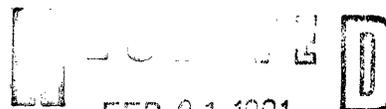


United States Department of the Interior
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National Register of Historic Places Multiple Property Documentation Form

**NATIONAL
REGISTER**

This form is for use in documenting multiple property groups relating to one or several historic contexts. See instructions in *Guidelines for Completing National Register Forms* (National Register Bulletin 16). Complete each item by marking "x" in the appropriate box or by entering the requested information. For additional space use continuation sheets (Form 10-900-a). Type all entries.

A. Name of Multiple Property Listing

Minnesota Hydroelectric Generating Facilities, 1881-1928

B. Associated Historic Contexts

Hydroelectric Power in Minnesota, 1880-1940

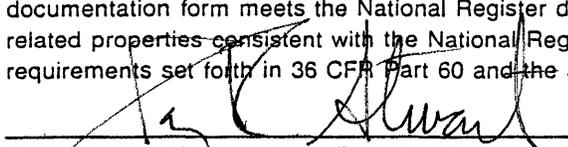
C. Geographical Data

State of Minnesota

See continuation sheet

D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards for Planning and Evaluation.


Signature of certifying official Ian R. Stewart
Deputy State Historic Preservation Officer

1/22/91
Date

State or Federal agency and bureau Minnesota Historical Society

I, hereby, certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.


Signature of the Keeper of the National Register

3/14/91
Date

Discuss each historic context listed in Section B.

HYDROELECTRIC POWER IN MINNESOTA, 1880-1940

Introduction

This study attempts to provide an historical and technological framework for evaluating the National Register eligibility of all Minnesota hydroelectric generating facilities that are at least 50 years old, which, at the time of writing, places their construction prior to 1940. Reliable evidence indicates that at least 85 hydroelectric generating facilities operated in the state before 1940.¹ Not all, however, fall within the purview of this study. Twenty were flour mill installations, and one was part of a woolen mill. In these cases, generating equipment was simply moved into the mill complex and hooked up to an existing waterpowered drive train, usually to provide light for the mill.² A 1912 description of the Farmers Milling Company operation on Sauk River at Cold Springs is typical: "Two of these [turbine] shafts are bevel geared to a horizontal shaft to which the mill machinery is geared, and the third is connected to a small generator used in lighting the mill." Occasionally, as in Mazeppa and Melrose, the local flour mill generated enough surplus electric power to sell current to the surrounding village. The flour mills, however, remained flour mills; the woolen mill remained a woolen mill. Their association with hydroelectricity should be assessed within the general contexts of their own industries, especially since their hydroelectric plant rarely required significant new construction or technological modification of the existing enterprise. Although several of these mills are still standing, none now produces hydroelectric power.

The sample of known hydroelectric generating facilities also includes five paper mills, all presently producing hydroelectricity for their own use.³ Constructed between 1898 and 1916, these mills were primarily hydromechanical facilities, employing direct-connected, horizontal, waterpower turbines to operate pulp grinders. In at least one case -- the Watab Pulp and Paper Company Mill (presently owned by Champion International Company) on the Mississippi River at Sartell -- the power plant also was originally equipped with direct-connected hydroelectric generating units, furnishing "light and power in the mill."⁴ Because of basic similarities in engineering, it was a fairly simple procedure to convert hydromechanical units into hydroelectric units, and this, in fact, occurred in all five mills. Eventually, hydroelectricity, along with steam-generated electricity, became the dominant form of site-produced power. Although these paper mill powerhouses now often resemble conventional hydroelectric powerhouses, their dimensions and design continue to reflect the demands of the original hydromechanical operation. Consequently, they should be evaluated within the context of the paper milling industry.⁵

After eliminating the 26 industrial generating facilities discussed above, the study group contains a total of 59 properties specifically designed for the production of hydroelectricity. Although these facilities sometimes incorporated pre-existing features (usually dams and canals), they achieved a technological identity distinct from the older engineering. Three of the hydroelectric generating facilities in the study group were built by manufacturing concerns, which subsidized their own power use by marketing excess current.⁶ The remainder were built by either privately owned utility companies or municipalities. At the time of writing, twenty-six properties are active generating facilities.⁷

Geography of Waterpower

Minnesota waterways flow into three principal basins: the Mississippi Valley, Hudson Bay, and Lake Superior.⁸ The Mississippi Valley Basin is by far the largest, draining all the state except for the northwest quadrant, which is tributary to Hudson Bay, and the northeast quadrant, which empties into Lake Superior. In addition to containing the state's largest waterway -- the Mississippi River itself, which drains most of central Minnesota -- the basin includes such major tributaries as Minnesota River, flowing through southwestern Minnesota, and St. Croix River, defining the state's east-central boundary with Wisconsin.

The Hudson Bay basin gathers the flow of two major river systems in northwest and north-central Minnesota: Red River and Rainy River. Fed by Otter Tail, Wild Rice, and Red Lake Rivers, Red River establishes the state's northwest boundary with North Dakota. Rainy River forms the state's north-central boundary with Canada. Its tributaries include Big Fork, Kawishiri, and Cross Rivers.

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The Lake Superior Basin is the state's third and smallest watershed, chiefly draining southern St. Louis County. The principal waterway is St. Louis River. Arising in a small lake about 60 miles northeast of Duluth, the river cuts a 150-mile-long, semicircular channel, swinging from southwest to southeast and finally emptying into Lake Superior, just south of Duluth. Compared to the principal streams in the Mississippi Valley and Hudson Bay basins, St. Louis River is unusual for its abrupt descent. The river concentrates 30 percent of its total fall, or about 375 feet, along a three-mile stretch near Thomson, Minnesota. Elsewhere in the state, abrupt drops of 50 feet are considered remarkable.

The gentleness of the state's topography is strongly indicated by Table 1, which lists maximum and median "head"⁹ statistics for hydroelectric developments in all three watersheds. The anomalous Thomson site gives the Lake Superior Basin top honors for the highest head; although the basin's next highest head of 74 feet, also on the St. Louis River, is in line with the figures for the other two watersheds. For all three basins, the median head is about 20 feet, which places Minnesota firmly in the "low head" category for hydroelectricity.

In his study of power development in Minnesota, Gene H. Hollenstein identifies 564 waterpower damsites in the state.¹⁰ As Table 1 reveals, these damsites were distributed among the three basins as follows: Mississippi Valley, 508 (90%); Hudson Bay, 49 (9%); Lake Superior, 7 (1%). To a certain extent, this rank ordering simply reflects the fact that some regions of the state are, geologically speaking, better endowed with waterpower sites than other regions. In 1910, for example, the State Drainage Commission estimated that the three watersheds divide the state's theoretical waterpower energy according to the following percentages: Mississippi Valley, 61%; Hudson Bay, 26%; Lake Superior, 16%.¹¹ These statistics, however, do not completely explain the overwhelming preponderance of waterpower dams in the Mississippi Valley Basin, nor their disproportionate scarcity in the Lake Superior Basin. For a fuller understanding, it is necessary to consider the period of settlement of the various basins.

The Mississippi Valley Basin is the oldest and most populous section of the state. When this woodland and prairie region was settled during the period 1840 to 1870, the United States was a waterpower society, and Minnesotans relied on their streams and rivers for power even more than Americans in general. In 1870, for example, steam power finally edged out waterpower in American industry, accounting for 52% of the country's total manufacturing power, compared to 48% for waterpower. In Minnesota, however, waterpower continued to dominate manufacturing, claiming 65% of total industrial horsepower, with the balance going to steam power.¹² Since the Mississippi Valley Basin was only just joining the national railway network, most communities still relied on local waterpower mills for grist, flour, and lumber.

In Minnesota, the Hudson Bay Basin contains the broad, fertile prairies of the Red River Valley region. When the railroad opened this area to settlement in the 1870s and 1880s, steam power was considerably cheaper and more efficient than 20 years before. By 1880, its influence was virtually equal to waterpower in Minnesota. At the same time, Minnesota had become part of a national market, increasingly dominated by large manufacturing firms. Henceforth, small local mills would find it difficult to compete, even in their own communities. During the 1880s, for example, the number of Minnesota grist mills and flour mills declined by almost 30 percent.¹³

By the time the heavily timbered Lake Superior Basin was settled in the 1890s and early twentieth century, it was unusual to develop new waterpower sites for hydromechanical purposes anywhere in the state.¹⁴ Although numerous dams were constructed in the Lake Superior watershed during this period, virtually all were designed for driving logs. The region's main industry, sawmilling, relied primarily on steam power. In a way, the lack of previous waterpower installations was a boon to the region's hydroelectric industry, which was able to plan its own development without great concern for pre-existing engineering structures or competing waterpower users. This partly explains why the region's hydroelectric developments tended to be larger and better rationalized than contemporary facilities in other watersheds. Although the basin's five hydroelectric developments account for less than one-tenth of the total number built in Minnesota before 1940, they represented about one third of the original

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TABLE 1: WATERPOWER DEVELOPMENT OF MINNESOTA DRAINAGE BASINS

<u>BASIN</u>	<u>WATERPOWER DAMSITES</u>	<u>HE PLANTS PRIOR TO 1940</u>	<u>HE PLANTS ON PRE-EXISTING DAMS</u>	<u>HIGHEST HEAD OF HE PLANT</u>	<u>MEDIAN HEAD OF HE PLANTS</u>	<u>KW¹</u>
Miss. Valley	508 (90%)	40 (68%)	12 (30%)	85'	20'	72,593 (61%)
Hudson Bay	49 (9%)	14 (24%)	3 (21%)	70'	19'	8,805 (7%)
Lake Superior	7	5 (8%)	0 (0%)	364'	18'	38,500 (32%)
Total	564	59	15	--	--	119,898

¹Original, installed, name-plate capacity. Data was not available for some smaller facilities.

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generating capacity installed throughout the state (see Table 1).

Development of Hydroelectricity in Minnesota, 1880-1930

In his study of American hydroelectric technology, historian Duncan Hay notes that the industry passed through three basic stages during its first fifty years, 1880 to 1930. He characterizes the first stage as the "pioneering period" (1880-1895), when "most hydro plants reflected a simple union of waterpower and electricity with comparatively little integration of the two technologies."¹⁵ According to Hay, the second stage (1895-1920) was a period of "technological ferment" in which "engineers borrowed freely from new as well as existing technologies, combining electrical, hydraulic, mechanical, and civil features in innovative ways." Although Hay recognizes that innovation continued beyond the industry's second stage, he believes it was "overshadowed" during the third period (1920-1930) by "a standardization in the design of many plants built after World War I":

Accommodations had been made; waterpower equipment had been successfully adapted to the specific needs of alternators, and vice versa; a genre of powerhouse architecture had been established. Although more hydroelectric plants were being built than ever before (or since), one could argue that in many sections of the country, they all looked pretty much the same.

For the most part, the development of hydroelectric power in Minnesota conformed to the broad patterns outlined by Hay. As was true nationally, the hydroelectric era opened in Minnesota in the early 1880s. In 1881, a group of Minneapolis business and professional men organized the Minneapolis Electric Light and Electric Motive Power Company, with the intention of developing a hydroelectric "central station" in the heart of the city's milling district, at the Falls of St. Anthony. A year later, the firm changed its name to the Minnesota Brush Electric Company, signifying that it had received the local franchise to introduce a system of electric-arc street lighting patented by Charles Brush of Cleveland.¹⁶

The first, commercial, Brush, street-light system was a steam-powered operation installed in Cleveland in 1879. In July 1880, Brush generators, or "dynamos" as they were called, were connected to a water turbine at a chair factory in Grand Rapids, Michigan, which thereby became the first, commercial, hydroelectric central station in the United States. The second apparently was a converted flour mill in Niagara Falls, New York, which began feeding current to Brush street lights in December 1881.¹⁷ The Minneapolis group got its plant into operation in September 1882, drawing water from the West Side Power Canal for a single turbine on Upton Island. Although Minneapolis historians have called the Upton Island development "the first hydroelectric station in the United States," there is no question that it was preceded by the Michigan and New York stations.¹⁸ It is likely, however, that the Upton Island facility contained the country's first hydroelectric central station to be housed in its own building -- a simple, one-story, frame structure, about 24 feet square, that was eventually demolished after the Minnesota Brush Company abandoned the installation in 1884 for a more reliable steam station upriver.¹⁹

Like most other American hydroelectric generating facilities of the 1880s and 1890s, the Upton Island facility embodied standard waterpower technology of the period. Its turbine was a stock-pattern, vertical²⁰ "Francis-type" reaction wheel connected by bevel gearing to a horizontal shaft, which, in turn, was belt-connected to the generating equipment. Countless Minnesota flour mills depended on the same kind of drive train, which partly explains why millers were often attracted to the new industry. Another explanation is that millers usually owned local waterpower rights and dams. This was particularly important during the first decades of the electric utility industry, when long-distance transmission of electric power was considered highly problematical.

The first electric systems in the United States operated on direct current (DC), which experienced significant

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voltage loss when transmitted more than a mile or so beyond the generating station. Although the Westinghouse Electric Company demonstrated during the late 1880s and early 1890s that alternating current (AC) could be successfully transmitted over long distances by means of the newly invented transformer, it still remained to work out the details of an integrated AC generating and distribution system, develop AC-compatible lights and motors, and overcome the entrenched opposition of DC advocates, including the powerful Thomas Edison, who was marketing his own DC system. Finally, in 1895, Westinghouse demonstrated an integrated AC system on a grand scale at the Niagara Falls Hydroelectric Station, transmitting current to Buffalo 26 miles away.

