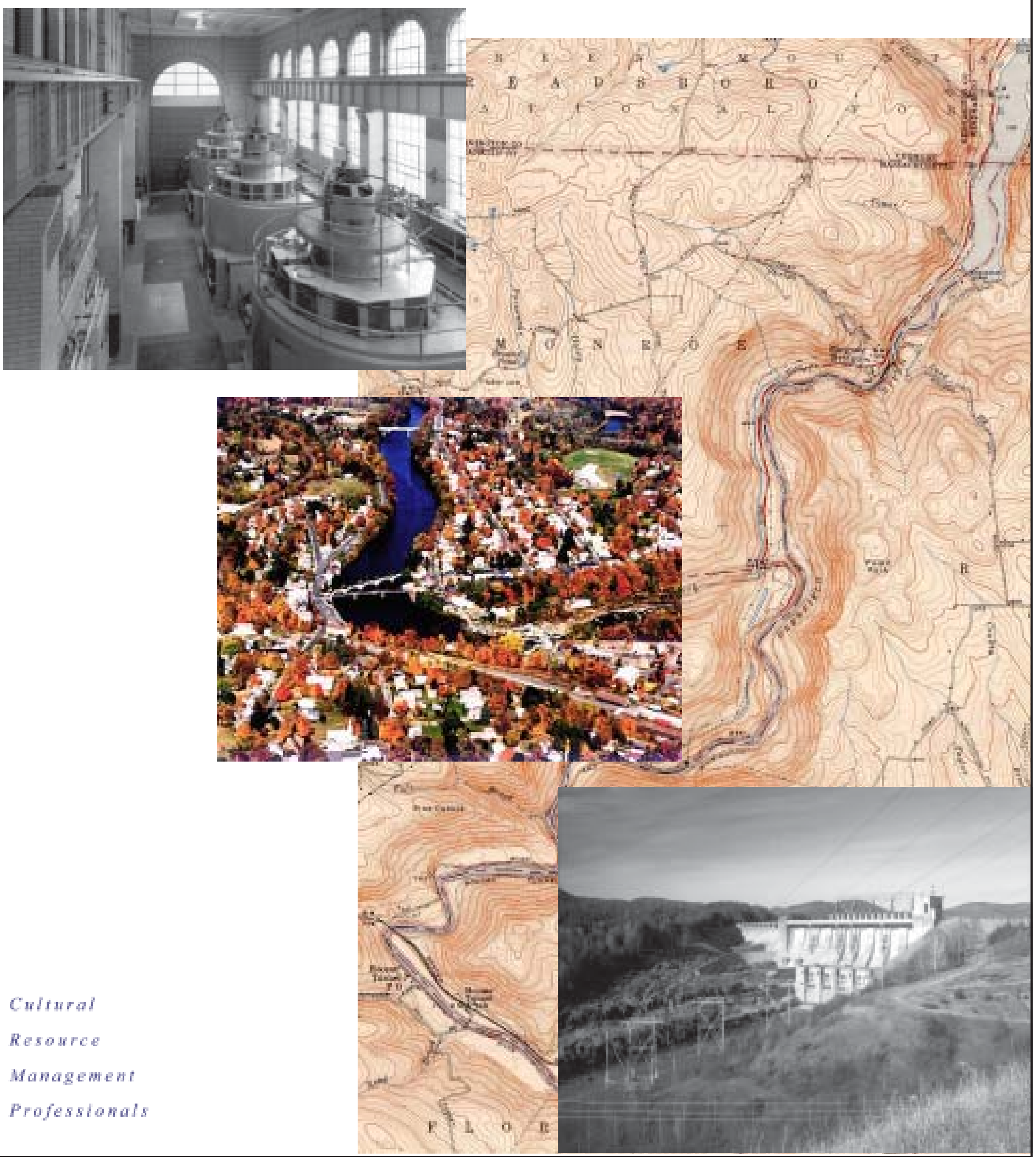
HISTORY OF HYDROELECTRIC DEVELOPMENT ON THE CONNECTICUT AND DEERFIELD RIVERS



Cultural Resource Management Professionals

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INTRODUCTION

In 1903, Malcolm Greene Chace (1875-1955) and Henry Ingraham Harriman (1872-1950) established Chace & Harriman, a company that, in its many incarnations over the course of the following decades, grew into one of the largest electric utility companies in New England. The company built a series of hydroelectric facilities on the Connecticut and Deerfield rivers in Vermont, New Hampshire and western Massachusetts, which were intended to provide a reliable and less expensive alternative to coal-produced steam power. Designed primarily to serve industrial centers in Massachusetts and Rhode Island, the facilities also provided power to residential customers and municipalities in New England. Chace & Harriman eventually evolved into the New England Power Association (NEPA) in 1926, which became the New England Electric System (NEES) in 1947. In the late 1990s NEES was purchased by the U.S. Generating Company and the hydroelectric developments were placed in a division of the company called USGen New England, Inc (USGenNE). (Landry and Cruikshank 1996:2-5, 29, 39, 67, 141; Cook 1991:13).

The history of electrical power generation in the United States is characterized by several stages of development. From about 1880 to 1895, direct current was produced by steam and/or hydroelectric stations and transmitted over small geographic areas, providing power to arc and incandescent lights. Improvements in the 1890s initiated a second phase of development, which focused on the potential of hydroelectric power for the transmission of alternating current over long distances. In the 1920s, the industry matured, equipment and designs became more standardized, and the structure of management companies became increasingly complex. While the Depression limited further growth of the industry, a new era emerged after World War II, with streamlined management structures and increased regulations and government involvement (Cook 1991:4; Landry and Cruikshank 1996:2-5). The first of the 14 hydroelectric facilities built on the Connecticut and Deerfield rivers by Chace & Harriman and its successors were developed in the early 1900s, shortly after the potential of hydroelectric power was realized on a large scale. Subsequent facilities were constructed during the maturation of the industry in the 1920s, and two of the stations were completed in the post-World War II era. The history of the companies that built these stations is intrinsically linked with broader trends in the history of electricity, hydropower technology, and industrial architecture in America. As such, the facilities together tell the story of hydroelectric power from its late- nineteenth-century origins to the present day.

EARLY AMERICAN ELECTRICAL HISTORY

Electricity first gained popularity in America in the 1870s with the introduction of the arc lamp by inventor Charles Brush of Cleveland. With their bright light and short life span, arc lamps predominated in commercial applications and public street lighting. Initially these lamps were run on individual generators, called dynamos. As their numbers increased, businesses began to support the construction of urban generating stations that could run up to a maximum of 60 lamps connected in series. These early stations used coal to drive a steam engine, which then turned a generator to produce electricity. The complex technology involved and the small size of the stations kept prices high and demand limited, posing little competition to the established gas-lighting companies. Despite these disadvantages, by 1880 Brush had installed central electric stations in major American cities like San Francisco, New York, Philadelphia, and Boston, and had over 5,000 arc lights in operation (Glover and Cornell 1951:671; Landry and Cruikshank 1996:11-14; Marcus and Segal 1989:143-5).

About the same time, Thomas Alva Edison's Edison Electric Company developed and introduced the enclosed incandescent light. In contrast to arc lamps, a large number of incandescent lights could be wired in parallel with low voltage direct current (DC), lowering the cost of illumination. The enclosed nature of the light, which was composed of a filament within a vacuum tube, also made it suitable for indoor use. While arc lights remained standard for public and commercial exterior use, these two factors immediately increased the demand for electric lights among residential consumers, creating a fierce rivalry with the existing gas companies. When Edison opened his first central generating station in New York City in 1882, the electrical power was initially distributed for free, enticing many converts (Landry and Cruikshank 1996:14-15; Marcus and Segal 1989:145-148).

Although Edison Electric had few rivals in the distribution and production of DC incandescent lighting, the technology had limited application until the development of alternating current (AC). The dissipation of DC electricity over distance caused most stations to be located in downtown areas, neglecting the demand for electricity in rural areas and preventing the exploitation of most potential water-power sites. DC also required a continual expansion in the number of powerhouses, as each quickly reached its maximum capacity.

