicate behind the Toronto Power Generating Station project would back him in doing so. KHPC eagerly granted him an exclusive option to arrange the financing.

Cooper was overly confident. The Toronto syndicate failed to support the Keokuk project. There was a major concern: No customers had been secured for the power Keokuk would generate, and the abundant cheap coal being mined nearby in the Mississippi Valley could make a power dam uneconomical.

It was imperative that customers be secured for the dam's hydropower. The best prospects were in the St. Louis area, which would require transmitting power nearly 150 miles from the dam site. This was farther than ever done before. Nonetheless, long-term contracts finally were signed in October 1908 to deliver 45 MW of electricity to St. Louis utilities, primarily to power electric street railways.

Fifty-eight financial groups turned Cooper down. The residents of Keokuk sank into deep gloom and despair. Failure appeared inevitable before Stone & Webster came to the rescue in 1909 as Cooper's option was on the brink of expiration. Stone & Webster formed the Mississippi River Power Company, with Edwin Webster as president and Hugh Cooper as vice president and chief engineer. The new company was assigned KHPC's project authorization. Due to Stone & Webster's expertise and

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6 Construction subsequently resumed under new ownership. The dam, renamed Holtwood Dam, was completed in October 1910.

reputation, its endorsement of the venture enabled it to arrange $21 million in project financing ($580 million in today's dollars). This was the largest financial placement Stone & Webster had handled. The residents of Keokuk again were jubilant.

Cooper began some excavation work on January 10, 1910, less than thirty days before federal authorization for the project would expire. Major construction efforts did not commence until late in the fall.

The Keokuk project was a blockbuster. It was the first time the Mississippi River had been dammed below St. Paul, Minnesota. Harnessing the river's power was considered an engineering feat on par with taming Niagara Falls or the construction of the Panama Canal then underway.[7] When completed, the dam was longer than any other dam in the world except the Aswan Dam across the Nile River, and it was the longest monolithic concrete dam in the world. The powerplant was the world's largest single powerhouse and low-head hydroelectric facility.

The project works stretch 9,100 feet between bluffs on either side of the river and encompass the dam, powerhouse, lock, drydock, and an ice fender designed to protect the powerhouse and lock from ice floes. The monolithic concrete gravity main dam extends 4,649 feet across the river from the Illinois side. The run-of-the-river dam contains 119 spillways between piers on 36-foot centers. Waterflow over the gently curved spillways[8] is

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[7] My paternal grandfather Paul H. Underwood, a long-time civil engineering professor at Cornell University, took a leave of absence from Cornell in 1911 to go to the Canal Zone and lead survey computing and mapping for the Isthmian Canal Commission.

[8] These technically are known as ogee-shaped spillways. The specific shape is chosen to smooth the flow of water overflowing the dam in high-water conditions with gates lifted.

controlled by the number of steel spillway gates that are open. The gates are operated by a gantry crane that moves on rails along the arched-span concrete service bridge atop the dam. The piers are about 55 feet tall and are anchored in the remarkably level and solid limestone river bedrock. The dam's backwater deepens the river for 60 miles upstream.

The powerhouse abuts the west end of the main dam and sits at a 110-degree angle to it. It is 894 feet long and is 177 feet tall from its foundation in bedrock below the river. Although Keokuk is a low-head hydropower facility with a normal head of 32 feet, the river's high flowrate of 100,000–200,000 cubic feet per second allows great power production. The powerhouse contains fifteen 25-cycle (or 25 Hz)[9] generators shaft-mounted to Francis turbines specially designed by Hugh Cooper. Total rated capacity is 135,000 kV.

In the early 1900s, electric power systems used many different frequencies. Higher frequencies worked better for lighting since they eliminated flickering; lower frequencies worked more efficiently with traction motors for streetcar systems. The United States had not yet settled on today's 60 Hz standard. The first generators at Niagara Falls were 25 Hz, so it is not surprising that 25 Hz was chosen for Keokuk. The Keokuk generators have been converted to 60 Hz since their initial installation.

The powerhouse originally was designed to be twice as long and contain fifteen more generator units. The substructure for

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[9] An alternating current's frequency is the number of complete oscillations, or cycles, it completes in a second. The Hertz (abbreviated Hz) is the standard unit of measure for cycles per second . One Hertz is defined as one cycle per second. The Hertz is named after German physicist Heinrich Hertz, who conclusively proved the existence of electromagnetic waves.

the lengthened powerhouse was built, but the powerhouse superstructure extension was not added.

Never before had so much power been generated from single turbine runners. Rotating turbine-generator units need thrust bearings on their shaft. Traditional roller or ball bearings wore quickly and, even for smaller power units, typically required repair or replacement within months. The 550,000-pound weight of the rotating part of each turbine-generator unit made this a critical concern.

Engineering professor Albert Kingsbury had just invented a revolutionary thin-oil-film bearing that promised to be long-lived. The first Kingsbury bearing was installed for testing in June 1912 at the McCalls Ferry Dam, Cooper's previous project. The next Kingsbury bearing installations occurred a short time later at Keokuk. Some of those original bearings still are functioning flawlessly. Kingsbury bearings became a standard and made possible the design of much larger hydroelectric units such as those installed at Hoover Dam.

The new lock was adjacent to the Iowa-facing side of the powerhouse. Its 110-foot chamber width was the same as that of the locks being constructed in the Panama Canal. Its 400-foot length easily could accommodate any river traffic.[10] Its 40-foot lift was higher than any of the Panama Canal locks. The lock and the dam's reservoir obsoleted the canal and three locks that had been bypassing the Keokuk rapids and cut transit time by more than two hours. Beyond the lock to the Iowa shore was the new 150-foot-by-463-foot drydock. It was the largest fresh-water drydock in the world. Title to the lock and drydock was trans-

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10 Another lock constructed in the 1950s replaced this lock as river traffic increased and barge tow lengths increased. The new lock is 1,200 feet long. The 1913 lock and dry dock have been abandoned.

ferred gratis to the federal government when construction was completed.