Although the Niagara Falls hydroelectric development would eventually establish AC as the industry standard, the long-distance transmission of electric power -- despite its technological feasibility -- would, for many years, remain beyond the financial reach of all but the most well-capitalized utilities, which, even then, required a reliable customer base, usually in the form of a major metropolitan market. Under these conditions, most generating facilities, hydroelectric or otherwise, were built in the immediate vicinity of their market, or "load center." As might be expected, the great majority of early Minnesota hydroelectric developments were located in the Mississippi Valley Basin -- the region with the longest tradition of waterpower use, the greatest number of settlements, and the most waterpower dams. Table 2 lists 34 hydroelectric developments constructed in Minnesota before 1914. Of these, the Mississippi Valley Basin claimed 24 (71%); the Hudson Bay Basin, 7 (21%); the Lake Superior Basin, 3 (9%). To quote Minnesota geographer Donald Warren Kress, the state's hydroelectric development was a "reiteration of the urban settlement pattern."²¹ In a sense, most Minnesota hydroelectric facilities built before World War I were equivalent to the waterpower gristmills of a previous era -- small, locally owned manufactories providing a staple product for a local market.

Table 2 also substantiates Hay's claim that early hydroelectric developments relied on traditional, waterpower, milling technology. All Minnesota developments built before 1895, for example, utilized some combination of bevel gearing, horizontal shafting, and belting to connect turbine to generator. An important break with such "predecessor" technology came with the construction of the Lower Dam Plant (since demolished) below the Falls of St. Anthony in Minneapolis in 1898. The installation was designed for the St. Anthony Falls Water Power Company by its Austrian-trained, chief engineer William de la Barre, who had been in charge of most of the important waterpower projects in the falls area ever since his arrival in Minneapolis in the early 1880s.

De la Barre clearly understood that hydroelectricity had evolved beyond its milling ancestry. In a traditional mill, where numerous machines of different types relied on a single power source, a drive train of shafts, belts, and clutches was a necessary expedient, although obviously wasteful of power. But in a uniform, AC hydroelectric development, there was no reason why turbine and generator could not be direct-connected, as had been done at Niagara Falls. Using 10 horizontal generating units under a head of about 20 feet, de la Barre accordingly direct-connected four turbines in tandem to each generator shaft, creating "an exceedingly compact and efficient unit." At the time, the design was considered "an innovation in low head work." By far the largest hydroelectric facility yet built in Minnesota, the Lower Dam Plant boasted an installed capacity of 7,000 kw. Generating mostly 35-cycle alternating current, the facility sold its entire output to the Twin Cities Rapid Transit Company, which was in the process of electrifying its streetcar system.²²

A few years later, de la Barre adapted the Lower Dam Plant design for another 35-cycle streetcar plant, located on Hennepin Island at the Falls of St. Anthony itself. Completed by the St. Anthony Falls Water Power Company in 1908, the Hennepin Island Plant contained four, double-turbine, direct-connected, horizontal units with an installed capacity of 9,000 kw, operating under a head of about 48 feet. The facility's nuts-and-bolts engineering, however, is only part of its historic interest. The Hennepin Island Plant is also significant for at least two other reasons. First, it appears to have been a training ground for Ralph D. Thomas, who was to become the state's most important, independent, consulting power engineer during the 1920s.

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TABLE 2: MINNESOTA HYDROELECTRIC PLANTS CONSTRUCTED BEFORE 1914 (N = 34)

NAME	COUNTY/CITY	BASIN/RIVER ¹	DATE ²	DAM ³	GU ⁴	C'TN ⁵	KW ⁶	HEAD
Upton Island	Hennepin/Minneapolis	M/Mississippi	1856/1882	T	1 v	bg-hs-be ?	?	
St. Cloud #2	Stearns/St. Cloud	M/Mississippi	1886/c.1890	T	2 v	bg-hs-be ?	15'	
Main Street (1st)	Hennepin/Minneapolis	M/Mississippi	1856/1895	T	3 hz	rd-hs-be ?	48'	
Little Falls	Morrison/Little Falls	M/Mississippi	1887/1890	T	2 v	bg-hs-be ?	23'	
Lanesboro (1st)	Fillmore/Lanesboro	M/Root	1868/c.1895	MA	?	?	22'	
Lower Dam	Hennepin/Minneapolis	M/Mississippi	1898/1898	MG	10 hz	dc	7,000	20'
Wright	Otter Tail/Fergus Falls	HB/Otter Tail	1878/1902	T	2 hz	dc	50	25'
Minnesota Falls	Yellow Medicine/MN Falls	M/Minnesota	1905/1905	MG	1 hz	dc	250	16'
Brainerd Elec. Lt.	Crow Wing/Brainerd	M/Mississippi	1888/c.1905	T	?	?	?	15'
Chatfield	Fillmore/near Chatfield	M/Root	?/c.1905	MG	1 hz	dc	55	33'
Crookston #1	Polk/Crookston	HB/Red Lake	1880s/c.1905	T	3 v	bg-hs-dc	375	12'
Heiberg	Norman/near Twin Valley	HB/Wild Rice	?/c.1905	T	1	?	75	18'
Red Lake Falls (1st)	Red Lake/Red Lake Falls	HB/Red Lake	?/c.1905	T	2	?	150	12'
Rushford	Fillmore/Rushford	M/Root	?/c.1905	T/R	2 v	bc	150	12'
Thief River Falls	Pennington/Thief R. Falls	HB/Red Lake	1890/c.1905	T	2 v	bg-hs-be	100	12'
Bemidji	Beltrami/Bemidji	M/Mississippi	1907/1907	T	1 hz	dc	500	22'
Thomson	St. Louis/Thomson	LS/St. Louis	1907/1907	CA	3 v	dc	22,500	364'
St. Croix Falls	Chisago/Taylor's Falls	M/St. Croix	1907/1907	CAG	4 hz	dc	10,000	60'
Royalton	Morrison/Royalton	M/Platte	1884/1908	T	?	?	?	?
Sandstone	Pine/Sandstone	M/Kettle River	1908/1908	T	1 hz	dc	475	20'
Hinckley	Pine/Hinckley	M/Grindstone	1908/1908	T	?	?	?	13'
Fergus Falls	Otter Tail/Fergus Falls	HB/Otter Tail	1908/1908	CG	1 hz	?	?	?
Hennepin Island	Hennepin/Minneapolis	M/Mississippi	1856/1908	T	4 hz	dc	9,000	48'
St. Cloud #1	Stearns/St. Cloud	M/Mississippi	1886/1909	T	1 hz	?	240	15'
Chengwatana	Pine/Pine City	M/Snake	1909/1909	T	2 hz	bc	250	9'
Dayton Hollow	Otter Tail/ near Fergus Falls	HB/Otter Tail	1909/1909	CG	2 hz	dc	900	39'
Redwood Falls	Redwood/Redwood Falls	M/Redwood	1902/1909	MG	2	dc	200	85'
Park Rapids	Hubbard/Park Rapids	M/Fish Hook	1880s/1910	E	2 hz	dc	200	15'
Byllesby	Dakota/near Cannon Falls	M/Cannon River	1911/1911	Amb	2 hz	dc	1,100	58'
Rapidan	Blue Earth/Rapidan	M/Blue Earth	1911/1911	Amb	2 hz	dc	1,500	63'
Main Street (2nd)	Hennepin/Minneapolis	M/Mississippi	1856/1911	T	3 hz	rd	1,960	48'
Granite Falls	Yellow Medicine/ Granite Falls	M/Minnesota	1911/1911	CG	2 hz	bc	300	18'
Tower	St. Louis/Tower	LS/Pike River	1911/1911	CG	?	?	?	22'
Sylvan	Cass/near Brainerd	M/Crow Wing	1913/1913	CG	2 hz	dc	1,200	22'

¹ HB = Hudson Bay; M = Mississippi Valley; LS = Lake Superior.

² The first date refers to the construction of the dam; the second to the power house. A date of "c. 1905" signifies that a precise construction date has not been determined, but that a given plant was described as an established facility by the State Drainage Commission in 1912.

³ Dam types are abbreviated as follows: Amb = Ambursen; CA = concrete arch; CG = straight-crested, concrete gravity; CAG = concrete gravity arch; E = earth filled; MA = masonry arch; MG = straight-crested, masonry gravity; R = rock filled; T = timber crib.

⁴ GU stands for "generating units." The following abbreviations apply: hz = horizontal; v = vertical.

⁵ Type of connection between turbine shaft and generator: be = belt connected; bg = bevel geared; dc = direct connected; hs = horizontal shafting; rd = rope drive. For example, the notation "bg-hs-be" means that a turbine shaft is bevel geared to a horizontal drive shaft, which, in turn, is belt connected to a generator.

⁶ Original, installed, name-plate capacity.

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About 1902, shortly after graduating from Tufts University in Boston, Thomas accepted an engineering position with the Minneapolis Mill Company, soon transferring to its companion firm, the St. Anthony Falls Water Power Company. Under single ownership, with de la Barre serving as chief engineer, the two companies jointly controlled the entire waterpower at the Falls of St. Anthony, including the Hennepin Island hydroelectric development, which gave Thomas his first hands-on experience with hydroelectric design and construction. About 1920, Thomas left his position as assistant engineer with de la Barre and established an independent consulting practice, specializing in hydroelectric engineering. Before the 1920s were over, he had designed new hydroelectric developments at Winton on Kawishiwi River in Lake County, at Scanlon (the Stevens Plant) on St. Louis River in Carlton County, and at Knife Falls, also on St. Louis River in Carlton County. During the same period, he also engineered additions to the hydroelectric facilities at Little Falls, Bemidji, Crookston, and Thief River Falls. Thomas remained in the power engineering field until his death in 1949, operating during the last few years under the firm name of R. D. Thomas and Associates, Inc.²³

Although Thomas published on hydroelectric engineering, he did not discuss his own work as a consulting engineer. Instead, his articles dealt with the Hennepin Island Plant, which, he felt, was particularly important for its innovative approach to water management. As he explained several years after its construction, the facility was the nation's first "surplus power development":

In 1908 the St. Anthony Falls Water Power Company completed an hydro-electric station on Hennepin Island designed primarily to use surplus water during periods when the flow exceeded the requirements of the manufacturing industries then leasing water, and which would otherwise pass over the dams and its energy be lost. At the time of its conception, a plant designed for this particular purpose was unique. There were, to be sure, many water power developments having an excess of generating capacity way beyond the limits of permanent power available, but this plant, even today [in 1917], stands almost alone as being deliberately conceived and built to utilize only such power as is available during times of high water and standing entirely idle for several months of each year. . . . Only the most favorable conditions have made possible [this project's] favorable results. In this case, the three controlling factors were water supply, low development cost, and suitable market for power of this class.²⁴

As was true for the Hennepin Island Plant, almost every Minnesota hydroelectric facility built after de la Barre's Lower Dam Plant used some type of direct connection between turbine and generator -- a clear sign that the industry had emerged from its "pioneer" period. There was, however, a notable exception, the Main Street Station at the Falls of St. Anthony in Minneapolis. Despite this plant's relatively late construction date of 1911, its generating units were connected by rope drives -- an unlikely piece of engineering for the period, made all the more improbable by the fact that the design was the work of Stone and Webster Engineering Corporation of Boston, an acknowledged leader in hydroelectric technology.²⁵

As is often the case, the unusual engineering responded to unusual site conditions. Main Street Station was built on the foundations of an 1895 rope-drive, hydroelectric powerhouse, which, when it burned in 1911, was the city's main generating facility. In an attempt to return the facility to operation as quickly as possible, Stone and Webster -- who happened to be the owner of the old facility as well as the designer of the new -- decided to reuse the original wheel pits and horizontal water turbines, which had escaped the fire unscathed. This decision tied the 1911 plant to a rope-drive power train. Although Main Street Station ceased power production in the late 1960s, its 1895 turbines and rope drive technology remain intact. It is the only surviving example of nineteenth-century hydroelectric engineering in Minnesota, and one of the few in the nation.²⁶

If the Lower Dam Plant pointed the way in mechanical engineering, it also broke new ground in hydraulic engineering, becoming the state's first hydroelectric facility to include a new dam designed solely for hydroelectric

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purposes. As Table 2 indicates, the prevailing practice, until about 1907, was to convert an older waterpower site into a hydroelectric facility by adding a new powerhouse to an existing mill dam. Of the 11 pre-1907 hydroelectric developments for which there is data, only two -- the Lower Dam Plant and the 1905 Granite Falls Plant (still an active facility) -- experienced the coordinated, simultaneous construction of dam and powerhouse. At the other installations, the dam was an older, "reused" structure, in most cases preceding the hydroelectric powerhouse by at least 15 years. While such reuse lightened initial construction costs, it also burdened the facility with an aging component, which, particularly if the dam was of the timber crib variety, would require considerable maintenance and possible replacement.²⁷

In the case of the Lanesboro Plant on Root River, the incorporation of an older dam into a hydroelectric facility helped preserve a rare engineering structure. Originally constructed as a municipal utility by the City of Lanesboro in the mid-1890s, and then completely rebuilt for the same purpose in 1922, the Lanesboro Plant drew waterpower from a 22-foot-high, 193-foot-long, masonry arch dam constructed in 1868. In addition to being the only example of its type in Minnesota, the Lanesboro Dam seems to be one of the earliest, true, masonry-arch dams in the nation. Although the Lanesboro milling industry closed down in the 1890s, the municipal hydroelectric facility is still in operation, requiring continued upkeep of the dam.²⁸

Turning once again to Table 2, we see that post-1907 hydroelectric generating facilities in Minnesota tended to rely on dams specifically designed and built for the installation. Along with irrigation projects in the Western states, the hydroelectric industry was a major impetus for the development of new dam-building technology, particularly in terms of concrete construction. In Minnesota, for example, hydroelectric projects introduced the buttress-type, or "Ambursen" dam. Named for its inventor Nils F. Ambursen, who founded the Ambursen Hydraulic Construction Company of Boston, the Ambursen dam was a reinforced concrete structure with a sloping flat slab on the upstream face supported by evenly spaced buttresses on the downstream side. Since the weight of the water helped anchor the upstream face, the dam was more stable than traditional gravity masonry structures; its hollow construction also saved on materials. By the end of its first decade of business in 1910, the Ambursen Company had built, or substantially completed, 59 dams, ranging in height from 10 to 135 feet. These included two Ambursen dams for Minnesota hydroelectric facilities, both completed in 1911: the 53-foot-high Rapidan Plant Dam on Blue Earth River at Rapidan; and the 68-foot-high Byllesby Plant Dam on Cannon River near Cannon Falls. Although shut down in the 1960s, both facilities were rehabilitated as active generating facilities in the 1980s.²⁹

Also among the earliest examples of their type in the state are the 54-foot-high concrete-arch dam of the Thomson Plant (1907) on St. Louis River near Duluth, and the 50-foot-high concrete-arch gravity dam of the St. Croix Falls Plant (1907) on St. Croix River.³⁰ Perhaps more than any other events, the construction of these two generating facilities signalled that the Minnesota hydroelectric industry had unswervingly entered the "period of technological ferment" inaugurated by the Lower Dam Plant ten years earlier. At the time of their completion, the St. Croix Falls Plant and Thomson Plant were the largest generating facilities in the state,³¹ boasting installed capacities of 10,000 kw and 22,500 kw, respectively. Still active generating facilities, the two developments were the first in the state to demonstrate the economic and technological feasibility of developing a hydroelectric station at a remote location in order to supply a load center by long-distance transmission. The St. Croix Falls Plant utilized a 40-mile-long, 50,000-volt transmission line to Minneapolis; the Thomson Plant, a 14-mile-long, 33,000-volt line to Duluth.