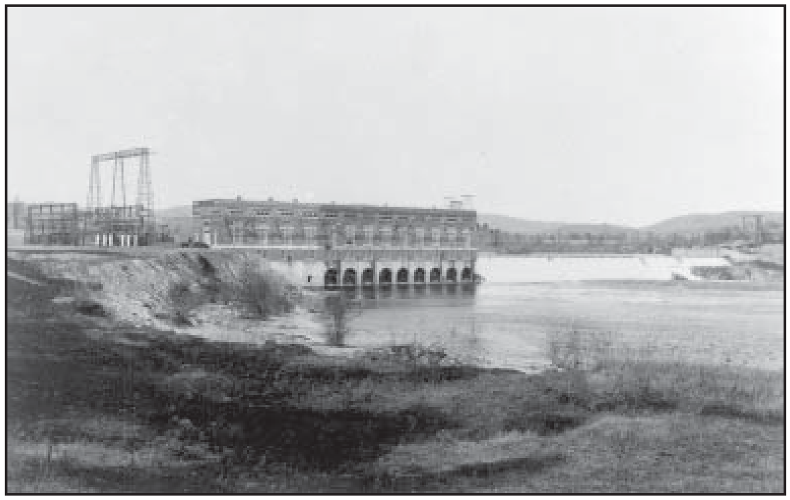
The introduction of AC electricity by George Westinghouse made electrical power more practical for both household and industrial use, allowing variations in voltage as well as decreased energy loss during transmission. At the 1893 World's Fair, Westinghouse won a contest that allowed him to build a generating station at Niagara Falls. His station was a brilliant success, transmitting power over a distance of 26 miles to Buffalo, New York with high profits, thereby triggering a "hydromania" for powerhouse construction and long-distance transmission. AC electricity was quickly embraced by those in thinly-populated areas who had not received DC power because of its prohibitively high cost. With its greater flexibility, lower cost, and unrestricted capacity, AC power began to challenge DC in the cities, encouraging the creation of larger central stations that could spread power throughout the outlying areas (Glover and Cornell 1951:674; Landry and Cruikshank 1996:18-23; Marcus and Segal 1989:149-150).

By the turn of the century, 18 utilities in Massachusetts generated hydroelectric power, although in most cases it was a supplement to, or back-up for, coal-produced steam power. The cost of transporting great amounts of coal to New England was high, however, and as hydroelectric technology improved, it became an obvious alternative. Unfortunately, most rivers were located in northern New England, far from the industrial centers that demanded the power source. Many also lacked the reservoirs needed to ensure a steady flow of water. Within three years demand had grown such that the Massachusetts legislature passed a law allowing special permits for new utility companies. Thus began the odyssey of Malcolm Greene Chace and Henry Ingraham Harriman, who built a series of remote hydroelectric power plants along the Connecticut and Deerfield Rivers, successfully transmitting the new power to the manufacturing centers of the region.

NEP HYDROELECTRIC POWER DEVELOPMENT ON THE CONNECTICUT AND DEERFIELD RIVERS

In 1903 Chace, the son of a textile worker, and Harriman, whose father was a judge and textile machinery inventor, formed Chace & Harriman with the intent of exploiting hydroelectric power in Maine. In 1907 a potential site was identified, not in Maine, but rather at Vernon, Vermont, on the

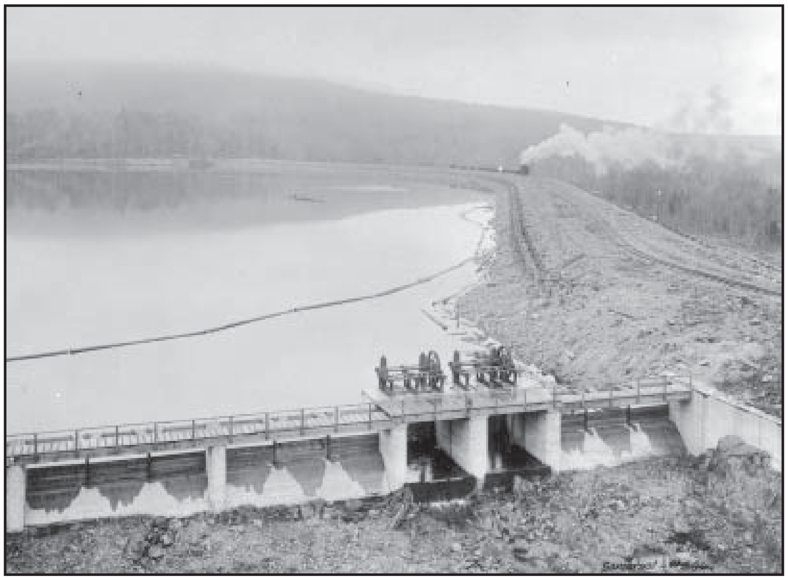
Connecticut River. This river, which flows approximately 400 miles from Third Lake in northern New Hampshire to Long Island Sound, drops 2,000 feet over the course of its journey. With its many falls, the river had attracted mills since colonial times. Local investors already had plans for its development as a hydroelectric power source by the time Chace & Harriman took over the project in 1907. The design of the Vernon Development was largely the work of the mechanical engineering firm of Charles T. Main, Inc., of Boston. An 1876 graduate of the Massachusetts Institute of Technology, Main was an authority on water and steam power and his firm, established in 1907, had been involved in the design of over 80 hydroelectric facilities by the time of his death in 1943. The construction of the Vernon station was completed by J. G. White & Company of New York, with 450 workers assigned to the project (Landry and Cruikshank 1996:26-35; Cook 1991:18-19).



Vernon Development, Hinsdale, NH/Vernon, VT, built 1907–1909, 1920. View looking northeast from the Vermont side of the Connecticut River, showing from left to right, the switchyard, powerhouse, and dam (undated photo). When completed, Vernon was the largest hydroelectric plant east of Niagara Falls, and was the first northeastern U.S. hydroelectric plant to deliver load via long-distance transmission lines.

Vernon was an ambitious facility that required raising the river 30 feet, flooding all or parts of 150 farms. Construction was finished within two years, however, and Chace & Harriman attempted to secure rights-of-way for transmission into north-central Massachusetts. After many complicated financial arrangements, including the creation of a holding company and a subsidiary company (Connecticut River Power Company of Maine and Connecticut River Transmission Company of Massachusetts, respectively), they received special permission to enter Massachusetts markets, provided sales were restricted to bulk customers. The first generator at the Vernon station went on line on July 27, 1909, supplying 60-cycle AC power at 19 kilovolts to the Estey Organ Works in Brattleboro, Vermont. By 1910 eight generating units produced a total of 20 megawatts, sent at 66 kilovolts a distance of over 60 miles, dwarfing the output of all other stations in the east. The unprecedented voltage and distance of transmission, as well as the construction of a line into Worcester, Massachusetts, quickly secured large customers such as the American Steel and Wire Company and Worcester Electric Light Company (Landry and Cruikshank 1996:26-35).

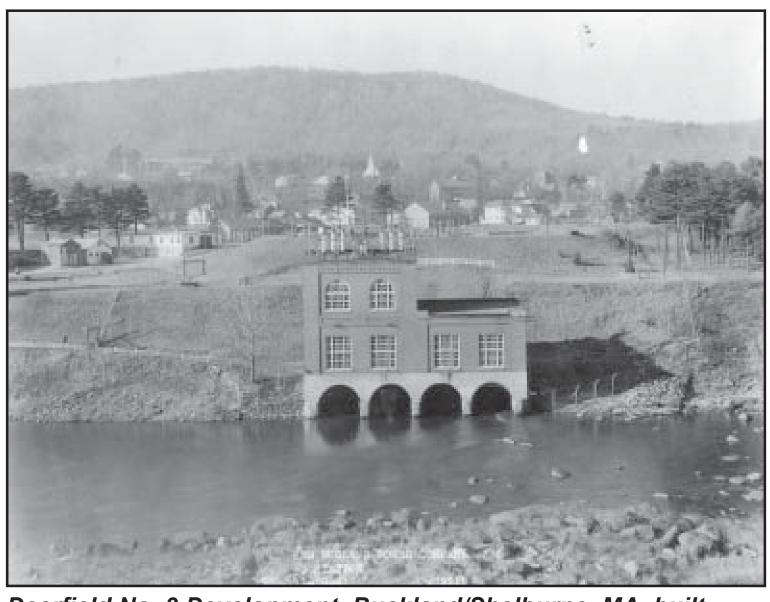
As demand grew and Vernon became unable to provide enough power during the dry season, Chace & Harriman focused their attention on the Deerfield River, which runs through southern Vermont and western Massachusetts before joining the Connecticut River below Turners Falls. Twenty miles southwest of Vernon, in Shelburne Falls, Massachusetts, the river drops 300 feet, creating an ideal location for a series of generating stations, provided a large reservoir could be built to regulate the flow and prevent flooding. Chace & Harriman created a Massachusetts-based company, New England Power, to oversee the construction of the Deerfield facilities, with financial backing from New England Power of Maine. The Power Construction Company, a subsidiary created by New England Power and headed by George Bunnell, managed the construction of the facilities. J. G. White & Company and Charles T. Main, Inc., both of whom had worked on the Vernon station, were employed as design consultants on the Deerfield River projects (Landry and Cruikshank 1996:38-40; Cook 1991:18-19; Cavanaugh et. al. 1993a; Cavanaugh et. al. 1993b).