The Keokuk project presented several significant construction challenges. Avoiding unnecessary delays was important. Cooper frequently pointed out that interest expense alone on the project's financing was more than three thousand dollars a day. Furthermore, because it was imperative that river traffic not be disrupted, Cooper built a trestle supporting a rail spur from the Iowa shore to the powerhouse construction area, with a steel drawbridge over the existing canal. Also, the river froze during the winter, with ice that was 2 to 3 feet thick. As the ice broke up in March and April, huge floes careened downstream.

Cooper and Stone & Webster divided construction responsibilities. Cooper was responsible for construction of the dam, powerhouse substructure, and navigation works. Stone & Webster designed and built the power station superstructure, electrical equipment, and all transmission lines. Cooper further segmented his work. Teams working from the Iowa shore were responsible for the powerhouse, lock, and drydock. Teams working from the Illinois side built the main dam itself.

Cooper drew upon his bridge-building experience for construction of the main dam. It was built section by section across the river. He designed a massive traveling cantilever crane to deposit cofferdam cribs, forms, and concrete as much as 125 feet beyond each just-finished pier and arch section. After completion of the arches and bridgeway, spillway bays were built one by one. Steel was used extensively for forms.

The last concrete in the dam was deposited on May 31, 1913. Less than a month later, the new lock was turned over to the Corps of Engineers. On July 1, Keokuk began sending electricity 144 miles to St. Louis over a 110,000-volt transmission line.

This then was the longest transmission line in the world,[11] and the receiving substation in St. Louis was the largest in existence.

A crowd of 35,000 people flocked to Keokuk to celebrate the dam's dedication in August. A mile-long parade wound down Main Street past cheering bystanders. Speaker after speaker spoke of a dream come true and praised those whose energy, faith, and extraordinary capacity had made the dam a reality. They foresaw Keokuk becoming a great manufacturing center in the days ahead. They extolled their hero, Hugh Cooper.

Stone & Webster managed the operations of the Keokuk Dam and associated power facilities until they were sold in 1925 to St. Louis's Union Electric Company (now Ameren Missouri). Today Keokuk plays a vital role in the reliability of Ameren Missouri's power grid by providing power needed quickly in a system emergency and helping meet peak-period demand.

Although commercially successful, the Keokuk hydroelectric facility never fulfilled the aspirations of the town's residents. The area never became a major manufacturing center. St. Louis and Chicago had too much of a head start and too many other advantages. Keokuk's population remains about the same as it was when the Keokuk project began.

Cooper went on to design and build a number of other major dams in the United States and internationally. He was made a colonel in the US Army during World War I and designed and supervised the construction of Wilson Dam across the Tennessee River. He later was retained by Soviet ruler Joseph Stalin to construct the Dneprostroi Dam across the Dnieper River in Ukraine. It was the largest hydroelectric plant in Europe.

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[11] Keokuk briefly held this distinction. Stone & Webster's Big Creek project in California began transmitting power 248 miles to Los Angeles in mid-November 1913.

When Cooper died in 1937, *The New York Times* editorialized:

> He stood apart. With no formal technical education, he gravitated as naturally to engineering as artists to painting and sculpture. … China, Egypt, Mexico, the United States, Soviet Russia, Chile—Colonel Cooper left his mark on them all in the form of engineering works which are as characteristic of our time as are the temples of the ancient world of theirs. And like the temples, his structures have the enduring quality that we associate with great masses. Long after this civilization has passed or merged into another, his magnificent dams will testify to the daring, imagination, and energy of an epoch dominated by the scientist and the engineer.[12]

The Keokuk hydroelectric project was unique for its scale and its innovations and for being the result of the vision and sheer willpower of the Keokuk community. This was hydropower's entrepreneurial time. The people of Keokuk and Hugh Cooper and the Keokuk Dam itself exemplified that spirit.

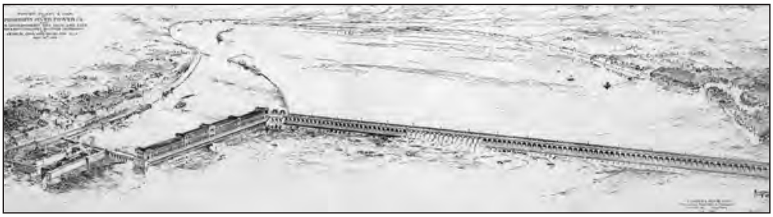

Fig. 7.1. Drawing of Keokuk Project Plan Prepared as Cooper Sought Financing in 1908. Some Details Changed Later.

[12] *The New York Times*, June 26, 1937, p. 16.

Fig. 7.2. Keokuk Dam and Powerhouse Panoramic View After Completion Lock and Drydock in Lower Foreground