Owned and designed by Stone and Webster, the St. Croix Falls Plant resembled the Lower Dam Plant in its general engineering: powerhouse integral with dam; direct-connected, horizontal, generating units; each unit driven by a four-runner turbine operating under a 55-foot head. Since the transmission-line voltage was "one of the highest at that time," the project caused "a considerable amount of comment in the technical press."³²

The Thomson Plant was a challenge in almost every respect, and its successful completion must be considered

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one of the state's great engineering triumphs. Designed by the New York engineering firm of Viele, Blackwell and Buck, the facility was particularly notable for its 364-foot head, placing it "among the very highest heads of the period, with only a handful of plants in the world having over 300 feet before 1908."³³ In Minnesota, for example, the second-highest head ever attempted was 85 feet at the 1910 Redwood Falls Plant. The Thomson Plant achieved its dramatic head by elaborate hydraulic engineering. Near the village of Thomson, a concrete-arch dam diverted a portion of St. Louis River into a 66-foot-wide canal. Cutting across country for almost two miles, the canal delivered the water to a holding pond (or "forebay") on a bluff overlooking a generating station on the river, which, following its own natural channel, had descended about 375 feet. The forebay dropped the waterpower into the generating station by means of a mile-long, underground, pipeline system, consisting of wood-stave flow lines and riveted steel penstocks, with an above-ground, metal surge tank to equalize pressure.

The generating station itself was originally equipped with three 7,500 kw generating units, each driven by a Francis-type, reaction turbine. Modeled after the Niagara Falls Plant, Thomson introduced the direct-connected vertical unit to Minnesota. By stacking generator above turbine, the vertical unit made it possible to increase the size and efficiency of the water wheel, while decreasing the size of the powerhouse. Despite these advantages, direct-connected vertical design was relatively rare. The main drawback was the lack of a practical bearing capable of supporting the full weight of the generating unit. This problem was eventually solved by various self-pressurized, oil-film bearings, such as the Kingsbury thrust bearing, which came into widespread use after 1912; virtually every Minnesota generating unit installed after that date, for example, was of direct-connected vertical design (see Tables 3 and 4). At the time of Thomson's construction, however, bearings for vertical units were still highly experimental. Following Niagara's example, Thomson's units relied on pump-pressurized, oil-film, step bearings that were difficult to maintain.³⁴ In the important area of turbine design, Thomson far exceeded its New York model. Rated at 13,000 horsepower, Thomson's turbines were, at that time, "the most powerful ever put into service," more than doubling the power of the original Niagara wheels. The plant's transformers, capable of stepping up the current to 60,000 volts, were also reputed to be "the largest ever built."³⁵

Unfortunately, Thomson's construction was a protracted ordeal. The dam partially caved in, killing two workers. The local firm digging the canal "threw up its contract," finding that "much of it had to be cut through rock formation, and the steam shovels used were inefficient."³⁶ Then the turbine castings cracked twice during installations, and a labor dispute at the factory delayed replacement. Finally, a full year behind schedule, Thomson's first generating unit went on line in September 1907, transmitting 3-phase, 25-cycle current to Duluth. The next two units began service the following winter.

As Bill Beck has noted in his history of the electric utility industry in northern Minnesota, Thomson's original generating capacity of 22,500 kw was "an almost unheard of amount [of power] at the time." Nevertheless, the plant was designed to accommodate expansion, which occurred in 1914 and 1918, bringing total capacity to a staggering 48,000 kw. -- more than twice the amount of the state's next largest hydro plant (St. Croix Falls). As late as 1940, Thomson ranked sixty-fourth in capacity among the nation's hydroelectric installations.³⁷

The optimism behind the Thomson development rested on what ultimately proved to be a realistic assessment of northern Minnesota's power needs. Like the Lower Dam Plant in Minneapolis, Thomson was conceived as a wholesale power, rather than a retail light, facility. Although Thomson did supply current for lighting in Duluth and Superior, it did so on a wholesale basis, selling the electricity to a private utility that did the actual distribution. Thomson's intended primary market, however, was industrial, initially the factories and docks of the "Twin Ports" of Duluth and Superior; ultimately the iron mines of northern Minnesota. By 1918, Mesabe Range mines were annually consuming five million kilowatt-hours of electricity, much of it supplied by Thomson. By 1924, electric power consumption in the mines had increased to 25 million kilowatt hours; by 1929, to 80 million.³⁸

Although Duluth business interests guided the Thomson development through its initial planning stages, the

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TABLE 3: MINNESOTA HYDROELECTRIC PLANTS CONSTRUCTED 1914-1919 (N = 12)

<u>NAME</u>	<u>COUNTY/CITY</u>	<u>BASIN/RIVER</u> ¹	<u>DATE</u> ²	<u>DAM</u> ³	<u>GU</u> ⁴	<u>C'TN</u> ⁵	<u>KW</u> ⁶	<u>HEAD</u>
Brightsdale	Fillmore/near Lanesboro	M/Root	1914/1914	CG	1 v	dc	375	33'
Coon Rapids	Anoka-Hennepin/Anoka	M/Mississippi	1914/1914	CG	5 v	dc	6,500	20'
Hoot Lake	Otter Tail/ near Fergus Falls	HB/Otter Tail	1914/1914	CG	1 v	dc	1,000	70'
Jackson	Jackson/Jackson	M/Des Moines	1914/1914	CG	2	?	125	9'
Crookston #2	Polk/Crookston	HB/Red Lake	?/1915	?	1	?	400	12'
Elk River	Sherburne/Elk River	M/Elk River	1915/1915	CG	1 v	dc	100	15'
Mantorville	Dodge/Mantorville	M/Zumbro	?/c. 1915	?	?	?	?	10'
Hastings	Dakota/Hastings	M/Vermillion	?/c. 1915	?	?	?	?	10'
Mazeppa	Wabasha/Mazeppa	M/Zumbro	?/1917	T	1 hz	dc	60	20'
Pillager	Cass-Morrison/Pillager	M/Crow Wing	1917/1917	CG	2 v	dc	1,530	20'
Pisgah	Otter Tail/Fergus Falls	HB/Otter Tail	1918/1918	CG	1 v	dc	520	25'
Lake Zumbro	Wabasha/near Mazeppa	M/Zumbro	1919/1919	CG	2 v	dc	1,840	55'

¹ HB = Hudson Bay; M = Mississippi Valley.

² The first date refers to the construction of the dam; the second to the power house. A date of "c. 1915" signifies that a plant was not included in the State Drainage Commission study of 1912, but was listed in the U. S. Senate tabulation of 1915 ("Electric Power Development in the United States," Part II, Table 55, 64th Cong., 1st Sess., Sen. Doc. 316).

³ Dam types are abbreviated as follows: Amb = Ambursen; CG = straight-crested, concrete gravity; T = timber crib.

⁴ GU stands for "generating units." The following abbreviations apply: hz = horizontal; v = vertical.

⁵ Type of connection between turbine shaft and generator: dc = direct connected.

⁶ Original, installed, name-plate capacity; several plants were designed for, and received, additional units.

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TABLE 4: MINNESOTA HYDROELECTRIC PLANTS CONSTRUCTED 1920-1929 (N = 13)

<u>NAME</u>	<u>COUNTY/CITY</u>	<u>BASIN/RIVER¹</u>	<u>DATE²</u>	<u>DAM³</u>	<u>GU⁴</u>	<u>C'TN⁵</u>	<u>KW⁶</u>	<u>HEAD</u>
Prairie River	Itasca/near Grand Rapids	M/Prairie River	1920/1920	CG	2 v	dc	1,084	35'
Knife Falls	Carlton/Cloquet	LS/St. Louis	1921/1921	CG	3 v	dc	2,400	18'
Sunrise	Chisago/near Kost	M/Sunrise	1883/1922	T	2 v	dc	94	12'
Lanesboro (2nd)	Fillmore/Lanesboro	M/Root	1865/1922	MA	1 v	dc	345	22'
Winton	Lake/Winton	HB/Kawishiwi	1923/1923	CG	2 v	dc	4,000	67'
Stevens (Scanlan)	Carlton/Scanlan	LS/St. Louis	1923/1923	CG	4 v	dc	1,600	15'
Fond du Lac	Carlton/near Duluth	LS/St. Louis	1924/1924	CAG	1 v	dc	12,000	74'
Red Lake Falls (2nd)	Red Lake/ Red Lake Falls	HB/Red Lake	?/1924	T	2 v	dc	600	15'
Ford (High Dam)	Hennepin-Ramsey/ St. Paul-Minneapolis	M/Mississippi	1917/1924	Amb	4 v	dc	14,400	38'
Friberg (Taplin Gorge)	Otter Tail/ near Fergus Falls	HB/Otter Tail	1925/1925	CG	1 v	dc	560	30'
Blanchard	Morrison/near Little Falls	M/Mississippi	1925/1925	CG	2 v	dc	12,000	45'
Frazee	Becker/Frazee	HB/Otter Tail	1923/1925	E	1	?	75	19'
Pine River	Cass/Pine River	M/Norway River	1909/1928	E	1 v	dc	100	9'

¹ HB = Hudson Bay; M = Mississippi Valley; LS = Lake Superior

² The first date refers to the construction of the dam; the second to the power house.

³ Dam types are abbreviated as follows: Amb = Ambursen; CG = straight-crested, concrete gravity; CAG = concrete gravity arch; E = earth filled; MA = masonry arch; T = timber crib.

⁴ GU stands for "generating units." The following abbreviations apply: hz = horizontal; v = vertical.

⁵ Type of connection between turbine shaft and generator: dc = direct connected.

⁶ Original, installed, name-plate capacity; several plants were designed for, and received, additional units.

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project's three-million-dollar construction estimate was beyond the reach of local investors, and it put an end to local autonomy. Eastern financiers raised the necessary capital, and Eastern utility magnates took control. Technically, the Thomson Plant was owned and operated by the Great Northern Power Company, organized in 1903. This firm, however, was under the sway of one or more holding companies associated with the General Electric Company of New York.³⁹

The holding company was a favorite financial tool of the American utilities industry. Unlike an "operating" company that actually owned a physical plant, a holding company simply owned shares in another company. During the early twentieth century, financiers divided the American utilities industry into a series of carefully balanced pyramids consisting of operating companies, management companies, engineering companies, and holding companies. By owning a relatively small number of shares in the holding company at the top of the pyramid, it was possible to control everything "underneath."

The holding company offered several advantages to the utilities industry. First, it reduced stockholder risk. By including utilities from all areas of the country, the holding company protected investors against failure in any one section. Second, it encouraged a type of regionalization that was particularly appropriate for electric utility technology. With its emphasis on corporate consolidation, the holding company helped create integrated, regional, power networks capable of benefitting from the economies of scale inherent in long-distance transmission and large-scale, centralized generating plants. Third, the holding company was able to provide the individual utilities within its empire with the capital and engineering expertise necessary for building cost-efficient regional systems. Although the holding company brought dependable electrical service to many regions of the country, it did so at least partly by eliminating competition, opening the door to unfair rates and excessive profits. Its complicated corporate structure also facilitated securities manipulation and fraudulent accounting practices. Congress eventually responded to these abuses by passing the Public Utility Holding Act of 1935, which outlawed national, corporate pyramiding in the industry. Henceforth, regional utilities would be truly regional companies.⁴⁰

The nation's largest utilities holding company was the Electric Bond and Share Company (EBASCO). One of several such companies set up by the General Electric Company, EBASCO eventually controlled about 13% of the country's generating capacity, including the Thomson Plant near Duluth. EBASCO consolidated its Minnesota properties under the American Power and Light Company, a subsidiary holding company of national scope, with a complicated hierarchy of its own. In 1923, American Power and Light set up a regional utility known as the Minnesota Power and Light Company (MPL), now doing business under the name of Minnesota Power.⁴¹

From its inception, MPL was the major supplier of electricity in northeastern and north-central Minnesota. Although Thomson was the workhorse of the system, the company significantly increased its generating capacity with four new hydroelectric facilities completed by 1925: Winton on Kawishiwi River, Blanchard on the Mississippi River, and Fond du Lac and Scanlan on St. Louis River (see Table 4). All are still in operation today. By the end of the 1920s, MPL's territory extended from the City of Winton in the northeast to the City of Long Prairie in the southwest, encompassing the three iron ranges and the Twin Ports of Duluth and Superior. As the federal government noted in 1931: "It appears to offer the only electric utility supply in the counties of St. Louis, Carleton, Pine, Itasca, Crow Wing, Morrison, Hubbard, Wadena, Todd, and Benton." In all respects, hydroelectricity dominated the MPL system, accounting for 11 of the 15 generating facilities, 90% of the total installed capacity of 106,000 kw, and, in some years, as much as 97% of the actual electricity produced.⁴²