Somerset Development, Somerset, VT, built 1911–1913. View of 2,100-ft-long, 110-ft-high modified hydraulic earth fill dam looking south with spillway in foreground. Construction railway track and steam locomotive pulling dump cars are visible on dam crest (ca. 1913).

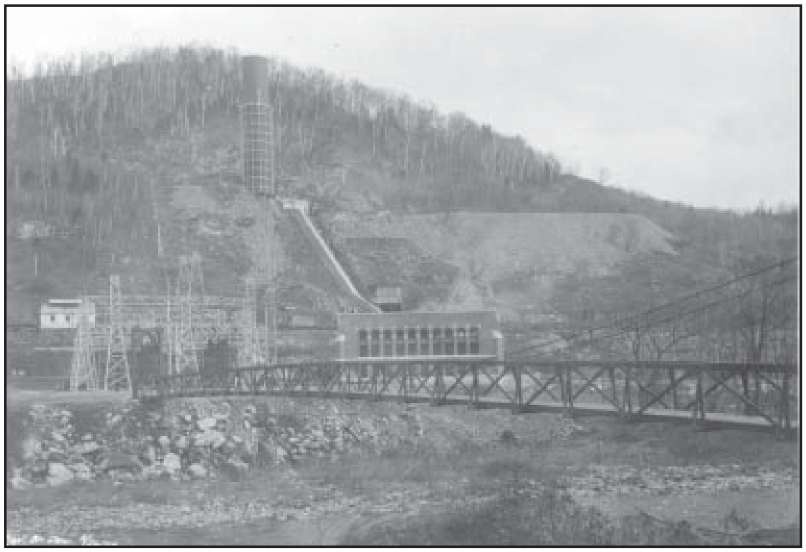
In 1914, Chace & Harriman's various companies were consolidated into the New England Company, a Massachusetts voluntary trust. At this time the company was the largest power provider in Massachusetts, providing more than all other companies in the state combined, Boston Edison aside. Rather than providing competition to steam power stations, however, the hydroelectric generating stations provided a convenient counterbalance to their output. In the winter, when more power was needed because of shorter daylight hours, water was more plentiful, while in the summer, when demand decreased, so did the flow of water. Advances in electric motor development also increased daytime industrial usage, expanding overall demand and distributing consumption more evenly over a 24-hour period. As the New England Company became more dominant in its position and demand continued to grow, it became evident that

By 1911, a three-mile-square (2.5 billion cubic foot) reservoir with a 456-foot long earthen dam had been built in Somerset, Vermont, north of Shelburne Falls. At the same time three standardized stations (Deerfield No. 2, Deerfield No. 3, and Deerfield No. 4) were built, each with its own concrete dam. These stations came online in 1912 and 1913, providing a total capacity of 18 megawatts. A fourth station, Deerfield No. 5, was built slightly upstream to provide power to the Hoosac Tunnel, a 4.75-mile-long railroad tunnel in the Berkshire Mountains that connected Boston with the Hudson River Valley. This station had a larger capacity of 15 megawatts, allowing it to accommodate the demand for sudden large bursts of wattage. Thus with the creation of the Deerfield transmission line and the addition of a full switching station at Millbury, Massachusetts, the transmission network was able to operate as a Vernon-Worcester-Millbury-Shelburne Falls-Vernon loop, allowing a broad customer base (Landry and Cruikshank 1996:38-40).



Deerfield No. 3 Development, Buckland/Shelburne, MA, built 1912 et seq. View of powerhouse looking south across Deerfield River from Shelburne Falls to Buckland (November 25, 1941photo). View shows turbine outfall arches below powerhouse. Deerfield No. 3 was the administrative and maintenance center for the Lower Deerfield developments, and several of the workshops and storage buildings are visible behind the powerhouse to the left.

the company needed to find its own seasonal steam-power backup, as well as build more stations. Satisfying these needs would require contracts with steam power producers, large investments in land, and costly reservoir construction (Landry and Cruikshank 1996:42-43).



Harriman Development, Whitingham/Readsboro, VT, built 1924 et seq. View of Readsboro facility looking east across Deerfield River, showing from left to right, switchyard, surge tank, powerhouse, and footbridge (November 26, 1924 photo). The Harriman Development incorporated several major works of engineering and was the showpiece of the Deerfield River developments.

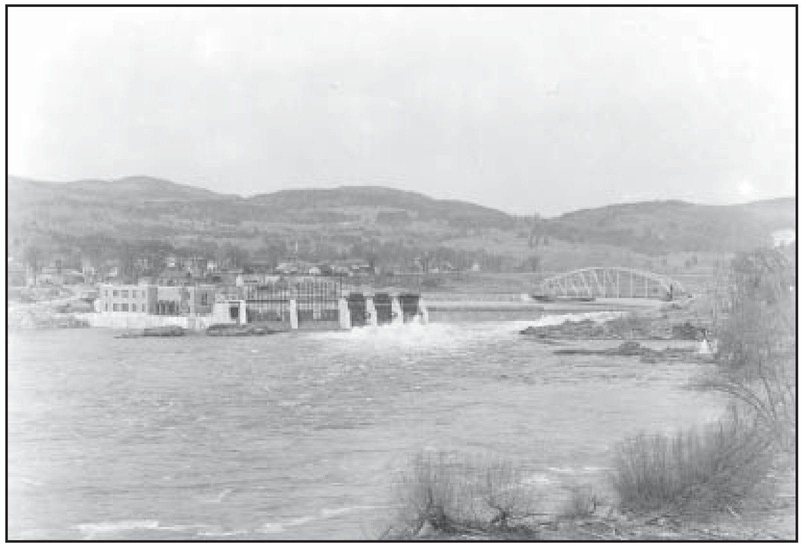
World War I caused severe shortages and a drastic increase in the cost of power. The price of coal doubled and the workforce was severely reduced, inspiring a push towards conservation and the adoption of daylight savings time. New construction was limited to connections to areas of strategic military importance, forcing small utilities to buy power from larger utilities, which were better able to balance power distribution to accommodate shifting needs. Despite rate increases caused by wartime shortages, annual kilowatt sales between 1916 and 1920 grew from 246 million to 431 million. The war also fostered an interconnection of transmission lines among utilities, and by 1920 the New England Company controlled 300 miles of line, a fivefold increase from a decade earlier, creating a network that stretched from Lake Erie to the Atlantic Ocean (Landry and Cruikshank 1996:52-53).

To ease the wartime power shortage, the U.S. Department of the Interior agreed to work with the company to pay for the Davis Bridge Development (later named Harriman) in Whitingham, Vermont. Called the "White Coal Project," this endeavor included an expanded powerhouse and two 4.2 megawatt generators at Vernon, nearly doubling its peak-hour capacity, as well as a 5-megawatt station and dam at Searsburg, Vermont. Despite Vernon's increased capacity, it was soon to be dwarfed by the Harriman station. Approximately 1,200 people worked on the $10 million project, which included the construction of a large powerhouse, a concrete spillway, and a 2,200-acre reservoir, creating the largest man-made lake in Vermont, with double the storage capacity of the Somerset reservoir. At 1,300 ft long and 215 ft high, the dam was the highest earthen dam built at the time of its construction. Previous Deerfield River projects regulated the western branch of the river; with the addition of the Harriman station, the eastern branch was brought under control as well. Together with the Somerset dam, the Harriman dam was one of the earliest structures outside of the Panama Canal to employ the hydraulic fill method of construction, which involved dumping material into two dikes, and then washing the dikes with water to filter the fines into the ditch between them. This procedure produced a dam with an impervious core. When it opened in 1924, the Harriman Development, named in honor of its founder, was the largest hydroelectric facility east of Niagara Falls and supplied 40,000 kW, almost doubling the total output of the Deerfield River. Its large size necessitated the construction in 1927 of a smaller hydroelectric station downstream at Sherman to even out any sudden discharges. After the construction of both stations was complete, power was transmitted from Harriman to Millbury, Massachusetts, on a 110 kilovolt line, the first to exceed the 66-kilovolt standard (Landry and Cruikshank 1996:38-40, 54-59; Cavanaugh et. al. 1993b).