Fig. 7.3. Hugh L. Cooper in 1913

Fig. 7.4. Keokuk Main Dam Construction

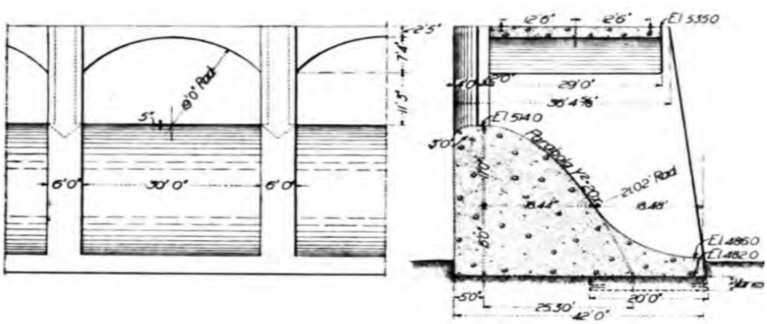

Fig. 7.5. Keokuk Main Dam Details Showing Spillway Shape

Fig. 7.6. Keokuk Powerhouse Construction

Fig. 7.7. Completed Keokuk Powerhouse

Fig. 7.8. Keokuk Generator Room

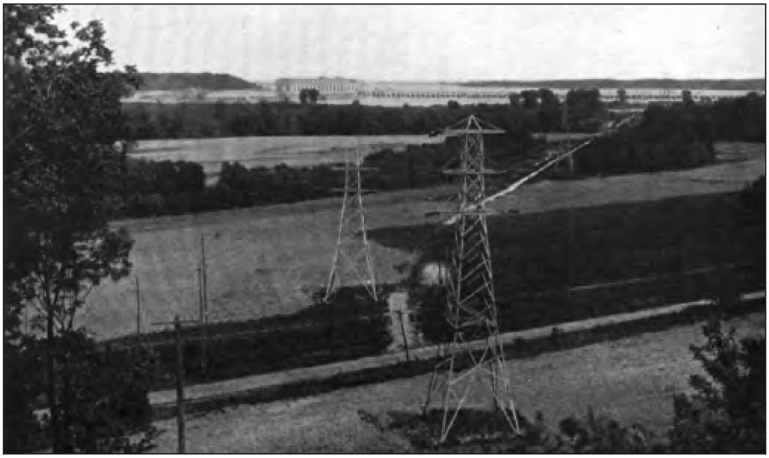

Fig. 7.9. Keokuk to St. Louis Power Transmission Line

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Fig. 7.10. Two Steamboats in Keokuk Lock on Opening Day June 1913

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Chapter Ten

Power Plays

While Ford's offer for Muscle Shoals was being debated in Washington, DC, big things were happening hydroelectrically out west in the other Washington: the State of Washington. From the earliest days of electricity onward, Washington State was hydropower nirvana. It is a geologically rugged state. Two mountain ranges, the Cascades and the Olympics, dominate the topography. The plentiful mountains are high, and water flowing from their snow-packed peaks is abundant. Studies in the 1920s concluded that Washington had the greatest hydroelectric power potential of any state. Today, Washington generates over 25 percent of the nation's total hydropower, with hydropower fulfilling 70 percent of the state's energy needs.

Demand for electricity in western Washington grew rapidly during and after World War I. Existing facilities could not meet the demand, and utilities decided to build new hydroelectric projects. By then, the most obvious, inexpensive potential waterpower sites near urban areas where loads were concentrated already had been exploited. Thus began the move to develop larger-scale, costlier remote sites. As shown in Figure 10.1, three significant projects were completed between 1924 and 1926: one by Seattle's municipal utility, one by the Tacoma municipal power utility, and one by the larger and more geographically extended Puget Sound Power and Light. Investor-owned Puget Sound Power and Light, as we learned in Chapter Six, was controlled by Stone & Webster.

Owner	Project	Project Description	MW	Completed
Seattle City Light (municipal)	Gorge Dam, Upper Skagit River	30-ft diversion dam, 11,000-ft tunnel, 294-ft head	60	1924
Puget Sound Power and Light (investor owned)	Lower Baker Dam, Baker River	293-ft-tall arch dam, 1,600-ft power tunnel	40	1925
Tacoma Power (municipal)	Cushman Dam No.1, North Fork of Skokomish River	275-ft-tall concrete arch dam	43	1926

Figure 10.1: Significant Washington Hydroelectric Projects, 1924–26

These projects highlighted the fierce, ongoing battle being fought between municipal utilities and investor-owned utilities in western Washington. In 1900, Stone & Webster had taken steps to consolidate all of Seattle's then-existing streetcar and electric utility firms into the Seattle Electric Company. Not everyone enthusiastically greeted this move. Belief that the Eastern money behind Seattle Electric would siphon dollars away from Seattle to the detriment of its residents, Seattle Electric's high rates, persistent service problems, and reports of underhanded political dealings spawned a movement to establish a municipal power company. A 1902 Seattle Chamber of Commerce resolution supporting municipal power included the following statement:

> Under the existing conditions, Seattle is at the mercy of one company which does not hesitate to take advantage of its monopoly.… An exorbitant charge is made to factories …

> a charge far in excess of what is taxed in Tacoma or Everett for a similar service. This condition of affairs could not last 24 hours had the city a municipal lighting plant ready to furnish power at a minimum of cost.[1]

In 1902 and 1903 elections, voters approved the creation and financing of a Seattle municipal power company, Seattle City Light, and the construction of a municipal hydroelectric plant on the Cedar River. By 1910, the municipal system was supplying about one third of the electricity consumed in the city.

In 1912, Seattle Electric was consolidated into Stone & Webster's newly-formed Puget Sound Traction, Light, and Power Company (re-named Puget Sound Power and Light Company eight years later). The war between Seattle City Light and Puget Sound Power and Light over Seattle's power grew intense as each maneuvered for position in western Washington's most concentrated center of demand.

In 1911, the State of Washington created a Public Service Commission to regulate investor-owned utilities. Municipal utilities, however, were not subjected to state regulation. This led Stone & Webster to complain that "the municipal plant in Seattle has had perfect freedom to conduct its business as it saw fit. Discrimination in rates, inducements to obtain business, intimidations in the matter of building permits and questionable accounting methods are abuses that this freedom from regulation has allowed."[2] In 1915, after extensive lobbying by Stone & Webster, legislation was passed prohibiting municipally-owned

1 Charles David Jacobson, *Ties That Bind*, Pittsburgh, PA: University of Pittsburgh Press, 2000, p. 114.

2 *Chronological History of the Puget Sound Power and Light Company and Predecessor Companies, 1885–1938*, company pamphlet, 1939, p. 7.

utilities from extending their distribution networks outside of a city's boundaries.

Seattle City Light's driving force was the legendary J.D. Ross, a self-taught engineer who had overseen construction of the Cedar River power plant. In 1911, he was named superintendent of City Light and held that position almost continuously until his death twenty-eight years later. Foreseeing the increase in demand for electricity in store for Seattle and recognizing that waterpower was the logical source of electricity to meet that demand, Ross first attempted a major upgrade of the Cedar River facility. A new, 215-foot-high masonry dam designed to increase generating capacity by 2.5 times was completed in 1914. It was built on glacial moraine after cautionary initial engineering studies were ignored; consequently, it was plagued by seepage and was practically useless as a hydropower reservoir. The embarrassed Ross scrambled to investigate every other possible water site within 150 miles of Seattle.