As was true for most holding company networks during the 1920s, the parent company -- in this case EBASCO -- provided architectural and engineering services for new construction, which is one reason why so many hydro facilities of this era show similar design and engineering. The powerhouses at Winton and Fond du Lac, for example, are virtually identical brick-clad, hip-roofed structures with false buttresses dividing the exterior walls into a series of recessed bays. Both buildings also have the same open-plan generating floor with an overhead

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rolling crane, supported by the interior steel frame, to service the generating units.⁴³

At the Blanchard Plant, EBASCO implemented a somewhat more unusual design known as the "outdoor-type plant." First used in the Jackson Shoals Hydroelectric Plant in Alabama in 1912, the outdoor design reduced the height (and theoretically the cost) of the powerhouse by placing the rolling crane on a framework outside the building, providing access to the generating units through removable hatches in the roof. Although Blanchard is the only example of the type in Minnesota, EBASCO had previously employed the outdoor design in Oregon at the 1923 Powerdale Plant of the Pacific Power and Light Company.⁴⁴

While EBASCO and its subsidiaries were consolidating the electric utility industry in northern Minnesota, H. M. Byllesby and Company (HMB) of Chicago was creating a similar power network in southern Minnesota. Established as a national utility holding company in 1902, HMB was named for its founder Henry Marison Byllesby, an engineer with extensive management experience in the electric equipment and utility industry, including a tenure in St. Paul as regional vice president of the General Electric Company. HMB first entered Minnesota with the purchase of the Stillwater Gas and Electric Company in 1909, quickly followed by acquisitions in Faribault, Mankato, and St. Paul. In 1913, the company greatly augmented its holdings by buying the Minnesota utility interests of Stone and Webster, thereby securing several Minneapolis power stations and the important St. Croix Falls Hydroelectric Plant. HMB also expanded its system by constructing new generating facilities, including the Rapidan Plant (1911) on Blue Earth River, the Byllesby Plant (1911) on Cannon River, and the Coon Rapids Plant (1914) on the Mississippi River.⁴⁵

Initially, HMB pyramided its Minnesota properties under three companies. At the top stood Standard Gas and Electric Company, a nation-wide holding company, similar to the American Power and Light Company. Next in the hierarchy was Northern States Power Company of Delaware, an intermediate holding company that controlled Consumers Power Company, the actual operator of the Minnesota plants. In 1916, HMB dissolved Consumers Power Company and replaced it with Northern States Power Company of Minnesota, generally known as NSP. After the federal government moved against utility holding companies in the 1930s, NSP became sole owner of the regional network, continuing in that capacity to the present day.⁴⁶

NSP bought and built generating plants in southern and central Minnesota throughout the 1920s, acquiring in 1923, for example, the three hydroelectric facilities at the Falls of St. Anthony (Main Street, Hennepin Island, and Lower Dam). By the end of the 1920s, the company's transmission lines stretched from western Wisconsin to eastern South Dakota, serving virtually every sizeable community between Eau Claire and Sioux Falls. In this three-state region, NSP operated 43 generating facilities connected in a giant grid. As in the MPL system in northern Minnesota, hydroelectricity dominated the network, claiming 26 generating facilities (12 in Minnesota) and about two-thirds of the company's total annual output (the Minnesota hydro facilities generated about one-quarter of the total annual output).⁴⁷

Both NSP and MPL found hydroelectricity far cheaper to produce than steam-generated electricity, which generally required a larger labor force and the consumption of an expensive fuel, such as coal. This was so much the case that both companies kept even small antiquated hydro plants in service, as long as they did not require costly repairs. As a government investigator commented on MPL's Sandstone Plant on the Kettle River in 1931: "This is an inconsequential plant, relatively costly to operate, nevertheless producing power at far less than the operating cost of a modern efficient steam plant."⁴⁸ To derive the greatest cost benefit from hydroelectricity, both NSP and MPL kept their waterpower plants in continuous operation to carry the "base," or main, load, holding the more expensive steam plants in reserve to make up the power deficit during periods of peak demand, usually in early morning and late afternoon. It was only during periods of extreme low water that Minnesota hydro plants occasionally functioned as peak load plants, and then, only because they could not serve in any other capacity. Under such drought conditions, the steam plants of the system were forced to carry the base load, while the hydro plants ponded what little water they could to help out during peak demand.⁴⁹

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NSP and MPL were by far the largest Minnesota electric utilities. In 1929, for example, the two companies accounted for approximately 85% of all utility-produced electric power generated in the state. Of the remaining 15%, approximately half was produced by about 45 municipally owned power plants, including five hydroelectric facilities.⁵⁰ The largest municipal hydro station was the Lake Zumbro Plant, a 1,840-kw installation on Zumbro River owned and operated by the City of Rochester. Although most municipal generating facilities stood within city limits, the Lake Zumbro Plant was not even in the same county as Rochester. Located about 15 miles north of the city in Wabasha County, the facility and its transmission line was the most ambitious example of municipal hydroelectric engineering in the state.

The Zumbro Lake facility is also notable for having been designed by one of the nation's foremost hydroelectric engineers, Hugh L. Cooper (1865-1937), a native of southeastern Minnesota who had apprenticed as a bridge engineer with a Rochester firm in the 1880s. During the 1890s, Cooper became interested in hydroelectric engineering and went to work for a nationally prominent manufacturer of water turbines. Setting up his own consulting practice in 1905, he immediately attracted international attention by successfully designing the Horseshoe Falls hydroelectric development above Niagara Falls in Ontario and the monster Keokuk generating facility on the Mississippi River in Iowa. His most famous American project, however, was probably the huge Muscle Shoals hydroelectric power development on the Tennessee River in Alabama, which he designed for the federal government in the 1920s. Having married into a Rochester family, Cooper maintained a close relationship with the city of his apprenticeship, which explains his involvement with the Lake Zumbro Plant, his only hydroelectric commission in Minnesota.⁵¹

There were also several privately owned power plants that served a limited geographic area. In terms of hydroelectric engineering, the most interesting of these stations was the 1909 Redwood Falls Plant in southwestern Minnesota, built by A. C. Burmeister, a local miller who had been supplying the city with hydroelectricity from his flour mill on Redwood River since 1898. To achieve an 85-foot head (the second highest in the state), Burmeister diverted the river through a 1,400-foot tunnel, blasting a good portion of it through solid rock. In 1946, the plant was taken over by the City of Redwood Falls as a municipal utility; it remains in operation today.⁵²

At about the same time that Burmeister entered the utility business in Redwood Falls, a Boston architect named Vernon A. Wright returned to his hometown of Fergus Falls in west-central Minnesota to study the financial possibilities of a family-owned waterpower dam on Otter Tail River in the heart of the city. In 1902, Wright developed the dam as a hydroelectric facility, which now carries his name. During its first years of operation, the Wright Plant was not significantly different from a dozen other small, Minnesota, hydroelectric stations serving their immediate communities. But unlike such facilities -- which either were absorbed by large "outside" utilities or remained isolated municipal facilities -- the Wright Plant itself became the nucleus of a locally owned, utility network that eventually supplied electricity to most of western Minnesota and eastern North Dakota. Encouraged by the success of his first hydroelectric facility, Wright in 1907 incorporated the Otter Tail Power Company (OTPC), which, during the next 20 years, built four more hydro facilities on Otter Tail River in the vicinity of Fergus Falls; all are still operated by the company. The most technically demanding was the Hoot Lake Plant, completed in 1914. At this installation, the company achieved a 70-foot head by diverting Otter Tail River through two lakes before piping the waterpower into a generating plant on the outskirts of Fergus Falls. The system required the construction of a concrete diversion dam, several canals, and two cast-in-place concrete tunnels, one 1,500 feet in length; the other, 450 feet.⁵³

OTPC was unique among Minnesota utilities in that it built a sizeable distribution network without the assistance of a national holding company. The network extended, east to west, 250 miles from Fergus Falls to Washburn, North Dakota. The company's growth was guided by its founder, Vernon Wright, who remained at the helm until his death in 1938. Although Wright had closed his Fergus Falls architectural office about 1905, he apparently served as architect for his own company. His most notable design is OTPC's Taplin Gorge Plant on

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Otter Tail River, about seven miles north of Fergus Falls. One of the last hydroelectric facilities built in Minnesota before World War II, the installation contained a two-story, reinforced concrete generating station that is the state's most striking example of powerhouse architecture.

Most Minnesota powerhouses built before 1930 were simple, box-like structures of brick or concrete. Architectural detailing generally was restricted to pilaster or buttress strips, and occasional corbelled cornices. The more important powerhouses, such as at Thomson and St. Croix Falls, sported arched window openings. All this followed the best authorities on the subject. As Creager and Justin advised in their Hydro-Electric Handbook of 1927 (and repeated word-for-word in their second edition of 1950): "A hydro-electric power house is a purely utilitarian structure. . . . Strength, solidity, and massiveness . . . should be the controlling motif throughout. The light, airy, and fantastic has no place whatever in a power-house design."⁵⁴

Although Wright gave the Taplin Gorge powerhouse enough strength, solidity, and massiveness to please the most conservative of architectural critics, the building nevertheless remains an utterly fantastic creation. Instead of turning to Neoclassicism -- the customary style for "serious" architecture of the period, as well as the informing doctrine of Wright's own architectural training at M.I.T and the Ecole des Beaux Artes in Paris -- Wright reputedly drew his inspiration for Taplin Gorge from a sixth-century *mausoleum* in Ravenna, Italy, the final resting place of Theodoric I, King of the Italian Ostrogoths. Later accounts would claim that the 1925 concrete powerhouse was a "replica" of the Italian tomb, but Wright's design is at best a loose interpretation.⁵⁵ According to Fletcher's History of Architecture, the Ravenna original is:

a two-storey structure of which the lower (externally decagonal) storey is, in effect, a crypt with a cruciform vault of fine ashlar. The principal storey is circular inside and is roofed by a unique single slab of stone, its under-surface cut in the shape of a shallow dome⁵⁶

Wright translated this design into a bold, two-story cube displaying a broad fretwork frieze below a shallow central dome, with lesser domes at each corner. Whatever its architectural inspiration, the building successfully communicates an austere byzantine dignity, which, although compatible with contemporary expectations about the "solidity" of powerhouse architecture, is nevertheless a wildly improbable addition to the Otter Tail County countryside.

Even by the standards of the period, Taplin Gorge, with its single 560 kw unit, was a small hydroelectric facility. In this respect, it resembled OTCP's four other hydro stations near Fergus Falls; the entire system had an installed capacity of less than 5,000 kw. Although the Otter Tail River developments were capable of handling the load requirements of the Fergus Falls region, they were inadequate for powering the company's expansion into North Dakota during the 1920s. OTCP briefly considered developing at least one other hydroelectric site on Otter Tail River, but abandoned the project, partly because "waterpower . . . was considered too unreliable for the larger installations that would be needed for future growth." Consequently, the company turned to steam as its major power source, adding three boilers to the Hoot Lake Hydroelectric Plant between 1920 and 1924, and constructing a large lignite-burning steam plant in North Dakota later in the decade.⁵⁷

Ultimately, hydroelectricity's "unreliability" overshadowed all other issues about its feasibility and future in Minnesota. Although the state's energy demands inevitably would have summoned into existence ever-larger steam plants to carry the base load, the necessity of steam-generated electricity did not, of itself, demand disillusionment with hydroelectricity. Yet hydroelectric development came to a virtual standstill in Minnesota after the 1920s. Despite the fact that several hydroelectric plants had been designed to accommodate expansion, almost no new generating units were added. Despite the fact that undeveloped hydroelectric sites existed in all three basins, no new facilities were built.⁵⁸ To be sure, the industrial depression of the 1930s had something to do with the curtailment of hydroelectric development, but probably not as much as might be supposed. During almost

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every year of the 1930s, the Minnesota private utility industry actually increased its electrical output. Although the industry's hydroelectric capability remained essentially the same throughout the decade, its installed steam capacity showed steady growth, increasing about 22 per cent between 1930 and 1935, and another 12 percent between 1935 and 1939.⁵⁹

All things being equal, there was no clear case, either technologically or economically, for the superiority of steam-generated electricity over hydroelectricity in Minnesota during the 1930s. But all things were not equal. In 1930, Minnesota entered an extended period of drought, which, over the next four years, cut the state's annual production of hydroelectricity by more than 40 percent. As one analyst of the state's electric industry noted at the very beginning of the drought, hydroelectricity lost its advantage over steam once it became unreliable:

... In normal times, hydro plants have certain values due to their small labor force, their independence of fluctuations in price and delivery of coal, their usual ability to meet sudden demands for power by rapid starting of idle units and utilization of draw down ponds for short emergency demands. However, their demonstrated unreliabilities as steady-year-round load carriers because of droughts and seasonal fluctuations in normal times more or less cancel these advantages.⁶⁰

Although precipitation returned to normal levels in the late 1930s and early 1940s, hydroelectricity never regained its pre-drought significance. In 1940, for example, hydroelectricity accounted for only about one-quarter of the state's utility-produced electricity, and by 1950, its share had slipped to 15 percent. In contrast, it had supplied more than one-half of the state's electricity in the last, pre-drought year of 1929.⁶¹ It is true that hydroelectricity continued to play a dominant role in certain utility networks, particularly the MPL system, where it overshadowed steam until the mid 1950s.⁶² But on a statewide basis, hydroelectricity's period of greatest historical and technological significance ended with the drought of the 1930s. Henceforth, steam-generated electricity -- more reliable, and eventually, more cost efficient -- would increasingly carry the state's base and peak loads.