Bellows Falls Development, North Walpole, NH/Rockingham, VT, built 1925–1928. View of powerhouse looking north with transformers at right (November 3, 1941 photo).

Despite the large scale of Harriman, demand for electricity continued to increase beyond the available supply. Much of this demand came from residential customers who were beginning to use electric appliances as well as electric lights. In 1918, less than one-third of American homes were wired for electricity. By 1929, however, the number had grown to over two thirds. Therefore, as soon as Harriman was finished, the company broke ground at a site 30 miles north of Vernon at Bellows Falls, the downtown location of a small subsidiary known as the Bellows Falls Power Company. This company had been created by Chace & Harriman in 1912 through the purchase and reorganization of a canal company and two small hydroelectric companies. In 1918 they decided to rebuild the canal and build a new power station, guaranteeing the Fall Mountain Paper Company (partial owners of the water rights) a supply of electricity. Within eight years the paper company shut down and sold their water rights to Bellows Falls Power. The construction of a new hydroelectric station began immediately, despite delays caused by the flood of 1927. While the old canal provided one million gallons per minute and produced 10,000 horsepower, the new canal was able to send 4.2 million gallons per minute to the turbines providing 60,000 hp to produce 49,000 kW. This dramatic increase in water capacity was achieved through the construction of a new dam, which was slightly higher than its predecessor. Although the head was only 60 feet, the power capacity of the Bellows Falls station matched that of Harriman (Landry and Cruikshank 1996:59-62, 72).

After World War I, the New England Company was desperately in need of financial backing and feared the loss of their customer base to the larger holding companies that had emerged in the prosperous years after the war. To assuage these worries, Chace & Harriman decided in 1926 to sell most of their company to the International Paper Company. While the International Paper mills were no longer economical paper producers, they were still capable of creating hydroelectric power. Archibald Graustein, President of International Paper, was open to replacing his failing paper empire with a power empire. At the same time, Chace & Harriman were anxious to get an infusion of equity capital from International Paper, thereby allowing the company to launch a counterattack against bigger companies and establish a larger customer base. Therefore, Graustein, Chace & Harriman developed the New England Power Association (NEPA), which was essentially a compilation of its old holding companies and all of its subsidiaries. International Paper, Northeastern Power, and Stone & Webster were ceded a majority position in the enterprise in exchange for $20 million, and Chace & Harriman retired to the board. This reorganization was followed by a wave of acquisitions handled by the newly-hired President, Frank Comerford. Even with the increased efficiency and capacity of the existing hydroelectric stations, the most efficient power sources continued to combine steam and water power, leading Comerford to purchase a gas company, multiple retail units, and more steam plants before the onset of the Depression (Landry and Cruikshank 1996:65-84).



McIndoes Falls Development, Monroe, NH/Barnet, VT, built 1931. View looking northwest from the New Hampshire side of the Connecticut River, showing, from left to right, the powerhouse and dam (April 13, 1931 photo). McIndoes Falls, one of three facilities in the Fifteen Mile Falls Development, was built as a run-of-river facility to even out discharge flows from the larger Comerford Development upstream.

Harriman had purchased the rights to an area known as Fifteen Mile Falls on the Connecticut River in 1910. At the time, the Falls' low volume made development impractical, and Harriman soon sold his rights. Immediately after the company's reorganization in 1926, however, NEPA was more confident and re-purchased the site. Its power potential was high, allowing for two large reservoirs of an extremely high volume. Unfortunately, NEPA's customer base was not large enough to justify building at such a large, yet cost-efficient size. To solve this problem, Comerford arranged a deal with Boston Edison in which they would buy one-third of the station's output (150 million kilowatts) at $2 million per year for 20 years. Thus began one of NEPA's greatest engineering feats. To divert the river, reshape the old river bed, and build the dam, the company excavated more than 1 million cubic yards of rock, mixed and poured 300,000 cubic yards of concrete, and consumed 5,000 tons of structural steel. A small town of workmen emerged on a hillside in Barnet Township, Vermont, to construct the complex, which doubled NEPA's peak capacity for hydroelectricity by adding 160 megawatts and saving the 200,000 tons of coal that would have been needed for steam power. Water first spun the turbines in September, 1930, after a month of accumulating in the reservoir behind the dam. Aptly named "Comerford," the station transmitted power to a switching station in Tewksbury, MA, traveling a distance of 126 miles, through 2,000 steel towers, and over 800 miles of aluminum cable (Landry and Cruikshank 1996:87, 90-91).

NEPA had planned three developments at Fifteen Mile Falls. The second project was located seven miles downstream from Comerford. A small auxiliary plant, the new facility was designed to even out any sudden discharges of water. This plant, called McIndoes Falls, came on line in 1931, one year after Comerford, bringing the Fifteen Mile Falls capacity to a total of 175,300 kW. The stations at Comerford and McIndoes Falls were both designed by Charles T. Main. The development of the third site at Fifteen Mile Falls was postponed until a further increase in demand warranted the investment (Landry and Cruikshank 1996:90-91, Cook 1991:18-19).

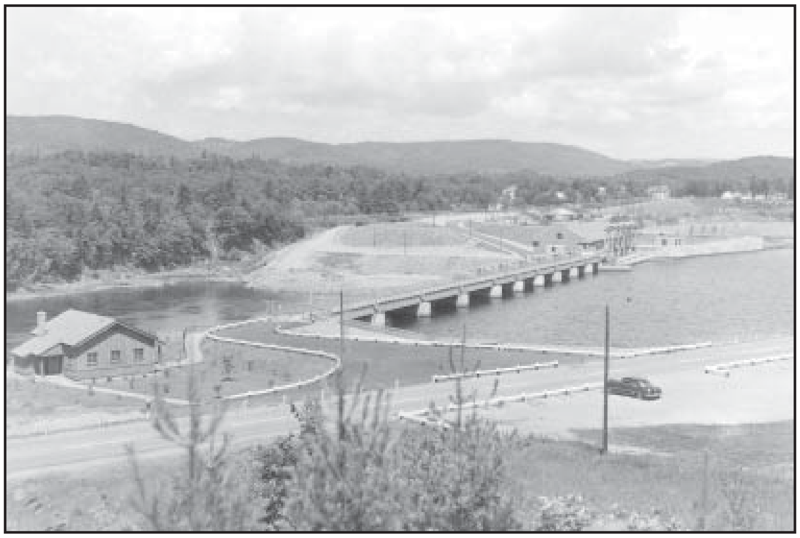
NEPA's period of expansion in the early 1930s came to a halt with the Depression, as the company struggled to pay for McIndoes Falls. Investors were scared off, emergency taxation was introduced, and NEPA was plagued with cumbersome finances, an overly complicated organization, overcapitalized holdings, as well as several new businesses. A series of natural disasters also plagued the company during the 1930s, including the great flood of 1936 and the Hurricane of 1938, both of which caused damage to several of NEPA's facilities. In 1932 the company's retail sales, which had always risen, declined for the first time and employment levels fell. When enraged investors forced the government to investigate utilities after the market crash, NEPA's convoluted financial organization was disclosed and the company was forced to implement an immediate simplification of the corporate structure. The Federal Trade Commission then passed the "Public Utilities Holding Company Act," which prohibited holding companies that unnecessarily complicate corporate structure and gave the Federal Power Commission the power to regulate interstate utilities. After working carefully together with the government on this issue, Harriman resigned, Comerford became president of Boston Edison, and International Paper and many of its subsidiaries were liquidated.

The Depression also spurred several positive changes, allowing NEPA to emerge as a stronger company when the economy finally bounced back. Government intervention made NEPA once again independent by 1947 and created a simpler organizational structure. The lower demand forced a decrease in rates, as well as an intensification of "load-building" programsCaggressive marketing and merchandising programs designed to increase residential demand. NEPA sold appliances to increase household electrical use and pushed for rural electrification by encouraging the agricultural use of utilities. By 1940 demand was again rising and employment was up, allowing NEPA to incorporate line extensions and upgrades (Landry and Cruikshank 1996:93-119).