Stone & Webster, meanwhile, attempted to prevent City Light from ever getting another hydro site. The company hastily bought two separate sites while City Light was negotiating for them. Stone & Webster also had tied up rights to another promising site 100 miles northeast of Seattle on the Skagit River, having obtained a federal permit for the site without developing it. It appeared that City Light was boxed in.

But Ross soon struck back.

The Skagit River flows from British Columbia to the Puget Sound, draining the North Cascades. As the upper portion of the river flows through the Washington National Forest, it descends 700 feet while passing 15 miles through a narrow gorge of solid granite. This remote, rugged, nearly inaccessible location had long been considered to have the greatest hydropower potential on the west slopes of the mountains. The US Department of Agriculture held authority over power sites in National Forests. Although Stone & Webster had secured rights to develop the Skagit River for power, the company's permit included a requirement that construction begin within a time period that expired early in 1916. This seemed to be good news for Ross.

Ross wrote to the Department of Agriculture stating that Seattle City Light was ready to build and that granting a permit to a municipally owned utility was in the public interest. The Department reacted by extending Stone & Webster's permit for a year (undoubtedly with strong persuasion by the company). Ross would not be dissuaded. Upon the second expiration of the permit, he personally approached David F. Houston, the Secretary of Agriculture in Washington, DC, with City Light's permit application in hand. He pointed out that Stone & Webster representatives were buying up other sites while attempting to hold the Skagit without developing it, thereby staking out more sites than Stone & Webster would ever need. The Secretary of Agriculture decided in Ross's favor on December 25, 1918. Ross triumphantly thereafter often characterized Stone & Webster's "greed" as "a case like the boy in Aesop's fable who put his hand in a jar of nuts and in trying to take them all was forced to drop them all."[3]

Stone & Webster continued its attempts to stifle City Light's Skagit project. Company operatives reminded Seattle City Council members of the Cedar River dam fiasco as the Council deliberated approving the Skagit project. When Seattle went to market to sell utility bonds to finance construction, Puget Power pulled strings with federal regulators in an unsuccessful attempt

3 J.D. Ross, "City Light: The Municipal Light and Power System of Seattle, Washington," *Public Ownership*, Vol. X, No. 10, October 1928, p. 181.

to block the sale. With President Coolidge ceremonially pressing a golden key in the White House in September 1924, electricity from the Gorge Dam powerhouse began flowing to Seattle.

J.D. Ross thought big. Gorge Dam was merely a stepping-stone for him. His reputation restored, he envisioned making City Light the sole supplier of electricity for Seattle—and the Skagit (and himself) a showcase for municipal power. He proclaimed that:

> By its very nature the handling of light and power is not in any way a legitimate private business but is a proper governmental function—a monopoly that should belong to the people only .... It is left to us to expand city ownership of light and power and interconnect cities in a superpower system as the most feasible and practical method.[4]

Between 1924 and 1961, the Upper Skagit project was expanded to include a series of three dams, the tallest of which was the 540-foot-tall Ross Dam.[5] The combined generating capacity of the three is more than 700 MW. Ross remained superintendent of City Light until his death in 1939. Four years earlier, in August 1935, when President Franklin D. Roosevelt signed the Public Utility Holding Company Act, which was to be administered by the Securities and Exchange Commission, he appointed Ross an SEC commissioner. In 1937, Roosevelt named Ross the first administrator of the Bonneville Power Administration,

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4 *Ibid.*, p. 187.

5 The third dam was the Diablo Dam, four miles upstream from Gorge Dam. Construction of the 389-foot-tall arch dam was finished in 1930. The Diablo powerhouse, however, was not completed until 1936. Ross Dam is 5 miles upstream from Diablo Dam. Ross Dam was constructed 1937–49; the first of its four generators began operating in 1952.

which was formed to market Bonneville Dam's hydroelectricity. In 1951, Seattle City Light acquired the Seattle assets of Puget Power. Seattle at last had a unified power system.

Seattle and Tacoma had been both neighbors and spirited competitors from their earliest days—a situation reminiscent of Minnesota's twin cities of Minneapolis and St. Paul. Each was an early member of the municipal power community. In 1873, Tacoma, then a small outpost on the bluffs overlooking Puget Sound's Commencement Bay with Mount Rainier visible in the background to the southeast, had its future assured when the Northern Pacific Railroad—to Seattle's horror—selected it as the future Pacific Coast terminus for Washington's first transcontinental railroad. The transcontinental link became a reality ten years later.

Seattle's growth, however, would permanently eclipse Tacoma's (see Figure 10.2) after Seattle became the transcontinental terminus of the Great Northern Railroad in 1893 and the primary point of departure for the Klondike Gold Rush of 1897–99.

	1870	1880	1890	1900	1910	1920	1930
Seattle	1,107	3,533	42,837	80,671	237,194	315,312	365,583
Tacoma	73	1,098	36,006	37,714	83,743	96,965	106,817

Figure 10.2: Seattle and Tacoma Population History (US Census Data)

In its early days, Tacoma was considered a company town of the Northern Pacific Railroad. The railroad and its officers controlled land sales and development. In 1884, Philadelphia financier Charles B. Wright, a Northern Pacific director and its largest shareholder, obtained a franchise from the city to organize the Tacoma Light and Water Company. The company built a primitive water system that drew water from several creeks and distributed it through pipes made from hollowed-out logs.

Starting in 1885, the waterflow also was used to power an Edison dynamo, and electricity became available to power streetlights and for sale to consumers. This was only three years after Edison's Pearl Street station had become operational on the other side of the continent.

In 1893, Wright sold the water and electrical utility systems to the city, almost a decade before the formation of Seattle City Light. As the city grew, the municipal electric utility (much later named Tacoma Power) distributed power purchased from competing private power companies to meet its expanding needs. By 1907, the Tacoma City Council had had enough of seemingly exorbitant prices for electricity purchased from Stone & Webster—and of the brownouts and blackouts created when Stone & Webster throttled availability to give priority to its other needs. Councilmembers decided that Tacoma Power should build its own hydropower facility and so put a bond measure for the required expenditure to a popular vote. Stone & Webster, in a highly questionable move to thwart the city's plans, announced rate increases and cut off power to the pumps that supplied the city's water.