Notes

1. The most comprehensive listing of Minnesota hydroelectric plants is found in Gene H. Hollenstein, Power Development in Minnesota, Bulletin 20 (St. Paul: Division of Waters, Minnesota Conservation Department, 1962), pp. 23-35. Unfortunately, Hollenstein does not cite his sources, and in a few instances, his identifications could not be substantiated in the following federal and state studies: State Drainage Commission, Report of the Water Resources Investigation of Minnesota, 1911-1912 (St. Paul: McGill-Warner Co., 1912); Electric Power Development in the United States, Part II, 64th Congress, 1st Session, Senate Document No. 316 (Washington, DC: Government Printing Office, 1916), pp. 372-376; Waterpower Plants in the United States, 76th Congress, 1st Session, Senate Document no. 125 (Washington, DC: Government Printing Office, 1939), pp. 18-19; Clarence H. Nelson, "Hydro Electric Stations in Minnesota," unpublished report prepared for Minnesota Department of Taxation, March 1946, Public Utilities Records, Taxation Department Papers, Minnesota State Archives, Minnesota Historical Society. A few ephemeral plants are noted in Bill Beck, Northern Lights: An Illustrated History of Minnesota Power (Eden Prairie, MN: Viking Press, 1985); Herbert W. Meyer, Builders of Northern States Power Company (Minneapolis: Northern States Power Company, 1957).

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2. The following list gives company or plant name, earliest known date of operation, city or town location, waterway, and source; unless otherwise noted, the page citation is from the 1912 State Drainage Commission study: Appleton Mill Company (1912, Appleton, Pomme de Terre River, p. 246); Cannon Valley Milling Company (1912, near Cannon Falls, Cannon River, p. 291); Consolidated Hydro Plant (1933, Minneapolis, Mississippi River; Nelson); Dakota Mill (1939, Minneapolis, Mississippi River; "Waterpower Plants in the United States," Senate Doc. 125); Dundas Mill (Dundas, Cannon River, p. 290); Farmers Milling Company (1912, Cold Springs, Sauk River, p. 163); Hanover Roller Mills (1912, Hanover, Crow River, p. 183); Mazeppa Roller Mill (1912, Mazeppa, Zumbro River, p. 303); Melrose Milling Company (1912, Melrose, Sauk River, p. 162); New London Milling Company (1939, New London, Crow Wing River, "Waterpower Plants in the United States"); North Star Woolen Mill (1939, Minneapolis, Mississippi River, "Waterpower Plants in the United States"); Pelican River Mill Company (1912, Elizabeth, Pelican River, p. 390); Pillsbury "A" Mill (1939, Minneapolis, Mississippi River, "Waterpower Plants in the United States"); Pillsbury Rye Mill (1939, Minneapolis, Mississippi River, "Waterpower Plants in the United States"); Redwood Falls Roller Mills and Electric Light Plant (1898, Redwood Falls, Redwood River, Franklin Curtiss-Wedge, History of Redwood County, vol. 2 [Chicago: H. C. Cooper and Company, 1916], p. 642); Sauk Center Milling Company (1912, Sauk Center, Sauk River, pp. 162-163); Sheffield King Manufacturing Company (1912, near Cannon Falls, Cannon River, pp. 289-290); Steinart Milling Company (1939, Clearwater River, "Waterpower Plants in the United States"); Waterford Mill (1912, Waterford, Cannon River, pp. 290-291); .

3. The five paper mills are: Northwest Paper Company Mill (now owned by Potlatch Corporation) in Cloquet on St. Louis River; Northwest Paper Company Mill (now Potlatch) in Brainerd on the Mississippi River; Itasca Paper Company Mill (now Blandin Paper Company) in Grand Rapids on the Mississippi River; Watab Pulp and Paper Company Mill (now Champion International Company), in Sartell on the Mississippi River; Minnesota and Ontario Power Company Mill (now Boise Cascade Corporation) in International Falls on Rainy River. Background information on the construction and operation of these mills was compiled from Dam Safety Files, Division of Waters, Minnesota Department of Natural Resources, St. Paul.

4. "The Hydro-Electric and Water Power Plant of a Large Paper Mill," Engineering Record, 55 (April 6, 1907); 442-445; State Drainage Commission, Report, p. 129.

5. For some indication of "why process power engineering is different from utility power engineering" in paper mills, see Grover Keeth, "Paper Mill Power," Midwest Power Conference (1940), 83-90; the discussion focuses on steam plants, but has relevance for hydroelectric plants.

6. Ford Motor Company Hydro Plant (also known as High Dam Plant; Lock and Dam No. 1 Plant) 1924, in Minneapolis/St. Paul, on the Mississippi River; Prairie River Plant (Blandin Paper Company), 1920, near Grand Rapids, on the Mississippi River; Sandstone Plant (Kettle River Quarry Company), 1908, near Sandstone, on Kettle River. For information on these plants, see Timothy C. Glines, "The Twin Cities Ford Assembly Plant," A Guide to the Industrial Archeology of the Twin Cities, ed., Nicholas Westbrook (St. Paul: Twelfth Annual Conference of the Society for Industrial Archeology, 1983), pp. 103-109; John

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S. Gulliver and others, "Hydropower Feasibility at the Kettle River Dam," Project Report No. 200, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, prepared for Minnesota Department of Natural Resources, 1981; "Prairie River Project, FERC Project No. 2361, Hydro Relicensing Data for Initial Stage of Agency Consultation," prepared by Minnesota Power, 1988, in State Historic Preservation Office (SHPO), Minnesota Historical Society; State Drainage Commission, Report, p. 35. The Ford Plant and Prairie River Plant are still in operation.

7. The 26 active facilities built before 1940 are: Bemidji Plant on the Mississippi River in Bemidji, Beltrami County; Blanchard Plant on the Mississippi River near Little Falls, Morrison County; Byllesby Plant on Cannon River near Cannon Falls, Goodhue County; Dayton Hollow Plant on Otter Tail River near Fergus Falls, Otter Tail County; Fond du Lac Plant on St. Louis River near Duluth, Carlton County; Ford Plant on the Mississippi River in Minneapolis/St. Paul, Hennepin/Ramsey Counties; Granite Falls Plant on Minnesota River in Granite Falls, Yellow Medicine County; Hennepin Island Plant on the Mississippi River in Minneapolis, Hennepin County; Hoot Lake Plant on Otter Tail River near Fergus Falls, Otter Tail County; Knife Falls Plant on St. Louis River in Cloquet, Carlton County; Lake Zumbro Plant on Zumbro River near Mazeppa, Wabasha County; Lanesboro Plant on Root River in Lanesboro, Fillmore County; Little Falls Plant on the Mississippi River in Little Falls, Morrison County; Pillager Plant on Crow Wing River in Pillager, Cass/Morrison Counties; Pisgah Plant on Otter Tail River near Fergus Falls, Otter Tail County; Prairie River Plant on Prairie River near Grand Rapids, Itasca County; Rapidan Plant on Blue Earth River in Rapidan, Blue Earth County; Redwood Falls Plant on Redwood River in Redwood Falls, Redwood County; St. Croix Falls Plant on St. Croix River near Taylors Falls, Chisago County; Stevens Plant on St. Louis River in Scanlan, Carlton County; Sylvan Plant on Crow Wing River near Brainard, Cass County; Taplin Gorge Plant on Otter Tail River near Fergus Falls, Otter Tail County; Thief River Falls Plant on Red Lake River in Thief River Falls, Pennington County; Thomson Plant on St. Louis River near Duluth, Carlton County; Winton Plant on Kawishiwi River in Winton, Lake County; Wright Plant on Otter Tail River in Fergus Falls, Otter Tail County.

8. The best discussion of Minnesota watersheds is State Drainage Commission, Report of the Water Resources Investigation of Minnesota, 1909-1910 (St. Paul: McGill-Warner Co., 1910); for a useful summary, see George A. Ralph, "Water Resources of Minnesota," Journal of the Association of Engineering Societies (May 1, 1912), 240-244.

9. Head measures the distance that water falls in powering a turbine at a waterpower installation. "High head" and "low head" are relative terms that have varied over time and place. Generally speaking, high head refers to a drop of at 200 hundred feet.

10. Hollenstein, pp. 7, 23-35.

11. State Drainage Commission, Report (1910), p. 312.

12. Lucile M. Kane, The Falls of St. Anthony (St. Paul: Minnesota Historical Society, 1987), p. 112.

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13. The virtual parity of waterpower and steam power in Minnesota in 1880 is noted in Kane, p. 112. On the state's flour mills in the 1880s, see Robert M. Frame Millers to the World (St. Paul: Minnesota Historical Society, 1977), p. 76. In Minnesota, the rise of steam power and decline of waterpower during the late nineteenth century followed national patterns; see Hunter, pp. 480-490.
14. The major exception was the paper industry, which built several waterpower mills in the Mississippi Valley Basin and Hudson Bay Basin during the early twentieth century. Noting this trend on a national level, Louis C. Hunter writes: "The explanation lies in the need for large amounts of both power and water in production, especially in pulp grinding and waste disposal, favoring waterpower with its low unit costs and placing a premium on river sites"; A History of Industrial Power in the United States, 1780-1930. Volume One: Waterpower in the Century of the Steam Engine (Charlottesville: University Press of Virginia, 1979), p. 490.
15. Duncan Hay, "Hydroelectric Development in the United States, 1880-1940," unpublished draft, prepared for Edison Electric Institute, 1987, pp. i-iii. I am greatly indebted to both Hay and the Edison Institute for permission to read and cite from this valuable study while still in manuscript form.
16. Kane gives the fullest discussion of the Minnesota Brush Electric Company, pp. 134-145. In the historical terminology of the electrical industry, a "central station" served many structures, as distinguished from an "isolated" plant, which generally served only a single facility. Minnesota's first major isolated electrical plant was apparently a steam powered system for lighting installed in 1879 at the Lake Elmo amusement park near St. Paul; see Kane, p. 135.
17. On the Brush hydroelectric plants in Grand Rapids and Niagara Falls, see Hay, p. 26.
18. Herbert W. Meyer, Builders of Northern States Power Company, p. 2; Kane, p. 134.
19. The Upton Island Plant is pictured and described in Meyer, pp. 1-2.
20. Turbines are characterized as either "vertical" or "horizontal," depending upon the orientation of their shaft.
21. Warren Donald Kress, The Geography of Electric Power in Minnesota (Ann Arbor, Michigan: University Microfilms, Inc., University of Minnesota Ph.d. thesis, 1962), p. 68.
22. On de la Barre, see Kane, p. 117; John William Leonard, Who's Who in Engineering, 1922-1923 (New York: John W. Leonard Corporation, 1922), p. 355. The plant's "innovative" engineering is discussed in "St. Anthony Falls Water-Power Plant," Street Railway Journal, 14 (May 1898), 272; see also "Electrical Transmission and Application of Power," Power, 19 (April 1899), 1-2; Meyer, pp. 91-92.
23. The information on Thomas' employment history was based primarily on Minneapolis City Directories. His signed drawings for the Winton, Scanlan, and Knife Falls hydroelectric facilities are on file in the corporate archives of Minnesota Power in Duluth. These projects, as well as his other

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work on hydroelectric facilities, are noted in an undated "Master Jobs List" for R. Thomas & Associates, Inc., on file at Northwest Architectural Archives, University of Minnesota. For a very brief biographical sketch, see Thomas' obituary in Minneapolis Tribune, December 17, 1949.

24. R. D. Thomas, "Water Power Development on the Mississippi River Above St. Paul," Bulletin of the Affiliated Engineering Societies of Minnesota, 2 (September 1917), 222. See also Thomas, "The Hennepin Power House of the St. Anthony Falls Water Power Company," Engineering Record, 59 (May 29, 1909), 676-679;

25. On Stone and Webster, see Thomas P. Hughes, Networks of Power (Baltimore and London: Johns Hopkins University Press, 1983), pp. 386-391.

26. The engineer of the original 1895 plant is unknown. On the first and second Main Street Stations, see Historical Research Inc. and Jeffrey A. Hess, "A History of Northern States Power Company's Main Street Hydro-Electric Station," in "NSP Main Street Hydroelectric Study Interim Report," unpublished, prepared by Alfred French and Associates and others for Minneapolis Riverfront Development Coordination Board, 1981, Minnesota Historical Society. Contemporary observers were well aware that the rope drive system was "not common"; see Thomas Wilson, "Twin-City Power Plants," Power 44 (September 5, 1916), 334; for a detailed contemporary description of the 1911 plant, see "Minneapolis General Electric Company's New Power System -- II," Electrical World, 59 (May 18, 1912), 1059-1063. The scarcity of 1890s-vintage hydroelectric plants in the nation is noted by Hay, p. 156.

27. The construction of the Hennepin Island Plant was economically feasible at least partly because "no dams were built, the water being used from the existing pond already created by the dams of the water power company"; Thomas, "The Hennepin Power House," 678.

28. A true masonry-arch dam resists water pressure primarily by its structural configuration rather than by its mass, thereby differentiating itself from a gravity- arch dam, which, despite its curved shape, primarily relies on its sheer mass for stability. Although the original plans and specifications for the Lanesboro Dam have not survived, the structure has been determined to be a true masonry arch dam by measurements and calculations recorded in "Design Report Lanesboro Dam and Canal," Appendix A, unpublished, prepared by Indeco, August 1984, in Dam Safety Files, Minnesota Department of Natural Resources. Although true masonry arch dams occasionally appeared in sixteenth- and seventeenth-century Europe, the type was not extensively studied until French engineers took up the subject in the mid-nineteenth century. The first American example is usually credited to the 1884 Bear Valley Dam (now submerged), a 64-foot-high structure across Bear Creek in Big Bear City, California. But as the Lanesboro Dam indicates, smaller masonry arches were built at an earlier date -- the number of such structures, as well as the circumstances of their construction, has yet to be determined; see N. J. Schnitter, "The Evolution of the Arch Dam," Water Power And Dam Construction (October and November 1976); Donald C. Jackson, Great American Bridges and Dams (Washington, D. C.: Preservation Press, 1988), p. 48. For basic historical background on the Lanesboro milling district and dam, see Paul H. Nelson, Minnesota Historical Properties Inventory Form for Lanesboro Stone Dam, Fillmore County, 1980, in State Historic Preservation Office, Minnesota Historical Society.

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29. On Ambursen dams, see Edward Wegmann, The Design and Construction of Dams (New York: John Wiley and Sons, 1927), pp. 210-214; Jackson, pp. 50-51. On the Rapidan Plant, see "The Blue Earth Hydroelectric Plant," Engineering Record 64 (August 26, 1911), 248-249; "Water-Power Development in Southern Minnesota," Electrical World, 57 (April 13, 1911), 913-915. On the Byllesby Plant, see Meyer, p. 17. Valuable information on both plants is also found in the Dam Safety Files, DNR.