With the onset of World War II, NEPA began strengthening those operations that had slackened during the preceding decade. Many employees were sent off to war, and those that remained were under pressure to meet the heavy demands of the many military and war-related factories despite severe shortages of labor and materials. Many of NEPA's employees also worked with the government to speed the transition of new weapons from experimental to operational. This advanced technical involvement gave NEPA the experience that would later give it a prominent role in post-war energy planning. As the economy began an upswing, civilian energy use remained limited and many furnaces were converted from oil (the newer fuel source) back to coal. During this time NEPA also saw an influx of new executives, including President Irwin Moore and Vice-President William Webster (Landry and Cruikshank 1996:121-135).

On June 3, 1947, NEPA was renamed New England Electric System (NEES), creating a new holding company and refinancing all other assets, including three wholesale companies, 36 retail companies, one service company, a street railway, and four miscellaneous companies. At the same time, a number of large shoe and textile manufacturers began to close, bringing unemployment to New England and threatening load growth. As increasing numbers of businesses were forced to close, the public began to blame utilities, which were consistently more expensive in New England than elsewhere in the country. Contrary to popular belief, utilities were expensive because of the higher costs of transporting fossil fuels over a large distance and the need for materials to withstand harsh weather. In addition, the failure of businesses was due less to high utility bills, and more to increases in unionization, wages, and taxation. The public also failed to acknowledge its increasing use of electricity, noting only the rising total cost. Regardless of the facts, dissatisfaction quickly led to the demand for public utilities. As the economy became more diversified, however, new jobs were offered at higher wages, increasing load and eventually silencing the public utility scare (Landry and Cruikshank 1996:137-149).

Despite the fact that hydroelectric power remained economical, post-war development included only two new hydroelectric plants, both on the Connecticut River. These complexes were the last conventional hydroelectric stations brought into the NEES system. In 1950, a $16 million, 33-megawatt plant went on-line in Wilder, Vermont, 40 miles north of Bellows Falls. This plant replaced an earlier facility called Olcott Falls, and drew substantial local opposition. The new 2,000-foot-wide dam raised the water level 15 feet, extending the existing pond 27 miles upstream toward the McIndoes station. Steep banks kept flooding to a minimum, affecting only 1,200 acres of land and submerging 335 acres of farmland. To ease tensions NEES agreed to pay for the flooded land and to move any utilities, such as railroads or roads, that were affected (Landry and Cruikshank 1996:149-151).



Wilder Development, Lebanon, NH/Hartford, VT, built 1950. View looking northwest from the New Hampshire side of the Connecticut River, showing from left to right, the visitors' center, dam, and powerhouse (July 17, 1952 photo). This development was the first built on the Connecticut River after World War II. It replaced a preexisting plant and was constructed to meet increasing peak period electricity demands.

The new Wilder complex covered some of the increasing peak demand, but in 1952 a dark forecast was issued by a group of utility executives known as the Electric Coordinating Council of New England. They predicted that peak load requirements would more than double over the next 20 years, from 3,800 megawatts to 8,000 megawatts. The generous reserve margins of the depression era had dropped to 16 percent, meaning that even more peak-load power would be needed. Bob Brandt, the head of power planning in the 1950s, worked with the Federal Power Commission and neighboring utilities to ensure that the New England region would remain covered. Only one potential site remained undeveloped: the property at the upper part of the Fifteen Mile Falls area, originally purchased in the 1920s. Whereas the site's development would have been excessive and impractical several decades ago, NEES was now criticized for taking so long to build an additional station. The new Samuel C. Moore station (named after President Irwin Moore's father and the company's longtime general manager) resembled Comerford in size and construction, with a massive concrete and earth core dam that created a reservoir covering 3,500 acres. The powerhouse, with four identical turbines producing 190 megawatts at full capacity, was located below the dam. The $41 million project took three years to complete, and employed 500 people. It was $9 million below budget and began producing electricity in 1957. This large conventional hydroelectric development allowed the Connecticut River to operate as a hydropower delivery system, combining multiple reservoirs and powerhouses. As the river wound from Moore to Vernon, each cubic foot of water produced 37 kilowatt-hours for the system. Downstream stations added an additional 530 megawatts and the Deerfield tributary another 110. No other river of comparable length in the country could equal the Connecticut for hydropower development (Landry and Cruikshank 1996:149-150).

In 1954, President Eisenhower signed Senator John Pastore's bill allowing the private development of nuclear power. NEES' Vice President, William Webster, who had returned from consulting on the wartime Atomic Energy Commission in 1951, was convinced that nuclear power was the energy of the future. He arranged a consortium of nine northeastern and midwestern companies to study the commercial applications of nuclear fission. With preliminary research behind him, he announced the formation of the Yankee Atomic Electric Company as soon as the bill was passed. His desire was for all of the regional utilities to share in the benefits, as well as the risks, inherent in the development of the new technology. Nine other utilities, as well as key government officials, businesses, and the press, decided to back the project. In 1957, after the completion of a smaller experimental facility by Westinghouse and Stone & Webster at Shippingport, Pennsylvania, construction began on the first full-scale demonstration plant, situated in Rowe, Massachusetts in the Deerfield River Valley. The plant went online in 1960 at a cost of $39 million, well below the $57 million estimate. It was the second commercial atomic plant in the country, setting many of the standards for subsequent reactors (Landry and Cruikshank 1996:162-167).

In the following decade, regional prosperity and lower-cost power combined to put NEES in a stronger operating position than in previous decades. Substantial savings from continual consolidation and the growing use of computers simultaneously allowed for wage increases and a decrease in rates. These two factors combined with tax cuts to allow New England to reach the national average in economic and load growth despite its low population increase. By 1962, NEES' electric properties had been consolidated along functional lines into one retail company, a single power wholesaler, and a service company in each state. Webster, president of the company since 1959, saw three possibilities for increased prosperity: lower costs through newer plants, economies of scale through higher loads, and lower fuel costs. Therefore, he began to try to license increasing numbers of nuclear plants, whose capacity dwarfed that of hydroelectric plants. In response to the blackout of 1965, Webster also participated in the philosophy of power pooling with other regional utilities, sharing resources in times of natural disaster. Consequently, the New England Power Exchange (NEPEX) was organized in 1967, linking all utilities to prevent shortages or blackouts. Shortly thereafter the New England Power Pool (NEPOOL) was formed to develop region-wide power dispatching (Landry and Cruikshank 1996:170-195).

The beginning of the fuel crisis was marked by a sharp increase in the price of imported oil in 1973. Escalating inflation exacerbated the crisis, causing many power companies to return to burning coal despite an increased sensitivity to pollution. In response to these problems, NEES began a large-scale initiative to cut back costs, improve finances, and develop a new customer relations strategy. Nuclear plants, which had been the hope of the future, were no longer tenable because of high interest rates, skeptical investors, and grass-roots environmental opposition. Thus NEES began a new strategy based on conservation and domestic fossil fuels, concentrating on domestic oil exploration. A large Research and Development department was created to explore alternate fuel sources and ways to reduce pollution. Other changes included the establishment of conservation and load management to minimize capacity requirements, the diversification of energy sources, and the decision to purchase power from plants that ran off of renewable energy sources such as trash, solar, and wind. Together, these changes reduced dependence on imported oil, allowing the country and the company to weather the crisis (Landry and Cruikshank 1996:199-229).

When prosperity returned in the 1980s, the focus on cost-consciousness and conservation remained. Most of the steam-generating units had been converted to coal and fuel prices fell dramatically. NEES emerged from the 1980s poised to face any future restructuring with stronger finances, an improved generating position, and slow load growth. The ever increasing environmental awareness, however, caused a number of small, yet significant changes. While hydroelectric plants are on balance non-polluting, they can prevent fish from migrating upstream to spawn. In the early 1980s, state wildlife officials required NEES to construct fish ladders, which channel fish around dams and turbines. These bypass mechanisms, built at a cost of $10 million each, were installed at Vernon in 1981, and later at Bellows Falls and Wilder, allowing anadromous fish such as Atlantic Salmon and shad to reproduce. By the 1990s the fish population in the Connecticut River had again reached healthy levels (Landry and Cruikshank 1996:231-242). Fish ladders are currently being installed at the Deerfield complexes.