Irate citizens approved the bond measure by a three-to-one margin in 1909. The LaGrande powerhouse became operational three years later 35 miles from the city on the Nisqually River. A 35-foot-high diversion dam directed water into a settling channel and then into a 2-mile tunnel. The tunnel fed penstocks that dropped 410 feet to the powerhouse.

The LaGrande facility met Tacoma's power needs until World War I escalated requirements. Stone & Webster said it would not sell power to Tacoma Power unless Tacoma agreed never to build additional hydroelectric facilities. Tacoma Power refused. It was impractical to expand the LaGrande project. For a new facility, Tacoma Power selected another site 44 miles northwest of the city on the north fork of the Skokomish River at Lake Cushman, originally a long, narrow broadening of a river formed in a glacial trough and dammed by a terminal moraine from the last ice age. The lake would be an unusually large storage facility in an area known for its heavy rainfall.

Attempts to develop a power plant at Lake Cushman actually first had been initiated by Seattle City Light in 1912, when Seattle citizens approved purchase of the site. As Ross later recounted, "The opposition of [Stone & Webster] delayed proceedings, blocked the city in its hydroelectric development in 1917, and resulted in the loss of the Cushman site."[6] Ross even accused Stone & Webster of planting a hidden microphone in his house to anticipate his every move.[7] Tacoma Power applied for Lake Cushman water rights and reservoir permits in 1919 and began land condemnation proceedings the same year.

After extended and acrimonious property acquisition proceedings, other obstacles, and Stone & Webster roadblocks, Cushman Dam No. 1 construction began in 1924. The constant-angle arch concrete dam was 275 feet tall and 1,111 feet long. The facility, with 43 MW capacity, became operational two years later. The power transmission line to Tacoma stretched across the Narrows between towers more than 1.25 miles apart, the longest single span in the world. Cushman Dam No. 2 was completed in 1930 just downstream from Dam No. 1.

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6 J.D. Ross, "Seattle City Light and Power," *Public Ownership of Public Utilities*, Vol. XVI, No. 5, May 1934, p. 84.

7 Paul Dorpat and Genevieve McCoy, *Building Washington: A History of Washington State Public Works*, Seattle, WA: Tartu Publications, 1998, p. 284.

The Cushman dams were designed by Lars Jorgensen, a noted California-based engineer who had designed the world's first constant-angle arch dam: Salmon Creek Dam built near Juneau, Alaska, in 1913.[8] The Cushman Dams were so successful that J.D. Ross, in an attempt to counteract criticism of his botched Cedar River upgrade, engaged Jorgensen to design the Diablo Dam, which he constructed on the Skagit River after the Gorge facility was completed.

In 1924, Seattle City Light and Tacoma Power built a tie line so that the two municipally owned utilities could share power when necessary. As Ross quipped, "The results to the two cities may be expressed by saying 'blest be the tie that binds.'"[9]

While Stone & Webster was doing everything it could to restrain the municipal power movement in Seattle and Tacoma, it simultaneously was following Samuel Insull's model to refine and extend its electrical grid in western Washington. Load growth throughout the company's system, particularly in the northern portion, required power development there. The only hydroelectric plant operated by the company in that region was the tiny, outdated Nooksack Falls plant (1,750 kW). For many years, Puget Sound Power and Light had been forced to divert power from its southern generating plants in the Seattle-Tacoma area and to purchase power from Canada to adequately serve the

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8 Jorgensen developed the theory for constant-angle arch dams. It was estimated that these dams required 20 percent less concrete than constant-radius arch dams that had been the norm. Both of these thin arch designs required significantly less concrete than traditional gravity dams. In addition to single arch dams, Jorgensen designed multiple-arch dams such as Gem Lake Dam on the eastern slope of the Sierra Nevadas in California. Reclamation consulted with him during its initial planning for Hoover Dam.

9 Ross, "City Light," p. 180.

Bellingham area. Bellingham itself, located on Bellingham Bay about 20 miles south of the Canadian border and 30 miles west of Mount Baker, was growing rapidly: Its population jumped from 11,000 in 1900 to 26,000 in 1920. In 1918, the load on the company's entire system began exceeding the capacity of its complement of waterpower plants.

Puget Sound Power and Light decided to build a new hydroelectric plant near Mount Baker on the Baker River just north of the town of Concrete. This would allow the company to better serve the northern areas of its system, rebalance its entire power grid, and discontinue purchasing electricity from Canada.

From near the Canadian border, the Baker River flows southward 30 miles through a steep glacial valley near Mount Shuksan and Mount Baker before joining the Skagit River at the cement-manufacturing town of Concrete. The river is fed by glaciers, heavy rains, and snow fall. From Concrete, the Skagit flows west about 25 miles into Puget Sound. Seattle City Light's Gorge Dam is approximately 40 miles up the Skagit from Concrete.

For the last half of its run, the Baker River traverses a nearly level valley closed at its southern end by a natural limestone wall more than 500 feet high and 2,000 feet thick. The river flows through Eden Canyon, a narrow gorge in this barrier with nearly vertical sides, then downstream 1.1 miles through Concrete and into the Skagit River. The canyon riverbed is roughened, solid limestone. Clearly, Eden Canyon was geologically an ideal site to locate Baker Dam. Furthermore, cement was available locally at Concrete, and sand, gravel, and stone were close at hand. The dam site could be connected to the Great Northern Railway by laying half a mile of track.

The Baker River site had been purchased in 1915 to be held in reserve until Stone & Webster's power needs would justify its development. The purchase undoubtedly was part of the company's efforts to impede Seattle City Light. Circa 1921, Stone & Webster's western regional staff in Seattle began developing, under the supervision of W.D. Shannon, detailed plans for the Baker River project. This included dam and electrical generation and transmission system design, construction plans, cost estimates, permitting, and myriad other details. Shannon, a University of Michigan civil engineer, also simultaneously oversaw a major upgrade (from 44 MW to 60 MW) of the company's White River hydroelectric facility just east of Tacoma. Later the Baker Dam reservoir would be named Lake Shannon in his honor. He went on to become a prominent Seattle citizen and a state senator.