30. The history and technology of Minnesota dams has yet to be studied in detail. The present study probably pulls together the most information; W. T. Mermel, for example, lists only 23 Minnesota structures in Register of Dams in the United States (New York: McGraw-Hill Book Company, Inc., 1958).

31. Straddling St. Croix River, which forms a boundary between Minnesota and Wisconsin, the St. Croix Falls Plant is located in both states, the powerhouse and east half of the dam being in Wisconsin; the west half of the dam in Minnesota. The facility is also known as the Taylor's Falls Plant, after the nearest Minnesota city.

32. Meyer, p. 20. For contemporary comment, see Wadsworth A. Williams, "The St. Croix Falls Power Plant," Yearbook of the Engineers Society, University of Minnesota 15 (1907), 69-72; Adolph Edsten, "Power Development at St. Croix Falls for The Minneapolis General Electric Company," Engineering Record, 53 (March 3, 1906), 297-299; "Taylor's Falls, Minn., Water-Power Development," Engineering Record, 55 (June 29, 1907), 752-755.

33. Shaw Livermore, "II. Power Pioneering: A Case Record," Journal of Land and Public Utility Economics, 13 (May 1937), 181. The first part of Shaw's study appeared in the February 1937 issue (49-56) of the same journal. The total study is the best account of Thomson's planning, design, construction, and operation. See also "The Hydro-Electric Development of the Great Northern power Co. -- Part I," Engineering Record, 56 (September 7, 1907), 250-254; "The Water-Power Development of the Great Northern Power Co., Near Duluth," Engineering News, 58 (December 26, 1907), 696-700; Arthur C. Ringsred, "The Hydro-Electric Plant of the Great Northern Power Company," Year Book of the Engineers' Society, University of Minnesota, 16 (1908), 25-32; C. A. Tupper, "Recent Developments in Hydro-Electric Engineering in the Northwest," Southern Electrician, 44 (January 1912), 10-13; F. M. Felker, "The Plant of the Great Northern Company of Duluth," Electrical World, 48 (July 28, 1906), 171-176; Claude Aikens, "Great Northern Power Company's Plant," Power and the Engineer, 29 (August 11, 1908), 213-218.

34. Hay (pp. 84-87) gives the following, excellent overview of bearing design:

"Bearings presented the principal obstacle to vertical settings. Step bearings, that supported turbine runners from below, had to be mounted on some sort of framework that produced unwanted tailwater turbulence. Step bearings were also difficult to maintain; they required that the wheelpit be dewatered for inspection, adjustment or replacement and they were prone to excessive wear in silt laden

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water

"Ball, cone, and roller bearings did not do a particularly good job of supporting suspended turbine runners. Oil pressure bearings held more promise. In these units the runners' thrust and weight were carried on a film of high pressure oil pumped between two flat plates. Oil pressures ranged from 80 to 350 pounds per square inch, depending on the size of the unit, and maintained an oil film of two-to-four thousandths of an inch. While this arrangement worked fairly well under normal plant conditions, if the system lost pressure the bearing surfaces were certain to be destroyed. . . . Pumps and backup units were expensive, took up space in the powerhouse, represented a large quantity of piping, seals, and machinery to be maintained, and were prone to failure. None the less, externally pressurized oil film bearings were used in a number of early large scale hydroelectric installations, including the 1895 plant at Niagara Falls.

"In 1898 Professor Albert Kingsbury invented an oil film bearing that did not require external pumps or pressure apparatus. The Kingsbury bearing consisted of a plate, attached to the revolving shaft, running on a lower plate divided into pie shaped segments. The segments were mounted on off-center pivots so that their faces were not exactly parallel to the surface of the revolving plate. With the entire assembly running in an oil bath, lubricating fluid was drawn between the plates by surface tension. . . . Other designs, based on Kingsbury's pressure wedge principle soon followed, including a popular variation that supported individual segments of the lower disk on multiple coil springs. . . .

"June 1912 saw the first commercial hydroelectric installation of Kingsbury pressure wedge bearing at the McCalls Ferry (Holtwood station on the Susquehanna River in Pennsylvania The Kingsbury bearing and other large capacity vertical thrust bearings, brought a dramatic change to powerplant design. They could be built in reasonable sizes to carry vertical loads of almost any magnitude. By 1914 many large scale low and medium head hydroelectric plants were being built with vertical reaction turbines hung from Kingsbury type bearings. By 1920 the changeover was almost complete"

It is not known when the Kingsbury thrust bearing first appeared in Minnesota hydroelectric plants. After the Thomson Plant, the state's next major vertical-unit station was the 1914 Coon Rapids Plant (since demolished) on the Mississippi River near Anoka. The facility was designed by H. M. Byllesby Company of Chicago. Although it employed roller thrust bearings instead of Kingsbury bearings, the plant attracted national attention by being among the first installations to mount the thrust bearings over the generator; see J. W. Link, "Coon Rapids Low Head Hydro-Electric Development on the Mississippi River Near Minneapolis, Minnesota," Journal of the Western Society of Engineering, 29 (December 1914), 1007; Wilson, "Twin-City Power Plants," Power (September 5, 1916), 334.

35. Aikens, 215, 217.

36. Shaw, (May 1937), 182.

37. Bill Beck, Northern Lights, p. 85. Data on the plant's expansion is found in the corporate archives of the Minnesota Power Company, Duluth. On Thomson's national standing, see "Water-Power Plants in the United States," 76th Cong., 1st Sess., Senate Doc. No. 126, Serial Set No. 10316 (Washington, D. C.: Government Printing Office, 1939), p. 46.

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38. On the initial hopes, and their ultimate realization, that Thomson's power would be consumed by the mining industry, see Beck, pp. 230-238; "Electric Power for Minnesota Ore Roads," Iron Trade Review (January 12, 1905), 40-42; "Duluth Hydro-Electric Development," Iron Age (January 19, 1905), 250; "Electric Power in Mesaba Mining," Iron Age (June 29, 1905), 2069-2070; R. S. Walker, "The First Complete Electrification of an Open-pit Iron-ore Mine in Minnesota," General Electric Review, 27 (September 1924), 580-591; David N. Skillings, "First Electric Shovels on Iron Ranges," Skillings' Mining Review, 19 (June 28, 1930), 4.

39. Livermore argues persuasively that General Electric had considerable influence over the Thomson development; see "Power Pioneering," (February 1937), 51-56; (May 1937), 182-185.

40. On holding companies, see Hughes, pp. 390-395.

41. For a historical sketch of Electric Bond and Share Company, see Hughes, pp. 392-399. On American Power and Light and the formation of Minnesota Power and Light, see Beck, pp. 181-191; Russell Ernest Johnson, "A Comparison of the Development of the Electric Utility Industry in Wisconsin and Minnesota," unpublished MA thesis, University of Minnesota, 1936, 87-89; "Report on Physical Properties, Operating Conditions, and Operating Results of the Minnesota Power and Light Co.," Exhibit No. 4925, Utility Corporations, 70th Cong., 1st sess., Senate Document No. 92, Part 35 (Washington, D.C.: Government Printing Office, 1931), pp. 341-342.

42. "Report on Physical Properties, Operating Conditions, and Operating Results of the Minnesota Power and Light Co.," p. 342. The eleven hydroelectric plants are as follows: Blanchard and Little Falls on the Mississippi River; Thomson, Fond du Lac, Knife Falls, and Scanlan on St. Louis River; Sylvan and Pillager on Crow Wing River; Park Rapids on Fish Hook River; Sandstone on Kettle River; Winton on Kawishiwi River.

43. In the early 1920s, the Minnesota Utilities Company, operator of several electric properties on the Mesabe Range, commissioned consulting engineer Ralph D. Thomas to design the Winton hydroelectric development. When Minnesota Utilities was taken over by EBASCO and MPL in 1923, Thomas remained in charge of the Winton engineering, but EBASCO supplied the plan for the powerhouse superstructure, using the same design as in the Fond du Lac development, which was under construction by EBASCO at the same time. On Thomas' involvement, see "Minnesota Power & Light Company, Winton H. E. Station," unpublished report, 1958, in Minnesota Power Archives. This report contains Thomas' drawing of the Winton generating equipment bearing the notation, "For details of superstructure of Power House see plans of Electric Bond and Share Co."

44. For a discussion of outdoor plants, with a list of those constructed by 1937, see A. C. Clogher, "Hydroelectric Practice in the United States," American Society of Mechanical Engineers Transactions, 59 (1939), 73. Like Blanchard, Powerdale was owned by EBASCO through American Power and Light; see Electric Power Development in the United States, Part 3, p. 299.

45. On Byllesby and his holding company, see Meyer, Builders of NSP, pp. 149-150.

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46. Electric Power Development in the United States, Part III, p. 387; "Report on Interstate Transmission of Electric Energy by Northern States Power Co. System in 1929 and 1930," Exhibit No. 5129 1/2 in Utility Corporations, Senate Document 92, Part 35, n.p. (chart opposite p. 449); Meyer, p. 150.
47. These statistics are for 1928; see "Report on Interstate Transmission of Electric Energy by Northern States Power Co.," pp. 450, 457. Most of the hydroelectricity for the NSP system came from three plants on Chippewa River in Western Wisconsin. By 1930, the 12 Minnesota plants in the system were: Byllesby on Cannon River; Minnesota Falls on Minnesota River; Rapidan on Blue Earth River; Red Lake Falls on Red Lake River; St. Croix Falls on St. Croix River; Sunrise on Sunrise River; and St. Cloud #1, St. Cloud #2, Coon Rapids, Main Street, Hennepin Island, and Lower Dam on the Mississippi River.
48. "Report on Physical Properties, Operating Conditions, and Operating Results of the Minnesota Power & Light Co.," Exhibit 4925, in Utility Corporations, 70th Cong., 1st sess., Senate Document No. 35 Part 92 (Washington, D.C.: Government Printing Office, 1931), p. 349. The federal investigation of the NSP system during this period elicited similar comments: "Small hydro plants, once in existence, if they can be operated at a unit production cost of not over the unit operating cost of the important steam stations of the system, are worth continuing until extensive replacements are required"; "Northern States Power Company," Utility Corporations, 70th Cong., 1st sess., Senate Document No. 92, Part 43, p. 415.
49. The role of hydro and steam in the NSP system is discussed in James A. Colvin, "Operation of a Combined Steam and Hydro System," American Society of Mechanical Engineers Transactions, 51 (1929), 177-182. The "standby" nature of steam in the MPL system is noted in the company's Annual Report for 1929, p. 3. During the early twentieth century, a series of dams and reservoirs were constructed on the headwaters of the Mississippi River and St. Louis River. Although these facilities benefited hydro plants downstream by evening out sharp seasonal variations in flowage, they were not designed to store and release water for peak load generation. After World War II, hydro and steam reversed roles. By that time, large steam-powered generating plants were so cost efficient that steam carried the main load, and hydro was held in reserve to assist with peak load; see Arthur V. Dienhart, "Water Power in Minnesota," Minnesota Engineer, 4 (August 1953), 5-7. The arrangement was not an efficient use of the state's hydroelectric plants; several were closed in the 1960s; see, for example, "Three Veterans Retire," NSP News (November 1966).
50. In 1929, electric utility power plants in Minnesota generated approximately 993 million kilowatt hours. The Minnesota plants of NSP and MPL produced, respectively, 413 million and 427 million, while municipally owned plants turned out 67.5 million. See Steven D. Emmings, Minnesota: Historical Data on Fuels and Electricity (Minneapolis: All-University Council on Environmental Quality, University of Minnesota, 1974), pp. 166-167; "Report on Physical Properties, Operating Conditions, and Operating Results of the Minnesota Power & Light Co.," p. 344; "Report on Interstate Transmission of Electric Energy by Northern States Power Co., System in 1929 and 1930," p. 385. 50. On municipal ownership in Minnesota during the 1920s, see Helen E. Heggie, "Developments in Municipal Ownership of Electric Plants in Minnesota," Journal of Land and Public Utility Economics, 4 (August 1928), 289-294. The four other municipally owned hydro plants known to have been

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operating in 1929 are Mazeppa on Zumbro River in Wabasha County; Jackson on Des Moines River in Jackson County; Lanesboro on Root River in Fillmore County; and Granite Falls on Minnesota River in Yellow Medicine County.

51. Good biographical sketches of Cooper are found in Transactions of the American Society of Mechanical Engineers, 60 (October 1938), 53-54; "Builder of Muscles Shoals Began by Making Minnesota Log Bridge," St. Paul Pioneer Press, October 11, 1925, sec. 1, p. 10; Dictionary of American Biography, Supplement 2, ed., Robert Livingston Schuyler (New York: Charles Scribners Sons, 1958), pp. 118-119.

52. On Burmeister and the Redwood Falls Plant, see Franklin Curtiss-Wedge, ed., History of Redwood County, vol. 2 (Chicago: A. C. Cooper and Company, 1916), p. 642; William Minn, "Valuation of Redwood Falls Light & Power Company Property in Redwood Falls . . . as of August 1st 1925," unpublished, 1925, in Dam Safety Files, DNR. The 1914 Brightsdale hydroelectric development on Root River was another ambitious engineering project for a small, rural plant. The local developers tunneled one-half mile through a limestone hill to create approximately 33 feet of head. The plant supplied electricity to the neighboring towns of Preston, Canton, and Harmony in Fillmore County. Although the powerhouse has been demolished, the tunnel remains; see the excellent construction history prepared by one of the original founders of the venture: A. H. Hanning, "History of the Root River Power and Light Company," unpublished, 1940, in Brightsdale Plant File, SHPO, Minnesota Historical Society.