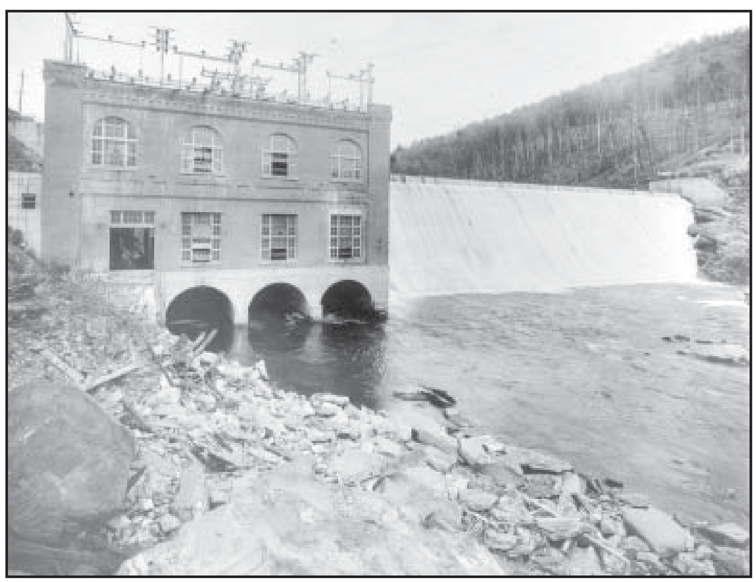
In the 1990s deregulation became a dominant theme in the restructuring of the power generation industry. It created a more competitive power-generating market that allows private power producers to utilize extant transmission and distribution systems, thereby providing consumers with a wider choice of producers. This development caused a number of large utilities, including NEES, to agree to separate power generation from transmission and distribution, recreating Chace & Harriman's initial arrangement. In 1998, USGenNE acquired the hydroelectric generating facilities on the Deerfield and Connecticut rivers. As part of the agreement NEES retained control of the transmission facilities. USGenNE was subsequently acquired by the PG&E Corporation and became part of the company's PG&E National Energy Group (PG&E NEG). In 2003, PG&E NEG and its subsidiaries, including USGenNE, declared bankruptcy. As part of the companies restructuring effort, PG&E NEG was separated from the parent company and changed its name to the National Energy and Gas Transmission, Inc. (NEGT). USGenNE continues to operate the hydroelectric developments on the Deerfield and Connecticut rivers as a subsidiary of NEGT.

HYDROPOWER TECHNOLOGY ON THE CONNECTICUT AND DEERFIELD RIVERS

At the end of the nineteenth century, hydroelectric generating technology was in its infancy, and utilized equipment configurations adapted from textile mill practice and other water-powered industrial applications. During the first quarter of the twentieth century, hydroelectric engineers developed a variety of water delivery systems, and standardized mechanical and electrical equipment that allowed generating capacity to meet growing demand. USGenNE's Connecticut and Deerfield river developments incorporate a range of water delivery infrastructure and generating equipment reflecting the history of hydropower technology from its earliest forms to mature industry standards.

The Vernon Development (1909), Chace & Harriman's first hydroelectric station, was conceived as a single project. Vernon was important technologically as the first northeastern U.S. hydroelectric plant built remote from a load center and to deliver its load via long-distance transmission lines. Transformers at Vernon raised the electricity to 66 kV, enabling it to be transmitted over 60 miles to Gardner and Fitchburg, Massachusetts, a voltage and distance that were unprecedented in the northeast. When Chace & Harriman turned their attention to the Deerfield River (1911-1927), they envisioned developing the whole river drainage as an integrated, multi-station system, much like the Big Creek and other hydroelectric systems being developed in California at that time. Upstream reservoirs at Somerset (1911) and Harriman (1924) insured a reliable, regulated flow of water, and run-of-river facilities like Sherman (1927) evened out sudden discharges from larger powerhouses. This integrated, river-as-system approach was also taken by the New England Power Association and New England Electric System with their development of the three Connecticut River developments at Fifteen Mile Falls, Comerford (1930), McIndoes Falls (1931), and Moore (1957), where McIndoes absorbed surges of water from Comerford.

Hydroelectric facilities incorporate two types of water delivery systems, concentrated-fall, and divided-fall. In a concentrated-fall system the dam



Deerfield No. 2 Development, Conway/Shelburne, MA, built 1912–1913. View of powerhouse and dam looking north from Conway side of the Deerfield River (ca. 1913 photo). Deerfield No. 2 is a concentrated fall facility, where the dam and powerhouse are integral.

Searsburg Development, Searsburg, VT, built 1922. View looking south across Deerfield River showing surge tank (above) and powerhouse (below) (June 29, 1923 photo). Searsburg is a divided-fall facility, where the dam and powerhouse are separate. Water from the Searsburg dam is directed to the powerhouse through a 3.5-mile-long, banded wood stave penstock.

and powerhouse are integral or closely spaced, and the impoundment behind the dam acts as a forebay, providing water directly to the powerhouse. In a divided-fall system, the dam and impoundment are located at some distance from the powerhouse. Divided-fall systems are usually found in more rugged terrain, such as in the Deerfield River Valley, and concentrated-fall systems are more typical of flatter areas, such as the Connecticut River Valley. On the Deerfield River, the large Somerset and Harriman storage reservoirs were built to provide a constant, regulated flow of water to a series of mostly divided-fall generating stations downstream, some of which received their water through a variety of delivery systems. On the wider Connecticut River, which has a greater, more regular flow, most of USGenNE's hydroelectric developments are of the concentrated-fall type.

At some of the Deerfield River developments, the water delivery systems involved considerable feats of engineering. On the Deerfield River, large dams were built at Somerset, Searsburg (1922), Hariman, and Sherman. These dams were constructed in whole or in part using variations on the hydraulic-fill method, where a series of parallel dikes of rock and earth were built up with dump cars or railroad cars, and water was sluiced over the dikes to wash the loose material into the space between them to form a core that was impervious to water (Hay 1991:53). The Harriman dam was the largest semi-hydraulic earth-fill dam built to date when it was completed, and created the largest man-made body of water in Vermont (New England Power Company 1992: AHarriman Development). Most of the dams at the USGenNE developments incorporate ogee-profile, gravity-type spillway sections. Gravity dams rely on their own weight on their bedrock foundation to hold back the water behind them. The first concrete gravity dam was built in San Mateo, California in 1887 (Hay 1991:xix). This type of dam was a departure from the rock-filled wooden crib dams that were typical in New England at the time, and came into standard use in the region during the first quarter of the twentieth century (Cook 1991:18-19). USGenNE's gravity dams are typical in their linear form and ogee profile. These dams incorporate a variety of types of height-regulating equipment including flashboards and sluice gates. Most of the larger dams use tainter-type gates, however, the Bellows Falls dam (1928) is unique on USGenNE's Deerfield and Connecticut rivers for its use of roller-type gates.

Some of the water delivery systems were comparable to those employed in hydroelectric developments in California and the rugged American west (Hay 1991:44, 53-58). At Searsburg, water was conveyed from the dam to the powerhouse via a sinuous, 18,412 ft long, 8 ft diameter, wood-stave conduit that provided 230 ft of head. The utilization of this type of water conduit was made possible by the invention of the surge tank, a type of large standpipe that equalized pressure differences within a pipeline that could potentially damage the system when turbine gates were closed rapidly (Hay 1991:58-59). At Searsburg, the New England Power Company incorporated a Johnson differential surge tank in the conduit system to regulate system pressure. The Deerfield No. 4 Development (1912) included a 1,514 ft long tunnel blasted out of bedrock to connect the dam to the forebay above the powerhouse. The Harriman Development incorporated two additional engineering feats. A 12,812 ft long, 14 ft diameter bedrock tunnel was built to connect the dam and powerhouse, providing 390 ft of head. The 180 ft deep vertical shaft spillway was the deepest such structure built up to that time. The Harriman water delivery system also incorporated a 184 ft high surge tank. Rock tunnels were also part of the Deerfield No. 3 and No. 5 developments, with the latter also incorporating a 2.8 mile long canal/conduit/tunnel water delivery system.