Figure 10.3 provides an overview of the project concept that emerged.

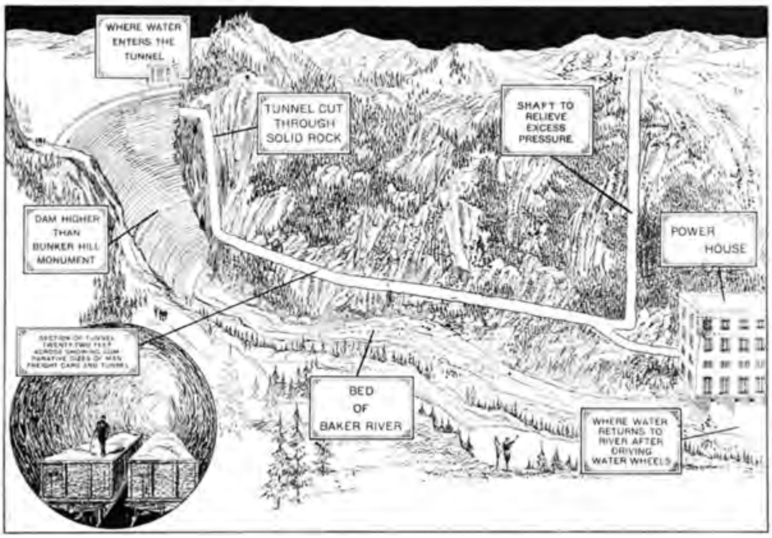

Figure 10.3: The Baker River Project

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Baker Dam is a 293-foot-tall, arch-gravity structure with spillway through control gates over the dam crest. The upstream face follows a 250-foot radius. The 1,600-foot-long diversion tunnel, bored through solid limestone, is 22 feet in diameter and lined with concrete. With a height almost identical to the length of a football field, the dam was the highest hydroelectric dam in the United States when completed. Its initial power output was 40 MW. After several upgrades, it now is 111 MW. The reservoir behind the dam, Lake Shannon, extends upriver 8 miles to another dam built in 1959. That dam now is called Upper Baker Dam; the original Baker Dam is referred to as Lower Baker Dam. Upper Baker Dam generates 107 MW of power. The dams are managed together to provide flood control for the Skagit basin downstream. These significant hydroelectric facilities continue to be key components of the electric grid operated by Puget Sound Energy, the successor company to Puget Sound Power and Light.

Construction of Baker River project preliminaries such as worker housing and a railway spur connecting to the Great Northern Railway line nearby began in April 1924. At about the same time, while George Jessup was completing the construction of the Henry Ford hydroelectric facility in Iron Mountain, Michigan (see Chapter Nine), he was told by Stone & Webster senior management that his next assignment was to be superintendent of construction for the Baker River project and that he was to report to Concrete as soon as possible.

Jessup clearly was a rising star at Stone & Webster, but his selection was not an obvious one. The Concrete project was much more complex than Iron Mountain—Jessup's only other dam-building experience. Nevertheless, he quickly boarded a train headed west. His wife and their three young children, an infant son and daughters ages five and nearly three, soon followed from Iron Mountain once family quarters were built in the construction camp on the bluffs above the dam site.

Construction proceeded at breakneck speed. By late July 1924, the railroad to the dam site had been completed, the construction camp had become a small city, and more than 900 men were transporting materials, building roads, erecting buildings, clearing ground, blasting rock, and doing the many, many other things that were necessary before actual construction work on the dam and powerhouse could begin. In August, the diversion tunnel bored in the canyon sidewall was completed, and the river's water began flowing through it to bypass the dam site. Coffer dams were built upstream and downstream of the dam site, and the riverbed was excavated down to the bedrock that was to support the dam's foundation.

Heavy rainstorms in September 1924 led to an unexpected rise in the river, washed out trestles and other structures on the dam site, inundated the area between the coffer dams, submerged machinery and equipment, and delayed operations by several weeks. Another rainstorm early in October again overflowed the coffer dams.

On October 10, the first concrete for the dam's foundation was poured. A week later, workers represented by the Industrial Workers of the World went on strike demanding "a 25 percent wage increase, more and better food, clean linen once a week, no overtime, safer working conditions, boycott of California products, and release of all class prisoners."[10] As the strike wore on, it became violent. In an incident seared in memory for the

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[10] *The Concrete Herald*, Vol. XXIII, No. 47, October 23, 1924, p. 1. Members of the IWW typically were referred to as "Wobblies." It was not shown how Stone & Webster could comply with the last demand.

rest of their lives, Jessup's two young daughters were awakened one night by a noise at the window of the bedroom they shared. They started screaming upon seeing a man looking in and brandishing a gun. Jessup family members were placed under armed guard until the strike ended. At one point, as the strike continued, a doctor had to be escorted by armed security men as he walked along the railroad tracks from town to Jessup's quarters to check on Jessup's ill infant son. According to Jessup, the strike was settled when each worker was given a bedsheet.

The timing of the strike was unfortunate. With a few more days' work, enough concrete would have been poured to protect the project from high water. The 1924–25 winter season was one of the wettest on record, with monthly rainfall of around 15 inches through February, causing wave after wave of flooding. It was not until March 1, 1925, that work crews were able to pour concrete to the height of the upstream coffer dam and entirely shut off the river flow.

In Summer 1925, about thirteen hundred men were working around the clock to complete the project. There was a shortage of at least three hundred men due to an urgent demand for men to fight forest fires raging in the area. One day, Jessup fell from the bluff above the river into the canyon below, breaking several ribs and sustaining multiple serious injuries. When workers brought him to his quarters motionless on a stretcher, his wife initially thought he was dead. Nonetheless, he somehow was able to recover quickly enough to resume managing the project construction. A Stone & Webster photograph (see Figure 10.4) taken a few months before the dam was completed shows Jessup (far left), normally a robust man, standing hunched over and emaciated:

Figure 10.4: Stone & Webster Officers at Baker River
Far left, George Jessup; fourth from left, Edwin Webster; fifth from left, W.D. Shannon; second from right, Charles Stone; far right, Samuel Shuffleton

Remarkably, especially given the impediments overcome during construction, the Baker project was completed ahead of schedule and in record-setting time. In October 1925, dam and powerhouse construction was completed, and Lake Shannon began to rise behind the dam. A month later, the hydropower facility became operational. Stone & Webster claimed the project construction set a world's record: No other plant of equal power was known to have been constructed in as short a period of time.