53. On Vernon Wright, the construction of the Wright Plant, and the formation of Otter Tail Power Company, see Thomas C. Wright, Otter Tail Power Company (Fergus Falls: Victor Lundeen & Company, 1955), pp. 12-29; Ralph S. Johnson, The Power People: The Story of Otter Tail Power Company (n. pub., c. 1987), pp. 2-17. The other three plants were Dayton's Hollow (1909), Pisgah (1918), and Taplin Gorge (also known as Friberg; 1924). Technically, the Pisgah Plant was built as a separate venture by Wright and his partners. OTCP bought all Pisgah's power and finally purchased the plant outright in 1938; see Wright, p. 58.

54. William P. Creager and Joel Justin, Hydro-Electric Handbook (New York: John Wiley & Sons, Inc., 1927), pp. 558-559; second edition, 1950, pp. 788-789.

55. Wright's formal architectural training is noted in Johnson, p. 5; his retirement from architecture, in Wright, p. 14. According to this last source, his last architectural designs in Fergus Falls were "the Wright Hospital, the old section of the Washington School, and the Public Library." The Taplin Gorge powerhouse is called a "replica" of Theodoric's tomb in "OTP's Use of Waterpower," Otter Tail Hi-Lights (November 1982), 4.

56. Banister Fletcher, A History of Architecture, ed. John Musgrove (London: Butterworths, 19th ed., 1987), p. 285.

57. Wright, pp. 30-33; Johnson, p. 21.

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58. Prior to 1930, several plants did receive additional generating units. These included: Thomson (St. Louis River, built in 1907, one unit added in 1914, another in 1918); Dayton Hollow (Otter Tail River, built in 1909, one unit added in 1917); Cannon Falls (Cannon River, built in 1911, one unit added in 1916); Hoot Lake (Otter Tail River, built in 1913, one unit added in 1916); Elk River (Elk River, built in 1915, one unit added in 1921). In the late 1940s, the Thomson Plant expanded with an additional unit.

The following plants were designed for, but did not receive, additional generating units before 1975: Coon Rapids (Mississippi River, built in 1914, space for two additional units); Jackson (Des Moines River, built in 1914, space for one additional unit); Pillager (Crow Wing River, built in 1917, space for 2 additional units); Lake Zumbro (Zumbro River, built in 1919, space for one additional unit); Little Falls (Mississippi River, powerhouse rebuilt in 1920, space for one additional unit); Winton (St. Louis River, built in 1923, space for one additional unit); Fond du Lac (St. Louis River, built in 1924, space for one additional unit); Blanchard (Mississippi River, built in 1925, space for one additional unit).

On potentially feasible, undeveloped hydroelectric sites, see Arthur V. Dienhart, "Water Power in Minnesota," Minnesota Engineer, 4 (August 1953), 5-7; Hollenstein, pp. 15-19.

59. Statistics on installed capacity and annual production are derived from Emmings, pp. 160-169; 142-151.

60. "Northern States Power Company," Utility Corporations, 70th Cong., 1st sess., Senate Document No. 92, Part 43, p. 415.

61. See note 50.

62. Minnesota Power and Light Company, Annual Report, 1949, p. 5; Annual Report, 1951, p. 11; Beck, pp. 349-358.

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Introduction to Discussion of Property Types

This discussion of property types is based almost completely on documentary research. In addition to standard texts on hydroelectric engineering and the history of the electric power industry, the principal sources were federal and state investigations of waterpower and electricity in Minnesota; published accounts of Minnesota hydroelectric plants in the national and state engineering press; the corporate archives and publications of the state's three major electric utility corporations (Minnesota Power and Light Company, Northern States Power Company, and Otter Tail Power Company); and the dam inspection files of the Minnesota Department of Natural Resources. The discussion also profited from previous descriptions of property types contained in multiple property documentation studies of the hydroelectric industry in the states of Utah (Fiege and Ore, 1988) and Washington (Soderberg, 1988).

Although documentary research identified at least 59 hydroelectric generating facilities constructed in Minnesota before 1940, it did not, in all cases, determine the exact nature of original construction, subsequent modification, and present condition. To fill these gaps, it will be necessary to conduct additional documentary research in local sources, as well as an actual field survey of all known sites. It is possible that such investigations may lead to revision of the property-type analysis presented below.

Based on research findings to date, it seems reasonable to evaluate pre-1940, Minnesota hydroelectric generating facilities in terms of two main categories of architectural and engineering works. The first category includes those works directly involved in translating waterpower into electricity. Comprising a functionally related technological system, these works are, for the purposes of this study, subsumed under a single property type: the hydroelectric generating plant.

The second main category of architectural and engineering works includes those buildings and structures that provided support services for the first category. Since these subsidiary facilities do not always appear in documentary descriptions of the larger hydroelectric generating complex, their precise nature, number, and distribution are unknown. There is evidence, however, that several Minnesota hydroelectric generating facilities originally contained operators' residences. Such buildings constitute a distinct property type. Future research may identify other auxiliary property types, such as shop buildings or office buildings.

If a hydroelectric generating facility contains more than one property type, it should be treated as an historic district. If the spatial or visual relationships of the property types are important for understanding their significance (for example, the platting or landscaping of an operators' residence compound near a powerhouse), then the district's boundaries should include the entire area in question.

In some cases, the designation of an historic district will be appropriate even if the hydroelectric generating facility contains only one property type. For example, a hydroelectric generating plant may contain numerous structures dispersed over a wide geographic area. Since the significance of these structures derives from their technological interrelationship as a water management system and not from their visual or spatial continuity, they properly form a discontinuous historic district. In other cases, a hydroelectric generating facility might best be treated as a single structure. For example, such treatment would apply to a concrete dam with integral concrete powerhouse, which, despite its diverse functions, remains a single structure.

As is true for electrical generating facilities of any kind, a hydroelectric facility is always connected to a transmission/distribution system that delivers the electricity to points of use. Although components of the transmission/distribution system, particularly transformers and transmission lines, occur in close proximity to hydroelectric generating facilities, they are not evaluated as a property type as part of this multiple property study. There are two reasons for this exclusion. First, electrical transmission/distribution comprises a distinct technology, with a sufficient number of specially designed structures, to merit its own historic context and property-type analysis. Second, the development of such a historic context requires a careful study of fuel-

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burning, electric generating facilities, which was beyond the scope of the present study.

I. Name of Property Type

Hydroelectric Generating Plant

II. Description

A hydroelectric generating plant is a functionally related technological system designed to convert waterpower into electricity. Reflecting different site conditions and periods of engineering, Minnesota hydroelectric generating plants display a wide variety of individual components. Functionally speaking, these components represent two major subsystems: headworks and powerhouse. For the purposes of this study, headworks is defined as those structures that create hydraulic head and convey the resulting waterpower to the powerhouse. A powerhouse contains the mechanical equipment that converts the kinetic energy of falling water into electrical current.

Headworks

At its most elaborate, a headworks consists of several dams and canals extending over several miles. At its simplest, it comprises a single dam with an "integral," or attached, powerhouse. In Minnesota, the most common headworks features are: the power dam, which impounds water to create hydraulic head and also assists in diverting the waterpower toward the powerhouse; the power canal (and occasionally power tunnel), which generally serves as the main conduit between dam and powerhouse; and the penstock, which is the actual intake pipeline of the powerhouse. When the power dam is located a considerable distance from the powerhouse, it is also known as a "diversion dam," and the connecting canal, as a "diversion canal." When the power canal extends only a short distance, it is often called a "head race," which is also the term used for feeder canals that allow several waterpower plants to operate off a main power canal. Since Minnesota hydroelectric plants are typically low-head facilities, they rarely incorporate standpipes or surge tanks, which are designed to regulate water pressure in long-distance, high-velocity pipeline systems, thereby facilitating smooth flowage in the penstocks.

Power dams are usually the most conspicuous feature of the headworks system. As the "Historic Context" points out (see Table 2), Minnesota hydroelectric plants constructed before 1907 employed either timber-crib or masonry dams, several of which had been built for earlier hydromechanical waterpower installations. After 1907, however, the state's hydroelectric facilities began to adopt concrete dams, which became the preferred type after 1910 (see "Historic Context," Tables 3 and 4).

Most concrete dams were of the "gravity" type, which means they resisted hydrostatic pressure by their sheer mass. In a few cases, the state's hydroelectric plants utilized the less common "structural" type of concrete dam, which owed their stability primarily to their shape rather than size and weight. Of the four known structural concrete dams associated with Minnesota hydroelectric developments, one was a concrete-arch dam, and three were flat-slab buttress dams (also known as "Ambursen" dams, after their inventor Nils F. Ambursen). As far as can be determined, Minnesota hydroelectric dams were strictly utilitarian structures, without any architectural adornment.

Power canals in Minnesota were constructed as unlined earthen and rock cuts, and as stone- and concrete-

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lined structures. Occasionally, sections of canal were joined or extended by metal, concrete, or wood-stave conduit, laid above or below ground. Power tunnels were also constructed as either lined or unlined structures, depending upon the nature of the rock through which the opening was blasted. When lining was employed, it generally was concrete.

The penstock is the final link between power dam and powerhouse. Usually buried below ground, the structure is basically a straight, sloping pipeline that conveys the waterpower directly into the turbine chamber of the powerhouse. In Minnesota, penstocks were constructed of wood-stave conduit, steel pipe, and reinforced-concrete culvert.

Powerhouse

The powerhouse contains the machinery that directly converts waterpower into electricity. Architecturally, Minnesota hydroelectric powerhouses have tended to be fairly simple structures, rectangular in plan, with concrete substructures and brick superstructures, although wood-framed, masonry, poured-concrete, and concrete-block superstructures were also built. For the most part, ornamentation was kept to a minimum, usually appearing in the form of pilasters or false buttress strips, corbelled cornices, and arched fenestration. Only one "high style" design has been identified: the Taplin Gorge Powerhouse in Otter Tail County, a curious Classical-Byzantine composition reputedly based on the sixth-century tomb of Theodoric I in Ravenna, Italy.

The most important part of the powerhouse is the actual generating equipment, consisting of two basic components: waterpower turbines and electrical generators. During the 1880s and 1890s, turbines and generators were usually connected by some arrangement of shafts, belts, clutches, and rope drives, in much the same way that flouring machinery was connected to the prime mover in a traditional waterpower mill. By the early twentieth century, however, it was becoming increasingly common to connect the generator directly to the turbine shaft, thereby forming a discrete "generating unit." In Minnesota, this new arrangement was first employed in 1898, in the Lower Dam Powerhouse on the Mississippi River in Minneapolis.

Direct-connected generating units are characterized as either "horizontal" or "vertical," depending on the orientation of the turbine shaft. Although vertical units offered the most efficient and compact arrangement, their popularity was limited by deficiencies in bearing design, which were not effectively remedied until the commercialization of the self-pressurized, oil-film, Kingsbury thrust bearing about 1912. Following the national pattern, vertical units did not become standard in Minnesota hydroelectric developments until after World War I (see "Historic Context," Tables 2, 3, and 4).

Although the selection of horizontal or vertical units affected powerhouse layout, the basic engineering considerations remained the same in both cases. In addition to providing sufficient support for the heavy generating units, the engineering of the powerhouse substructure was concerned with conveying water from the penstocks on the upstream facade to the turbine chambers, and then evacuating the flow through tail race channels on the downstream side. The superstructure was little more than a shell for the generators and their control equipment. The height of the superstructure was generally dictated by the clearance required for "pulling" the generating units by means of a rolling overhead crane supported on an interior steel frame. Among Minnesota hydroelectric powerhouses, the only departure from this standard superstructure plan is found in the Blanchard Plant, constructed on the Mississippi River in Morrison County in 1925. This installation embodies what is known as the "outdoor-type" design, first implemented at the Jackson Shoals Powerhouse in Alabama in 1912. In this arrangement, the height (and theoretically the cost) of the powerhouse is reduced by placing the rolling crane on a framework outside the building, providing access to the generating units through removable hatches in the roof.

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III. Significance

Period of Significance: 1881-1929

From the establishment of the first hydroelectric generating facility at the Falls of St. Anthony in 1881, to the onset of a severe state-wide drought in 1930, hydroelectricity played a dominant role in the Minnesota electric power industry. Many cities were first introduced to electricity by means of their local hydroelectric station, which, like the waterpower grist mills of a previous era, were often locally-owned enterprises.

As long-distance transmission became more common during the first decade of the twentieth century, new hydroelectric developments were increasingly planned to serve an entire region, instead of a neighboring community. This trend was distinctly encouraged by the formation of large, regional power companies in Minnesota after World War I. By 1929, the two largest companies, Northern States Power Company (NSP) and Minnesota Power and Light Company (MPL), accounted for approximately 85% of all utility-produced electric power generated in the state. Both companies were heavily dependent on hydroelectricity. During the late 1920s, NSP's Wisconsin and Minnesota hydroelectric plants supplied about 75% of the power in the company's regional grid; for MPL, the statistic was over 90%. In 1929, the last good hydroelectric year before the drought reduced river flows, Minnesota hydroelectric generating facilities supplied more than half the state's electrical power.

After the onset of a severe, extended drought in 1930, the state's utility companies increasingly turned to steam-powered generating plants as a more reliable source of electricity. Although the drought ended in the late 1930s, hydroelectricity never regained its former importance. In 1940, it accounted for only about 25% of the state's utility-produced electricity; by 1950, its share had slipped to 15%.

The selection of 1929 as the upper limit of the period of significance has only a modest impact on evaluating the state's historic resources. All surviving hydroelectric generating facilities that are currently 50 years old had already been constructed by 1929. Indeed, there is no record of new hydroelectric plant construction in Minnesota during the entire period 1930 to 1945. Consequently, there is no need, now or in the immediate future, to evaluate the special significance of any property that might have been constructed after the period of significance for the industry in general.

The 1929 cut-off date, however, does have bearing on the evaluation of alterations to surviving hydroelectric facilities. For the most part, alterations that occurred during the period of significance should be considered valid historic expressions that do not adversely affect integrity, unless they entailed drastic demolition that put the plant out of operation (such cases are discussed below in the integrity section of the "Registration Requirements"). Alterations that occurred after the period of significance should not be considered valid historic expressions, although they may be compatible with historic fabric. This distinction means that the same alteration (for example, major remodeling of a dam with a new material) may legitimately be evaluated as either an expression of integrity or as an impairment of integrity, depending upon whether it occurred during or after the period of significance.