In addition to constructing new water delivery infrastructure, preexisting industrial waterpower infrastructure was adapted and modified for subsequent hydroelectric development. This was not an unusual practice in New England, where many major waterpower privileges had been developed for industry (Hay 1991:44). Examples include the use of the International Paper Company's mill rights and power canal at the Bellows Falls Development, the development of the Lamson & Goodnow Manufacturing Company's dam site at the Deerfield No. 3 Development (1912) and the use of the former James Ramage Paper Company's dam at the Deerfield No. 5 Development (1913).

One of the most important improvements in hydroelectric technology was the development of the modern vertical-shaft turbine-generator unit, which dictated the configuration of powerhouse infrastructure including the penstocks, generator room, and foundation substructure. Around 1900, most turbines were set vertically, which was a more efficient orientation hydrologically, however, the thrust bearing technology required to practically link vertical turbines and generators had not yet been developed, and most electrical generators were designed for horizontal shaft operation. Early vertical-shaft hydroelectric turbine-generator configurations consisted of single- or multiple-runner Francis-type fixed-blade turbines set into open flumes, where the weight of the water in the open flume pressing against the turbine blades spun them by force of gravity. Horizontal Francis turbine-generator settings placed the turbine in a cylindrical steel case that was prone to efficiency-robbing turbulence and made maintenance of submerged bearings problematic. These were the limitations of the two basic turbine-generator configurations at the time that Chace & Harriman began to plan their hydroelectric developments.

The first practical direct-connected vertical turbine-generator units were developed in 1905 by Gardner S. Williams and placed into service in a hydroelectric plant at Sault Ste. Marie, Michigan. This new technology may have influenced the choice for vertical units at Chace & Harriman's 1909 Vernon powerhouse, which incorporated vertical turbine settings with triple Francis runners in open flumes for the first eight units installed. These generating units were a hybrid of new and old technology. They

Deerfield No. 3 Dam, Buckland/Shelburne, MA, built 1912, The dam was constructed on an existing water priviledge initially developed in the nineteenth century by the Lamson & Goodnow Manufacturing Co. (undated photo).

incorporated new vertical bearing technology with open flumes and stock pattern turbines, which were typical of lower-efficiency, late- nineteenth-century mill waterpower technology (Hay 1991:65-67).

Early vertical thrust bearings were, however, maintenance-prone as they employed mechanical ball, cone, or roller bearings, which wore out rapidly. This may have prompted Chace & Harriman to choose horizontal shaft settings for Deerfield 2, 3, and 4 developments, built between 1911 and 1913. The turbines at these developments were set in cylindrical, riveted sheet steel "boilerplate" cases, with the shaft passing through a stuffing box into the powerhouse where the generators are located.

Subsequent improvements in vertical thrust bearings incorporated pressurized oil films, although these systems required pumps and extensive piping. In 1898 Albert Kingsbury developed the pressure-wedge thrust bearing, which did not require pumped oil. This bearing saw its first application in 1912 at the McCalls Ferry hydroelectric station on the Susquehanna River in Pennsylvania. The introduction of pressurized oil-film and Kingsbury pressure wedge-type bearings resulted in a dramatic change in hydroelectric plant design, as it made possible vertical-shaft turbine and generator settings of much greater size. The vertical setting swept hydroelectric plant design, and by 1915 many plants were being built with vertical settings (Hay 1991:71-75). The Deerfield No. 2, 3, and 4 developments are USGenNE's only horizontal-shaft units. The remainder of the Deerfield River and all the Connecticut River developments incorporate vertical shaft turbine settings using variations on oil-film bearings.

The development of successful vertical-shaft turbine settings led to advances in turbine efficiency. New powerhouse substructures began to be built with specially designed scroll cases surrounding the turbines. These spiral-shaped cast concrete or metal channels directed water into the turbine blades in a spiral motion, increasing the efficiency of the turbines. Improved elbow-shaped draft tubes were also developed to improve the efficiency of tailraces that carried water way from the turbines (Hay 1991:80-85).

In 1920 the New England Company added two new generating units to the Vernon powerhouse, consisting of two vertical-shaft, Francis-type, single fixed-runner turbines set into concrete substructures with scroll cases and draft tubes. The improved efficiency of this new technology prompted the New England Company to reequip units 5-8 with improved wheel cases and runners to improve efficiency in 1921-1922. Between 1923 and 1925, units 1-4 were radically redesigned, their triple-runner turbines replaced with single-runner units and updated substructures. All units were subsequently outfitted with improved, Gibbs-type vertical thrust bearings. The variety of turbines and substructures installed at Vernon is evidence of efforts to keep its equipment in line with industry advances over time (New England Power Company 1992: "Vernon Development," New England Power n.d.: Vernon Station).

During this time, increasingly large and powerful vertical shaft turbine-generator units with improved thrust bearings and scroll case/draft tube substructures were employed on the Deerfield River at Searsburg, Harriman, and Sherman. At the time of its completion, the Harriman Development was the largest hydroelectric power development east of Niagara Falls, supplying power on a 110-kV line to Millbury, Massachusetts. This line was the first to exceed the 66-kV standard. In total Harriman produced 140 million kV annually, almost doubling the previous output of the Deerfield River (New England Power Company 1992: "Harriman Development," New England Power n.d.: Davis Bridge Development). The Harriman Development, notable for its major engineering feats in its water delivery system, was also important for its powerhouse design, which represented the culmination of progress in hydroelectric generating made during the first quarter of the twentieth century. Its multiple-unit, vertical-shaft, large-diameter, single-runner, Francis-type turbine arrangement, combined with oil-pressure bearings and special scroll cases and draft tubes, were a mature expression of hydropower technology and infrastructure, and was the mode adopted for the New England Power Association's expanding development of the Connecticut River starting with the Bellows Falls Development in 1928, which incorporated the same technology and types of equipment.

After Bellows Falls was completed, the Connecticut River developments increased dramatically in physical size and generating capacity. These developments include Comerford, McIndoes Falls, Wilder (1950), and Moore. The increase in generating capacity was due to ever-increasing power of head, turbine runner diameter, and generator size. Technologically, these Connecticut River developments are typical of hydroelectric generating facilities of the mid- twentieth century that incorporated standardized equipment configurations that were interconnected to provide electricity to larger areas (Cook 1991:4, Hay 1991:xi-xii). The powerhouses incorporate the major elements that characterize large-scale hydroelectric generating technology during this period, including multiple, vertical-shaft, single-runner, large-diameter, high-horsepower, low-rpm turbines with scroll cases cast into their foundations, vertical thrust bearings, and improved tailrace draft arrangements. The technological advances incorporated in the Connecticut River developments mainly consisted of changes in turbine blade design and speed control governors.

The Comerford Development was a massive undertaking and the largest hydroelectric development in New England when completed. The powerhouse generated 162,300 kW, twice the combined capacity of the three previous New England Power Association Connecticut River hydroelectric developments. The high generating capacity of these large units is evidence of the ability of technological advances to meet increased electrical demand. The Comerford turbine-generator units incorporate fixed-blade, Francis-type turbines. Although this type of turbine has its origins in nineteenth-century technology, the runners at these later powerhouses are of modern design incorporating highly-efficient vane contours, and are appropriate for their high-head water sources, which provide flows of little variation (Hay 1991:78-80).

In 1931 the McIndoes Development was built downstream from Comerford as a run-of-river station to even out any large releases of water from Comerford. It is not a high-capacity station. The most significant technological feature of the McIndoes Falls Facility was its use of variable-pitch, Kaplan propeller-blade turbines, a first for New England (Cook 1991:26). The first Kaplan-type propeller runner in the U.S. was installed at the Lake Walk powerhouse in Del Rio, Texas, in 1929 (Hay 1991:xix). Kaplan-type turbines were smaller, lighter, less prone to debris damage, operated at higher speeds, and were more economical for low-head applications like McIndoes, where the volume of water was more variable (Hay 1991:79). The low-head Wilder Development also incorporated Kaplan-type, variable-pitch propeller turbines.

During the mid-1930s a significant change took place in the technology of governor mechanisms that controlled turbine runner speed. Turbine governors utilized a feedback-loop system with a speed sensor attached to the generator shaft that actuated a hydraulic arm that controlled the wicket gate openings on the turbine, thus regulating its speed. All USGenNE Connecticut River and Deerfield River powerhouses up to and including the McIndoes powerhouse incorporated hydraulic systems with traditional flyball-type

mechanical governors. By the 1920s the Woodward Company of Rockford, Illinois, had come to dominate the market for this type of equipment. During the mid-1930s, Woodward introduced governors with electromagnetic speed sensors attached to generator shafts. This no longer required that governors be located close to turbines, and "cabinet" type governor stands could be placed almost anywhere near the unit (Hay 1991:88-89). The original hydraulic, flyball governor units are in place and in varying states of modification at

McIndoes Falls and all other earlier powerhouses. The first-generation cabinet governor control units are still in place at Wilder and Moore, although they have been superceded by more modern equipment. Comerford's early governor cabinets have been removed and are stored at the Moore powerhouse (Cultural Resource Consulting Group 1997:15).