While the Baker dam and powerhouse were being built, Stone & Webster simultaneously was constructing 92 miles of high-voltage transmission lines and two large substations. Once the Baker River plant became operational, power generated there could be delivered to almost any part of Washington served by Puget Sound Power and Light.

Immediately after the Baker River facility began transmitting electricity, Puget Sound Power and Light placed full-page advertisements in Seattle-area newspapers to continue its feud with

J.D. Ross and Seattle City Light. Under the banner headline "More 'Puget Power,'" the advertisements proclaimed:

> Baker River is harnessed to add its age-old strength to the upbuilding of the Pacific Northwest. … The investment of over eight thousand citizens of Western Washington in our securities has aided in making this plant possible. It will be added to the taxable wealth of this state and will aid in reducing the taxes not only of the people of Skagit County, where the plant is located, but of every taxpayer in the state. Just a few miles away is the plant of the City of Seattle, tax-exempt and tax-free. The Baker River plant will not only light the homes and stores of the Pacific Northwest, but will furnish the power for new factories, new industries, adding more payrolls and more taxable property to the entire Puget Sound District. It is another step in the industrial progress of this state—additional proof that the Puget Sound Power & Light Company will always maintain an adequate supply of electric power well in advance of the needs of the district which it serves.[11]

There is an interesting tall tale, an important fish story, associated with Baker Dam. Hydropower developers of that era were notoriously insensitive to environmental issues. That was not the case with the Baker River project. At the time the dam was to be constructed, the Baker River was the only stream in Washington State in which sockeye salmon spawned. The sockeye salmon, 24 to 33 inches long and weighing 5 to 15 pounds, is among the smaller of the seven Pacific salmon species, but

[11] This text appeared in an advertisement in the *Seattle Post-Intelligencer*, November 27, 1925, and in the Sedro-Woolley *Courier-Times*, November 26, 1925.

its succulent, bright-orange meat is highly prized. As with all other Pacific salmon, sockeye journey upriver from the ocean to spawn in fresh water. They require a nearby lake in which to rear their offspring. Once hatched, juvenile sockeye stay in their natal habitat for one to two years. They then journey out to sea, where they grow rapidly, feeding mainly on zooplankton. They stay in the ocean for one to four years. It was critical to the Pacific Northwest's fishing industry, to the livelihood of Native American tribes living in the area, and to nature's ecological balance more generally that the Baker Dam allow passage for adult salmon migrating upstream to spawn and for salmon fry heading downstream toward the ocean.

But the dam's 293-foot height presented a conundrum previously never encountered. Fish never before had been lifted over an obstruction more than 50 feet high. Project managers consulted with state and federal fisheries officials, area Native American tribes, and renowned marine biologists and university researchers. A committee was formed to address the various issues involved. After a number of committee meetings, it was evident that there were a number of conflicting ideas and that no resolution was imminent. Jessup later related that he told the committee he had a dam to build and a schedule for completing it. Based on all he had heard, he was going to proceed with the design and construction of a Baker fishway, working directly with the state superintendent of hatcheries. The result was a unique and highly innovative lift system.

It incorporated a forebay downstream of the dam adjacent to the tailwaters of the powerhouse, where salmon were corralled and confined into a fish ladder with 2-foot falls. The fish ladder was designed so that the fish could move upwards from one pool to the next but could not return. The 2-foot elevation between pools was chosen so that the fish could conserve strength between jumps. The fish ladder reached upward to a staging area partway up the height of the dam. There, the fish entered a water-filled car and were transported on an incline railway the rest of the way to the top. In addition, one of the dam's spillway gates was left open during the June run of fry to the ocean. The danger that fry would encounter passing over the dam on their way downstream was mitigated by designing the dam spillway with a special apron at its base to spread the fall of the water and smooth the transition to the river downstream. It also was discovered that most fry that happened to enter the powerhouse water intake tunnel were able to pass through the powerhouse turbines unharmed.

According to press reports, the success of the Baker fish transport system was lauded as a major advance and studied by the fish management community and power plant engineers in all parts of the world. The *Journal of Electricity* reported that:

> The success of the whole enterprise means a great deal to both the salmon and the power industry of not only this state but of the whole country, fisheries experts have declared. This is the first time so far as is known that the migratory fish have been successfully transported over a high dam. It is predicted that no longer will the power companies be restrained from building as high a dam as is needed across any of our salmon streams and no longer will the great salmon industry of the state be menaced as a result of such power dams.[12]

This innovative approach to solving the salmon issue was just one of the ways in which western hydroelectric facilities differed

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12 *Journal of Electricity,* Vol. 57, No. 6, September 15, 1926, p. 197.

from their eastern brethren. First, western dams usually are much taller (i.e., higher head) since they can be placed where waterways run through draws or canyons. Second, due to their remote location, western dams often require power transmission over long distances. Third, construction in remote, rugged, western locations can be especially difficult. Fourth, seasonal water flow variability and topographic specifics can lead to reservoir storage far from dams and/or power plants and connection via lengthy flumes or tunnels.

As Washington's electrical demand continued to increase after the completion of Baker Dam, both Puget Sound Power and Light and Stone & Webster zeroed-in on Rock Island on the Columbia River as an additional hydropower site. The site was 12 miles downstream from Wenatchee and 463 miles upstream from the mouth of the river.

Four years after Baker became operational, the Federal Power Commission issued Puget Sound Power a license to build a Rock Island hydroelectric facility, the first to span the Columbia. Despite the onset of the Great Depression, construction began in January 1930. The 78 MW facility became operational in February 1933. Building upon the lessons of the Baker River project, a gently sloping fish ladder was included. After several major upgrades, the facility now is rated at 624 MW. In 1956, the Rock Island facility was acquired by the Chelan County Public Utility District, which continues to operate it.