Criterion A

As a major source of power -- locally, regionally, and state-wide -- Minnesota hydroelectric generating facilities have contributed to the broad patterns of the state's industrial and commercial development. In addition to their significance as a general source of power, hydroelectricity facilities also may be associated with the development of certain, historically important, local and regional enterprises. For example, the

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Hennepin Island Plant was important for the development of electric street-car service in Minneapolis; the Ford Plant for automobile manufacturing in St. Paul; the Prairie River Plant for the paper industry in Grand Rapids; and the Thomson Plant for the mining industry in northern Minnesota.

Under Criterion A, a hydroelectric facility may also be significant for its instrumental role in the development of a specific electric utility company that had a major impact on the state's hydroelectric industry. An example is the Wright Hydroelectric Generating Facility in Fergus Falls, which served as the nucleus for the development of Otter Tail Power Company, the most important utility in western Minnesota and eastern North Dakota.

Criterion B

In all probability, significance under this criterion will derive from a hydroelectric facility's association with its original developer who achieved local, regional, or national prominence. To properly apply Criterion B, it is necessary to establish two basic points: (1) the hydroelectric facility directly contributed to, or appropriately reflected, the developer's historical significance; (2) the developer was indeed historically significant (see "Guidelines for Evaluating and Documenting Properties Associated with Significant Persons," National Register Bulletin No. 32). After 1920, almost all Minnesota hydroelectric facilities were built by utility corporations rather than individual entrepreneurs. It is therefore doubtful that Criterion B will apply to this later period.

For Criterion C

Properties eligible under this criterion will embody notable engineering or exemplify the work of notable engineers. Under "notable engineering," we include those hydroelectric generating facilities that (1) introduced significant innovations in hydroelectric engineering in Minnesota; (2) provided a successful solution to challenging site conditions; (3) presently embody a rare form of hydroelectric engineering for the state. Under "notable engineers," we include those practitioners who significantly contributed to the development of hydroelectric engineering on a state or national level.

IV. Registration Requirements

It is possible that a hydroelectric generating facility, or its individual components, may be eligible for the National Register for reasons that have nothing to do with hydroelectricity. A generating facility, for example, may be historically important for its role in the state's municipal ownership movement. Similarly, a dam may be eligible for its previous association with milling, or a powerhouse for its architectural qualities. The registration requirements listed below are relevant only for evaluating a property within the historic context of "Hydroelectric Power in Minnesota, 1880 - 1940."

For All Criteria

The facility must have been completed during the period of significance, 1881-1929.

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For Criterion A

A property is eligible if it fulfills any one of following conditions.

1. It strongly influenced the industrial, commercial, or residential development of a community or region.
2. It fostered the acceptance of electricity in a community or region, thereby promoting increased use or additional development of hydroelectricity.
3. It played an instrumental role in the development of an electric utility company that had a major impact on the state's hydroelectric industry.

For Criterion B

A property is eligible if it is associated with the life of a significant person.

In most cases, this criterion will apply to the original developer of the hydroelectric generating facility. If the developer's identity is known, research should be conducted to determine his/her significance.

For Criterion C

A property is eligible if it fulfills any one of following conditions.

1. It introduced a significant innovation to hydroelectric engineering in Minnesota, such as: AC generation for long-distance transmission; the direct-connected generating unit; the vertical generating unit; the concrete power dam; or the concept of surplus water management.
2. It provided a successful solution to challenging site conditions, such as in the form of extensive power canals or power tunnels.
3. It presently embodies a rare form of hydroelectric engineering for Minnesota, such as a rope-drive generating unit; a concrete-arch dam; an Ambursen dam; a "high-head" installation (i.e., hydraulic head exceeding 200 feet); an "outdoor-type" powerhouse.
4. It was designed by a notable engineer, such as William de la Barre, Ralph D. Thomas, and Hugh L. Cooper.

Integrity Requirements for Criteria A, B, and C

The three main qualities affecting the integrity of a hydroelectric generating plant are those of design, materials, and workmanship.

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Design

By "design," we mean the conceptualization and interrelationships of the entire technological system, as well as the specific form of the individual components. In its most basic concept, a hydroelectric generating plant is a system for converting the flow of waterpower into electricity. If individual components have been so altered that it is no longer possible to trace the historic flow of the waterpower, then the system's basic design integrity has been destroyed.

Such damage would almost always result from the demolition of a system's historic dam or historic powerhouse, and it would probably result from the demolition of major canal sections, especially when demolition has obliterated visible evidence of the route. The destruction of buried penstocks or subterranean tunnels is less crucial, since these features never were a visible resource.

Alterations to individual components are more common than wholesale demolition. For dams, alterations destroy design integrity when they effect a change in the historic structure type (for example, a flat-slab buttress dam converted into a gravity dam, or a true arch dam converted into a gravity arch dam). For powerhouses, design integrity is adversely affected when the historic substructure or historic superstructure is demolished, or the historic powerhouse type is changed (for example, conversion of an "outdoor type" to an "indoor type"). Major alterations to architectural detailing, constituent engineering features, or specific pieces of machinery do not necessarily affect integrity unless the architecture, engineering, or equipment are themselves the basis of significance.

It should also be emphasized that the demolition or adverse alteration of an historic powerhouse does not necessarily render its associated dam ineligible for the National Register. It only eliminates the dam's consideration in the context of "Minnesota Hydroelectric Generating Facilities." It is possible that the dam might be eligible under another context, such as "Minnesota Dam Engineering." Similarly, a powerhouse without its dam might be eligible for its architectural significance.

Materials and Workmanship

Qualities of materials and workmanship are best discussed as a unit, since alteration of the one almost always entails alteration of the other. Once again, the dam and powerhouse are the main features to consider. A dam's integrity is destroyed if a preponderance of its historic material is replaced or significantly obscured by another material (for example, a masonry gravity dam largely converted into a concrete gravity dam, or a concrete dam entombed in an earth embankment). Alterations to individual dam components, such as gates, trash racks, spillways, flash boards, and so forth, are not detrimental to integrity, unless the components are themselves the basis of the property's significance, or the alterations are so sweeping that they constitute a major change in the dam's historic materials or structural type.

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I. Name of Property Type

Operator's Residence

II. Description

When hydroelectric generating plants were constructed in remote, undeveloped areas, it was usually necessary to provide nearby housing for the operators. Typically, these residences were modest structures reflecting the architectural style, workmanship, and materials appropriate for rural housing of the place and period.

III. Significance

As a support facility for a hydroelectric generating plant, an operator's residence derives its individual significance from the significance of its associated generating plant. In other words, if the generating plant is significant, the operator's residence is significant as well. Conversely, if the generating plant is not significant, the operator's residence is not significant. Of course, these considerations apply only to the historic context, "Hydroelectric Power in Minnesota, 1880-1940." It is possible that an operator's residence may be significant for its architecture, or historical associations outside of hydroelectricity.

IV. Registration Requirements

The registration requirements listed below are relevant only for evaluating a property within the historic context, "Hydroelectric Power in Minnesota, 1880-1940."

1. The building must be associated with a significant hydroelectric generating plant.
2. The building must have provided housing for plant personnel during the plant's period of significance.

Integrity Requirements

The evaluation of integrity should follow customary practice for assessing architectural properties in general, with the following special considerations:

1. It is not essential that the building occupy its original site, as long as it was relocated near a hydroelectric generating plant for use as an operator's residence during the plant's period of significance.
2. The building's integrity is adversely affected if the immediate area no longer recalls the remote, undeveloped setting that made it necessary to provide plant housing in the first place.

G. Summary of Identification and Evaluation Methods

Discuss the methods used in developing the multiple property listing.

See Continuation Sheet

See continuation sheet

H. Major Bibliographical References

See Continuation Sheet

See continuation sheet

Primary location of additional documentation:

- State historic preservation office
- Other State agency
- Federal agency

- Local government
- University
- Other

Specify repository: _____

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Section G: Summary of Identification and Evaluation Methods

Administration

Sponsored by the State Historic Preservation Office (SHPO) of the Minnesota Historical Society (MHS), this study of Minnesota hydroelectric generating facilities was initiated by means of a contract between MHS and the firm of Jeffrey A. Hess, Historical Consultants. Susan Roth and Thomas H. Hruby of SHPO served as project coordinators, while Jeffrey A. Hess served as principal investigator, responsible for overall project conceptualization, data analysis, field survey, and preparation of the final report. On a subcontract basis, Mr. Hess received research assistance from historians Charles P. Quinn, Marilyn Seven, and Thomas Major.

Identification of Study Group

As a consequence of budgetary and time constraints, the project was, from the very outset, conceived as a documentary study, with only a limited, informal, field-survey component. The initial direction of the documentary research was guided by the simple fact that there was no firm information concerning the number or location of potentially eligible (ie., at least 50-years-old) Minnesota hydroelectric sites. The consultant's first task, then, was to compile a study group of all known hydroelectric sites developed before 1940. To this end, the consultant conducted a thorough literature search of the Minnesota hydroelectric industry in the following bibliographic sources: Engineering Index, Poole's Guide to Nineteenth-Century Periodical Literature, Industrial Arts Index, Readers' Guide, Bulletin of the Minnesota Surveyors' and Engineers' Society (individual volume indexes for 1896-1915), Bulletin of the Affiliated Engineering Societies of Minnesota (individual volume indexes for 1916-1940), Minnesota Techno-log (individual volume indexes for 1920-1940), card catalog of the Minnesota Historical Society, card catalog of the University of Minnesota, and various indexes to Congressional publications.

In addition to numerous published studies of individual Minnesota hydroelectric plants, the literature search yielded four major listings of the industry as a whole: Gene Hollenstein, Power Development in Minnesota (Bulletin 20, Minnesota Conservation Department, 1962); Minnesota State Drainage Commission, Report of the Water Resources Investigation of Minnesota, 1911-1912 (McGill-Warner Co., 1912); Electric Power Development in the United States (64th Congress, 1st Session, Senate Document No. 316, 1916); Waterpower Plants in the United States (76th Congress, 1st Session, Senate Document No. 125, 1939).

Background research in published sources was supplemented by investigations of the following three, major, unpublished collections: Dam Inspection Files of the Division of Waters, Minnesota Department of Natural Resources; Historic Site Inventory Files of SHPO, Minnesota Historical Society; and Electric Utility Files of the Minnesota Department of Taxation, State Archives, Minnesota Historical Society. All three collections provided extensive information on individual hydroelectric developments.

Preliminary Data Analysis

On the basis of research in published and unpublished sources, the consultant identified 85 hydroelectric sites developed in the state before 1940. To assist in the typological analysis of individual plants, as well as to determine broad historical patterns, the consultant prepared a detailed data sheet for each hydroelectric site. To

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the limits of the available information, the data sheets recorded the following: plant location; date of development; original and subsequent owners; designing engineer; type of dam and powerhouse; nature of original generating equipment; modifications to architecture or engineering; unusual historical or technological circumstances; present condition.

Additional Research

The data sheets indicated that there were two major gaps in the information compiled to date. First, a national context was lacking for assessing the significance of Minnesota hydroelectric facilities. Second, basic historical or engineering data was lacking for several plants. To remedy the first deficiency, additional research was conducted in historical and technological studies of the American hydroelectric industry. The following sources proved particularly valuable: Duncan Hay, "Hydroelectric Development in the United States, 1880-1940" (unpublished, Edison Electric Institute, 1987); Thomas P. Hughes, Networks of Power (John Hopkins University Press, 1983), Louis Hunter, A History of Industrial Power in the United States, Volume One: Waterpower in the Century of the Steam Engine (Eleutherian Mills-Hagley Foundation and University Press of Virginia, 1979); and various standard texts of American hydroelectric engineering practice, such as William P. Creager and Joel Justin, Hydro-Electric Handbook (John Wiley & Sons, 1927). As a means of addressing the second deficiency, the consultant held telephone interviews with past and present plant managers of several hydroelectric installations, and conducted intensive research in the corporate archives of the state's two largest electric utility companies, Minnesota Power and Light Company and Northern States Power Company, which owned several of the plants with incomplete data sheets.

Field Survey

At the conclusion of the research program, the data sheets provided fairly complete historical and technological information for almost all of the state's operating hydroelectric facilities, which, because of federal licensing requirements, were most urgently in need of National Register evaluation. The major exception was the Lake Zumbro Plant in Wabasha County, a municipal facility owned by the City of Rochester. Accompanied by the plant superintendent, the consultant conducted an informal field survey of the plant, taking field notes, black-and-white, 35mm photographs and 35mm color slides. No official inventory form was prepared.

Formulation of Historic Context, Property Types, and Registration Criteria

In developing the historic context for Minnesota's hydroelectric industry, the consultant reduced the initial study group from 85 to 59 installations, retaining only those sites that were specifically developed as hydroelectric generating facilities, thereby eliminating all hydromechanical waterpower sites that happened to have a hydroelectric generator on the premises. For the most part, the consultant based his context on Duncan Hay's broad developmental analysis of the national hydroelectric industry, largely relying on the plant data sheets prepared as part of the present study to provide local, regional, and state perspective. Since Minnesota hosted one of the nation's first hydroelectric plants, the context began its historical narrative in 1880, at the very outset of American hydroelectric development. To help evaluate the hydroelectric industry's "period of significance" in Minnesota, the context continued its narrative to 1940 and slightly beyond, although, for all practical purposes,

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hydroelectric development in the state ended with the 1920s. The date range for the multiple property listing itself, "Hydroelectric Generating Facilities in Minnesota, 1881-1928," reflects the construction dates of the state's first hydroelectric development, and its last hydroelectric development before 1940 (see "Historic Context," Tables 2 and 4).

Since a hydroelectric generating facility is primarily a technological system, the consultant relied on a functional analysis to identify two property types: hydroelectric generating plant and operator's residence. For the hydroelectric generating plant, standards of integrity were also primarily derived from a functional, systemic analysis of significant features. For the operator's residence, standards of integrity generally conformed to National Register standards for assessing the integrity of architectural properties.

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