The Moore Development, completed in 1957, has a generating capacity of 191,300 kW, and remains the largest single development of a natural resource for power production in New England. Like Comerford, it utilizes conventional, although large, Francis-type, fixed-blade turbines appropriate for its high-head setting (New England Power 1992: "Moore Development").

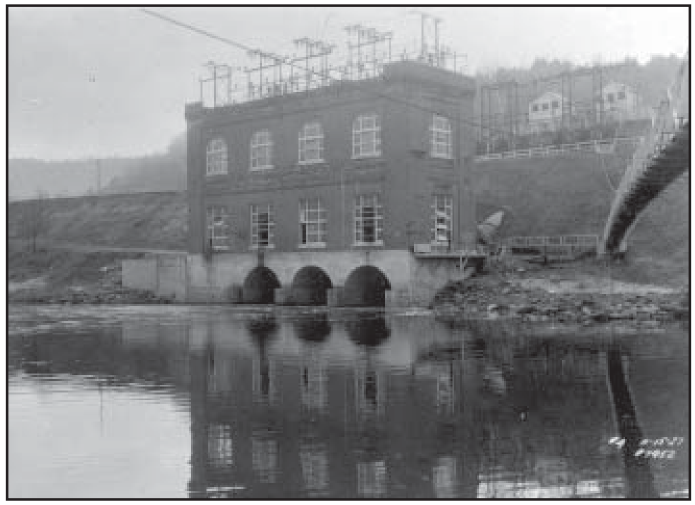
Automation and remote control are also part of the hydropower technology on USGenNE's Connecticut and Deerfield hydroelectric systems. When completed in 1922, the Searsburg hydroelectric power facility was said to be the largest fully automated plant in the United States, producing 25 million kilowatt-hours per year. It was designed for non-attendant automatic operation run off a time clock that allowed the turbine to be opened at a certain time and carry a predetermined load, and shut itself down. It was also designed to carry load based on pool height behind the Searsburg Reservoir by means of an electric float switch (Cavanaugh et al.1993). Most other developments on USGenNE's Deerfield River and Connecticut River systems were designed for full-time manned control, and have been automated over time. All Deerfield River developments are now controlled from the Harriman powerhouse. On the Connecticut River, the Moore and McIndoes developments are controlled from Comerford, and Vernon, Bellows Falls, and Wilder remain manned facilities.

USGenNE's Connecticut River and Deerfield River hydroelectric developments encompass the full range of hydroelectric generating technology developed and utilized from the late-nineteenth to mid- twentieth centuries. Turbine settings range from the triple-runner, vertical-shaft, open-flume configuration still in use in several units at Vernon; through horizontal-shaft, double-runner, "boilerplate"-case units at Deerfield Nos. 2, 3, and 4; to modern vertical-shaft settings with specially-designed scroll cases and draft tubes at the remaining developments. Conventional, fixed-blade Francis-type turbines predominate. However, Kaplan-type fixed and variable-pitch propeller type turbines are in use on the Connecticut River at the McIndoes Falls and Wilder powerhouses. The developments include a range of types of dams, spillways, gate mechanisms, water delivery systems, governors, and other mechanical and electrical equipment. The Deerfield River system incorporates particularly dramatic engineering solutions, and a landmark early automated powerhouse at Searsburg. The showpiece Harriman Development, which culminated the development of the Deerfield River, included engineering superlatives including its earth-fill semi-hydraulic dam, vertical shaft spillway, underground tunnel, and powerhouse with its mature expression of hydroelectric generating technology.

HYDROPOWER ARCHITECTURE ON THE CONNECTICUT AND DEERFIELD RIVERS

Architecturally, American powerhouses represent a synthesis of constant, highly specific functional and structural requirements, and changing popular corporate architectural styles. Powerhouses are a specialized derivative of the "erecting shop," a type of industrial building designed to house moveable cranes for building large, heavy machines. These buildings required wide, open interior spaces unobstructed by interior support columns, and incorporated steel-framed outer walls and trussed roofs, often enclosed in a masonry skin. The dimensions of powerhouses are primarily dictated by the size and number of generating units required, and the volume of the interior open space required for the structurally-integral traveling crane that is used to install and maintain the interior equipment.

As most early twentieth-century heavy manufacturing buildings were privately-owned, out of the public eye, and designed to be purely functional, they exhibited little, if any, significant decorative elements. Early powerhouses, however, were often more visible, provided a public service, and were constructed by concerns eager to promote an image of strength and reliability. Examples of early twentieth-century precedents for elaborate clear-span-interior structures intended to convey a positive public image included buildings such as banks and large urban railroad terminals, which were often modeled after historical building types ranging from medieval fortresses to Roman baths.



Deerfield No. 4 Powerhouse, built 1912. The powerhouse is an example of the Classically inspired architecture used in the designs of the early twentieth century hydroelectric facilities on the Deerfield and Connecticut rivers (November 15, 1927 photo).

Throughout the history of powerhouse construction, the regular spacing of wide structural bays and the need for large quantities of natural interior light have inspired a variety of stylistic architectural surface treatments. Early twentieth-century powerhouse architecture was clearly influenced by a lingering Victorian historicism. Most of the architectural schemes for these powerhouses were spare and Classically-derived. Examples of this phase of powerhouse architecture include the Deerfield No. 2, 3, and 4 (1912-1913), and Searsburg (1922) powerhouses. These powerhouses were designed in a restrained Renaissance Revival-style scheme most evident in the large, repeated arched windows and decorative brickwork.

Some early twentieth-century powerhouses were more decorative, and incorporated elements of other architectural styles including the Romanesque, seen at Vernon (1909) and Gothic, at Harriman (1924) and Bellows Falls (1928). The Vernon Powerhouse was designed in a restrained Renaissance Revival-style scheme, and its decoration includes elements of the Romanesque, notably the triple machicolations repeated in the cornice in the west and south elevations. The Harriman and Bellows Falls powerhouses incorporated a variety of mostly Classical details, but also included skewed Gothic buttresses with cast stone trim at the corners.

By the late 1920s, this “Powerhouse Renaissance” style was slowly abandoned in favor of a “Stripped Classicism” that incorporated rectangular windows rather than the previously ubiquitous arched ones, and retained a more limited selection of masonry embellishments, such as Sherman (1927) and McIndoes Falls (1931). The Sherman Powerhouse was designed in a transitional style that combines the restrained Renaissance Revival style popular in earlier powerhouses with the emerging stripped Classical Revival-style scheme that was becoming more common for large utility and industrial buildings of its period. The building does incorporate a Spanish terra cotta tile roof, a typical Renaissance Revival style roof cladding material, but lacks the hallmark arched windows that are characteristic of true Renaissance Revival powerhouse. The McIndoes Falls Powerhouse incorporates rectangular windows instead of arched windows, and decoration limited to a thin continuous string course below the roofline.

During the 1930s, the influence of the Art Moderne style incorporated in new skyscrapers and institutional buildings led to the adoption of hybrid styles for industrial buildings that emphasized verticality, such as the Collegiate Gothic style chosen for the Comerford Powerhouse (1930). It was designed in a Streamlined Moderne version of the Collegiate Gothic style, the most distinctive elements of which are the flat, pointed Gothic arches in the windows, which are repeated in the downstream face of the Dam, and the general emphasis on verticality. The widespread popularity of the Colonial Revival style also manifested itself in powerhouse architecture, as seen at Wilder (1950), which includes Colonial Revival features including elliptical arches, prominent gable roof returns, mock end chimneys, and ocular gable pediment windows. Ultimately, the functional tenets of Modernism resulted in the abandonment of historical references and decorative elements in powerhouse architecture in favor of buildings incorporating pure geometry and simple materials, such as the Moore Powerhouse (1957), which exhibits bold, sharp, rectangular form; lack of ornamentation; and functional use of metal sash and copings, and glass block windows.

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