The investor-owned Rock Island Dam was not a multi-purpose dam: Its sole purpose was to generate electricity. In the same year that Rock Island became operational, construction of the mammoth, federally funded, multiple-purpose Bonneville and Grand Coulee dams began downstream and upstream on the Columbia.

The battle between publicly owned and investor-owned power utilities shifted dramatically within the decade after the three dams highlighted in this chapter were completed. The Great Depression, President Franklin D. Roosevelt's New Deal, the dismantling of utility holding companies, the advent of large, multipurpose federal hydropower projects, and other factors altered the playing field.

Undertaking new hydroelectric projects became increasingly difficult, especially for investor-owned utilities. In Washington State, voters in 1930 approved legislation allowing the formation of county public utility districts for electricity distribution. These PUDs could acquire properties of investor-owned companies by condemnation. Investor-owned Puget Power and Light and Stone & Webster had fought hard against the bill.

By 1936, thirteen Washington counties had formed PUDs. Then, in 1937, Congress created the Bonneville Power Administration to distribute the cheap and abundant electricity to be generated by the Bonneville and Grand Coulee dams. Prices were to be the same for all users, and publicly owned utilities were to be given preference. With service areas and revenue bases threatened, investor-owned companies found financing new construction projects to be extremely difficult. Hydropower's entrepreneurial days were ending.

Fig. 10.5. Seattle City Light's J.D. Ross

Fig. 10.6. Seattle City Light's Gorge Dam Powerhouse
(left section added in the 1940s)

Fig. 10.7. Construction of Seattle City Light's Cedar River Dam Nearing Completion

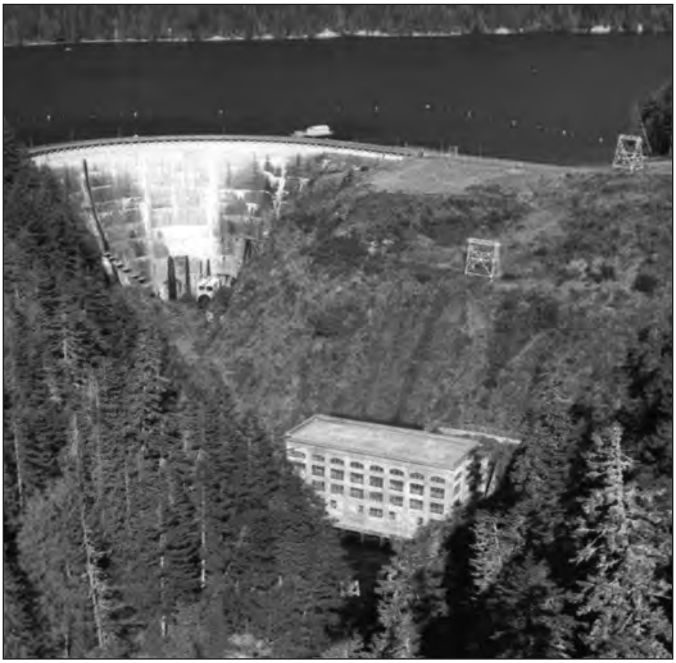

Fig. 10.8. Tacoma Power's Cushman No. 1 Dam and Power House

Fig. 10.9. Tacoma Power's Record-Setting 1.3 Mile Single-Span Transmission Line from Cushman No. 1

Fig. 10.10. Baker River Dam Site Before Construction Began

Fig. 10.11. Puget Sound Power & Light's Baker Dam

W.D. Shannon
Genl. Supt.

G.P. Jessup
Supt. of Const.

Fig. 10.12. Stone & Webster Project Managers At Baker River 1925

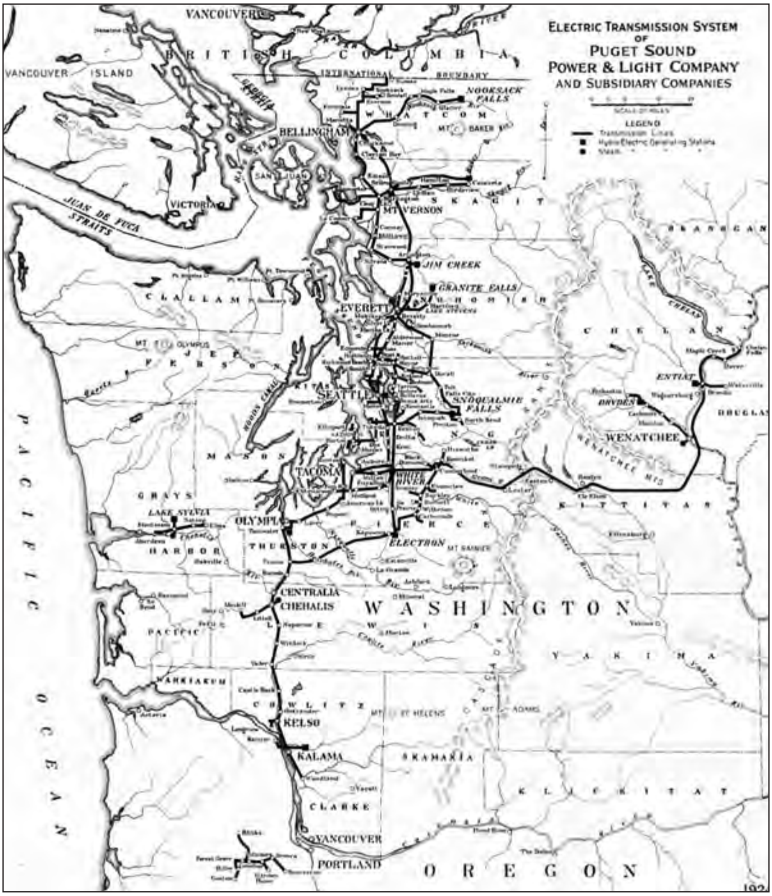

Fig. 10.13. Puget Sound Power & Light's Electric Transmission System in 1924–25

Pages 221-404 are not included in this sample.